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FIELD GUIDE FOR THE BIOLOGICAL CONTROL OF WEEDS IN THE NORTHWEST

RACHEL WINSTON, CAROL BELL RANDALL, ROSEMARIE DE CLERCK-FLOATE, ALEC MCCLAY, JENNIFER ANDREAS AND MARK SCHWARZLÄNDER

Forest Health Technology Enterprise Team

University of Idaho Extension

FHTET-2014-08
Reprinted August 2016

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/

Cover photos: *Aphthona nigriscutis* (R. Richard, USDA APHIS), *Mecinus* spp. (Bob Richard, USDA APHIS PPQ), *Chrysolina hypericic quadrigemina, Eustenopus villosus* (Laura Parsons & Mark Schwarzländer, University of Idaho), *Cyphocleonus achates* (Jennifer Andreas, Washington State University Extension)

BIOLOGICAL CONTROL OF WEEDS IN THE NORTHWEST

RACHEL L. WINSTON
Environmental Consultant
MIA Consulting, LLC
Sandpoint, ID, USA
rachel@getmia.net

CAROL BELL RANDALL
Entomologist, Forest Health Protection
USDA Forest Service
Coeur d'Alene, ID, USA
crandall@fs.fed.us

ROSEMARIE A. DE CLERCK-FLOATE
Weed Biocontrol, Lethbridge Research Centre
Agriculture and Agri-Food Canada
Lethbridge, Alberta, Canada
rosemarie.declerck-floate@agr.gc.ca

ALEC S. MCCLAY
McClay Ecoscience
Sherwood Park, Alberta, Canada
alec.mcclay@shaw.ca

JENNIFER E. ANDREAS
Integrated Weed Control Project
Washington State University Extension
Puyallup, WA
jandreas@wsu.edu

MARK SCHWARZLÄNDER
Associate Professor for Entomology
University of Idaho, Department of Plant, Soil and Entomological Sciences
Moscow, ID, USA
markschw@uidaho.edu

For additional copies of this publication, contact:

Mark Schwarzländer
University of Idaho
PSES Department
Moscow, ID 83844
208.885.9319
markschw@uidaho.edu

Richard Reardon
USDA Forest Service
180 Canfield Street
Morgantown, WV 26505
304.285.1566
rreardon@fs.fed.us

ACKNOWLEDGMENTS

Significant help in reviewing and compiling the content in this field guide was provided by Eric Coombs (Oregon Department of Agriculture), Jeffrey Littlefield (Montana State University), Dan Bean (Colorado Department of Agriculture), Robert Bourchier (Agriculture and Agri-Food Canada), and Susan Turner (British Columbia Ministry of Forests and Range). We would like to thank all of the photographers who granted permission for the use of photos. We also extend our gratitude to Denise Binion, Forest Service-Forest Health Technology Enterprise Team (FHTET) for help with editing, layout and graphics, and Richard Reardon (FHTET) for producing this guide.

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About This Field Guide

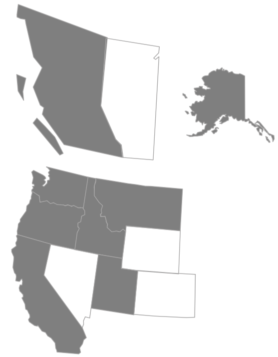
Invasive plants are a major concern worldwide. They displace native species, decrease forage/agricultural production, alter soil nutrient and water cycling, and lower the aesthetic value of natural areas. With the increase of world travel, exotic plant introductions are on the rise. Biological control of weeds (also called "biocontrol") is the deliberate use of living organisms to limit the abundance of a target weed. In this field guide, biological control refers to "classical biological control," which reunites host-specific natural enemies from the weed's native range with the target weed in its introduced range. Natural enemies used in classical biological control of weeds include different organisms, such as insects, mites, nematodes, and fungi. In North America, most weed biocontrol agents (also called "agents") are plant-feeding insects, of which beetles, flies, and moths are among the most commonly used.

This field guide focuses on the most problematic weeds in northwestern North America for which there are at least some biocontrol agents established. Multiple photos and descriptions of each weed included in this guide emphasize key identification traits and plant ecology. Comparison tables are included to further aid in identification of related weed species, where applicable. For each weed included in this guide, all biocontrol agents currently found in North America are described individually. Photos highlighting key identification features and damage are included. The release history, current status, and recommended use for each agent are described in great detail. Because current impact and recommendations often vary between the USA and Canada, information is presented separately for each country.

Symbology has been added for each biocontrol agent described in this manual to allow for a quick redistribution recommendation:

USA	Can	Recommendation
■	●	High priority; recommended for release/redistribution
■	●	Medium priority, recommended to complement other agents or control methods
■	●	Low priority; typically low impact and/or survival
■	●	Caution when redistributing; not recommended for use in all areas
☒	⊗	Illegal to redistribute
?	?	Still actively released, but establishment is not yet confirmed
□	○	Released, but failed to establish

Many agents are already widespread. All target weed infestations should be surveyed prior to release to ensure the desirable biocontrol agents are not already present. Keep in mind that many species are approved for use in only the USA or Canada, but not both. In addition, some agents cause nontarget damage to desirable species. **Red text indicates the biocontrol agent is not recommended for release in all areas.**



Plant distribution data from the USDA-PLANTS database is presented in a map for each weed. Though significant effort is put into keeping the PLANTS database current, weed spread can be rapid, making distribution information quickly out of date. Please visit plants.usda.gov/du/DistributionUpdate.html for information on how to help update weed distribution information on the PLANTS site.

Maps depicting each agent's current establishment were created using available literature and numerous personal communications with regional land managers. Like weeds, biocontrol agents can spread rapidly, making accurate distribution information elusive. EDDMapS is a web-based mapping system for documenting invasive species as well as biocontrol agent distribution in the USA. EDDMapS combines data from existing sources (e.g. databases and organizations) while soliciting and verifying volunteer observations, creating an inclusive invasive species geodatabase that is shared with educators, land managers, conservation biologists, and beyond. Information can be added in online forms through home computers and/or apps created for smartphones. For more information on how to utilize or contribute to these tools, visit www.eddmaps.org/about/ and apps.bugwood.org/.

Agents that were released but did not establish or are not currently approved for redistribution in the USA and/or Canada are addressed separately from approved agents. The description, ecology, and history/status are described for each species, accompanied by a photo. Should you encounter agents not believed to be established during field surveys, contact your local weed superintendent, land grant university, or extension service personnel to confirm and document their establishment. Caution must be taken during field redistribution to ensure that agents not approved for use are not inadvertently collected and redistributed along with approved agents.

The remainder of this introduction describes biocontrol regulations, agent life cycles, and techniques for collecting, transporting, and releasing established agents.

Biological Control of Weeds

Biocontrol agents may attack a weed's flowers, seeds, roots, foliage, and/or stems. Effective agents 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. Root- and crown-feeding biocontrol agents are usually more effective against perennial plants that primarily spread by root buds. Alternatively, flower- and seed-feeding biocontrol agents are typically more useful against annual or biennial plants that only spread by seeds.

To be considered for release in North America, it is crucial that biocontrol agents are host-specific, meaning they must feed and develop only on the target weed; or in some cases, on a few closely related plant species. They must never feed on any crop or any protected plant species. Tests are necessary in order to ensure that the biocontrol agents are effective and that they will damage only the target weed. Potential biocontrol agents often undergo more than five or more years of rigorous testing to ensure that host specificity requirements are met.

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 providing the testing guidelines and authorizing the importation of biocontrol agents into the USA. 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, environmental protection agencies from the USA, and representatives from Canada and Mexico. TAG reviews all petitions to import new biocontrol agents into the USA and makes recommendations to USDA-APHIS-PPQ regarding the safety and potential impact of prospective biocontrol agents. Weed biocontrol researchers work closely with USDA-APHIS-PPQ and TAG to accurately assess the environmental safety of potential weed biocontrol agents and programs. In addition, some states in the USA have their own approval process to permit field release of weed biocontrol agents. The Canadian counterpart to TAG is the Biological Control Review Committee (BCRC) which uses the North American Plant Protection Organization's (NAPPO) Regional Standards for Phytosanitary Measures (RSMP) number 7 (NAPPO RSMP NO.7)- as their review/petition requirement.

Biocontrol practitioners have adopted the International Code of Best Practices for Biological Control of Weeds. The Code was developed in 1999 by delegates and participants of the Tenth International Symposium for Biological Control of

Weeds to improve the efficacy of and reduce the potential for negative impacts from biological control. In following the Code, practitioners reduce the potential for causing environmental damage through the use of biological control by voluntarily restricting biocontrol activities to those most likely to result in success.

INTERNATIONAL CODE OF BEST PRACTICES FOR CLASSICAL BIOLOGICAL CONTROL OF WEEDS[1]

1. Ensure that the target 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

[1] Ratified July 9, 1999, by the delegates to the X International Symposium on Biological Control of Weeds, Bozeman, MT

As per rule 4 of the Code of Best Practices above, **biocontrol agents that have not been approved are illegal to introduce to the USA and Canada. When biocontrol agents arrive accidentally, it is generally illegal to redistribute them intentionally within the USA**. A few cases where this is legal are described in this manual. Some agents introduced accidentally to Canada are safe to utilize, however **redistribution of accidentally introduced agents should only be done under the guidance of Canadian biocontrol experts**.

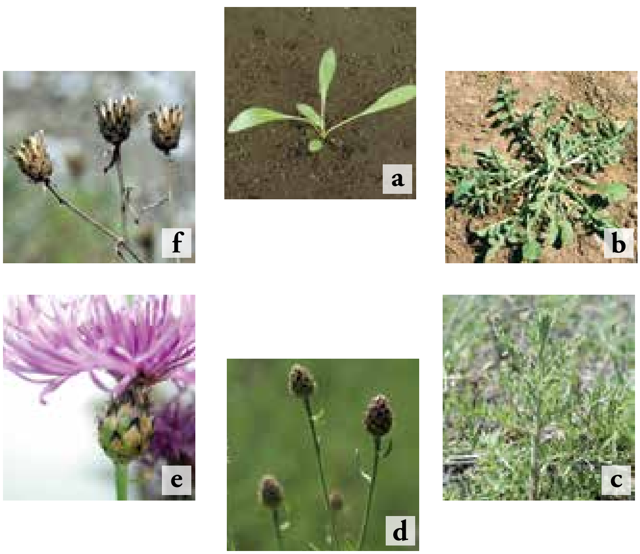
Although weed biological control is an effective and important weed management tool, it does not work in all cases and should not be expected to completely eradicate the target weed. Even in the most successful cases, bioontrol often requires multiple years before impacts become noticeable. Ideally, biological control should be integrated with chemical, mechanical, and/or cultural methods of weed management to improve overall weed control success.

WEED BOTANICAL TRAITS

Weed descriptions utilized in this manual refer to a variety of life stages and characteristic features to help readers determine the key traits that set the weed apart from others. Traits referred to most commonly include:

LIFE CYCLE

The first recognizable stage of plant life cycles is seedling, when a plant has one to only a few small leaves. Many perennial plants then grow into rosettes, which are clusters of leaves typically of the same height. Annual plants and vining species frequently do not have obvious rosette stages. Plants then grow a flowering stem in a stage called bolting. In bud, immature flowers appear on the ends of flowering stems and branches. These open during flowering and then set seed upon maturation. At senescence, a plant has typically released its seeds and dies back for the winter or permanently.

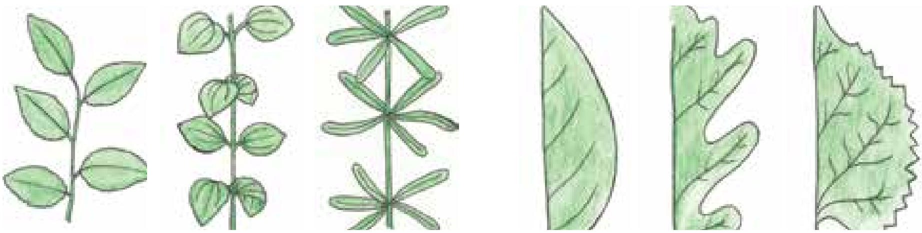


Generalized stages of spotted knapweed a) seedling, b) rosette, c) bolting, d) bud, e) flowering, f) senescence (Credits: a, f Ohio State Weed Lab Archive, Ohio State University; b Steve Dewey, Utah State University; c K. George Beck & James Sebastian, Colorado State University; e Michael Shephard, Forest Service (all www.bugwood.org)

DURATION

Annual species complete their life cycle (from germination to the production of seed) within one year and then die. Summer annuals germinate during spring/early summer and mature by fall of the same year. Winter annuals germinate during fall and mature during the spring or summer of the following calendar year. **Biennial** species take two years to complete their life cycle. In the first year, the plant is a rosette. During the next spring or summer, the plant bolts, sets seeds, and dies. **Perennial** species live for more than two years.

Leaf Arrangement and Margination



ALTERNATE OPPOSITE WHORLED SMOOTH LOBED TOOTHED

Jacqi Moulton, MIA Consulting

Flower heads

Many of the weeds included in this manual are members of the sunflower family (Asteraceae). Members of this family produce flower heads, or capitula, that are an aggregation of many individual flowers. These flowers, called florets, are clustered together and attached to a receptacle. There are two types of florets: disc and ray. Some species produce only one type, while others produce both. The receptacle and florets are enclosed by modified leaves called bracts. The type, color and shape of florets and bracts can help in weed species identification. 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.

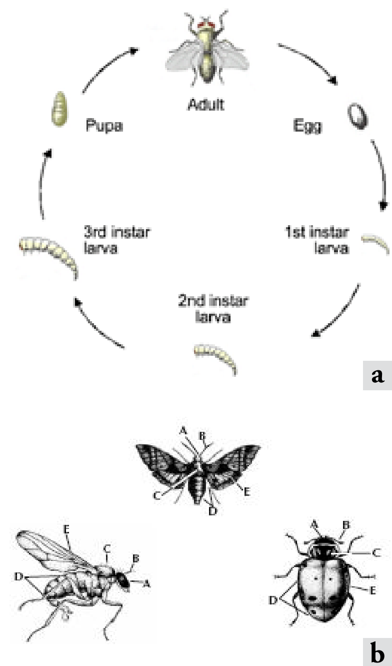
a) Canada thistle, all disc florets, b) rush skeletonweed, all ray florets, c) tansy ragwort, both disk (center) and ray (outer) florets (photo credits on respective weed pages)

Biological Control Agent Life Cycles

Classical biocontrol agents may be found in a number of taxonomic groups. The majority of approved biocontrol agents are arthropods in the class Insecta. More specifically, most biocontrol agents are insects in the orders Coleoptera (beetles), Lepidoptera (butterflies and moths), and Diptera (true flies). In addition to insects, there are also nematodes and fungi biocontrol agents.

Insects

Insects are the largest, most diverse class of animals in the phylum Arthropoda. An understanding of basic insect biology and anatomy will help users recognize and identify the insects used as biocontrol agents of weeds. Most insects included in this field guide have complete metamorphosis, which means they exhibit a life cycle with four distinct stages: egg, larva, pupa, and adult. Most adult insects also have an exoskeleton (a hard external skeleton), a segmented body divided into three regions (head, thorax, and abdomen), three pairs of segmented legs, and may have one or two pairs of wings. The head of an adult insect has one pair each of compound eyes and antennae.



a) Complete metamorphosis of an insect (L. Wilson), b) body parts of adult insects A. head, B. antenna, C. thorax, D. abdomen, E. wing (Biocontrol of Weeds in the West)

Immature insects have an exoskeleton that must be shed in order for them 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 pupae. During the pupal stage, insects change from larvae to adults. Insects do not feed during the pupal stage.

Aphids (in the order Hemiptera) are a group of insects included in this manual that have gradual metamorphosis. In this process, there is no pupal stage. Instead, their young are called nymphs, and resemble the adults to a large degree. The transformation from nymph to adult largely involves the development of wings (only in some species) and functioning sexual organs.

Butterflies and Moths (Order Lepidoptera)

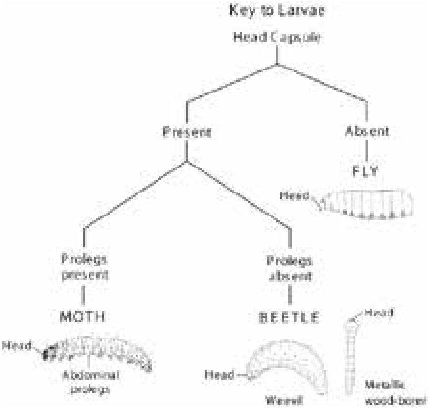
Adult Lepidoptera have two pair of membranous wings, covered (usually completely) by minute powder-like scales. Antennae are prominent. The larvae (caterpillars) have a toughened head capsule, chewing mouthparts, and a soft body that may have hair-like or other projections, three pairs of true legs,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

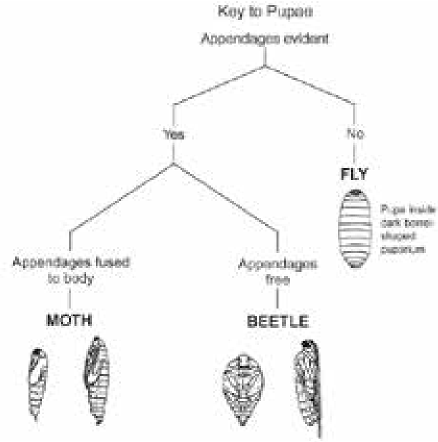
Beetles (Order Coleoptera)

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 and are folded under the elytra when not in use. Beetle larvae are grub- or worm-like with three small pairs of legs. Most are pale white with a brown or black head.

Flies (Order Diptera)

Adult true flies are easily distinguished from other orders of insects by their single pair of membranous wings and typically soft bodies. Larvae of most true flies, called maggots, are legless and wormlike. Many insects have the word "fly" in their 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 name (e.g., butterfly in the order Lepidoptera and mayfly in the order Ephemeroptera).





Identification key to to differentiate biological control insects as a) larvae and b) pupae (both L. Wilson)

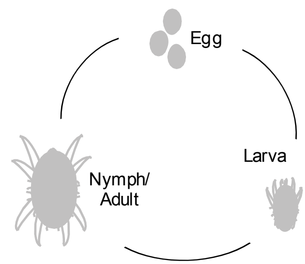
Biological Control Agent Life Cycles

Aphids (Order Hemiptera)

Most aphids have soft bodies and vary in color from green, black, brown, pink to almost colorless. The mouthpart is unique from other insects described in this manual in that it consists of a stylet enclosed in a sheath (rostrum). This combination allows them to pierce and suck plant tissue (typically sap) for feeding. Most aphids have a pair of abdominal tubes through which they exude droplets of a defensive fluid.

Mites

Like insects, mites are in the phylum Arthropoda. However, they belong to a different class, Arachnida, whose adult members are characterized by having 8 legs (compared to the 6 legs of insects). Mites have gradual metamorphosis. The first immature stage in mites is called larva; mites in this stage have only 6 legs. The second immature stage is called nymph and has 8 legs. Nymphs are usually very similar in appearance to adults.



Rachel Winston, MIA Consulting

Nematodes

Nematodes, or roundworms, belong to the phylum Nematoda. They are cylindrical, unsegmented worms that are typically 0.1-2.5 mm long and 5-100 µm thick. They have tubular digestive systems with openings at both ends. In free-living nematodes (such as the species in this manual), eggs hatch into larvae, which appear essentially identical to the adults, except for an underdeveloped reproductive system.

Fungi

Fungi belong to their own kingdom (Fungi). The fungi described in this manual are rusts, which are in the phylum Basidiomycota. Rust fungi are obligate parasites, meaning they require a living host to complete their life cycle. They obtain nutrients from living plant cells. Rusts can produce up to five spore types during their lifetime. Rusts are most commonly seen as colored powder (typically yellow, orange or brown), composed of tiny aeciospores which land on vegetation and produce pustules, or uredia, that form on the lower surfaces. Urediniospores are red/orange and are a characteristic sign of rust fungus infection. These spores can re-infect the same host plant. During late spring or early summer, hair-like structures called telia grow on the leaves and produce teliospores which will germinate into aerial basidiospores to spread the infection to new hosts.

Scientific Name Changes

The weeds included in this guide are listed according to their common name, beneath which is included their scientific (Latin) name. The biocontrol agents are listed by their scientific name. Some species have recently undergone updates with their taxonomy. The following tables list weeds and biocontrol agents whose names have changed most recently (listed in the order in which they appear in this guide).

Weed Common	Scientific Name	Previous names
Spotted knapweed	*Centaurea stoebe*	*Centaurea biebersteinii, C. stoebe subsp. micranthos, C. maculosa*
Russian knapweed	*Rhaponticum repens*	*Centaurea repens, Acroptilon repens*
Musk thistle	*Carduus nutans*	*Carduus thoermeri*
Scotch broom	*Cytisus scoparius*	*Cytisus scoparius subsp. scoparius, Sarothamnus scoparius*
Orange hawkweed; Whiplash hawkweed	*Pilosella aurantiaca; Pilosella flagellaris*	*Hieracium aurantiacum; Hieracium flagellare*
Tansy ragwort	*Jacobaea vulgaris*	*Senecio jacobaea*
Dalmatian toadflax	*Linaria dalmatica ssp. dalmatica*	*Linaria genistifolia, L. genistifolia ssp. dalmatica, L. dalmatica*
Scentless chamomile	*Tripleurospermum inodorum*	*Matricaria perforata, Tripleurospermum maritimum subsp. inodorum, T. perforatum*

Agent Current Name	Target(s)	Previous names
Mogulones crucifer	Houndstongue	*Mogulones cruciger*
Subanguina picridis	Russian knapweed	*Paranguina picridis, Mesoanguina picridis*
Cheilosia grossa	Thistles	*Cheilosia corydon*
Hadroplontus litura	Thistles	*Ceutorhynchus litura*
Larinus carlinae	Thistles	*Larinus planus*
Trichosirocalus horridus	Thistles	*Ceuthorhynchidius horridus*
Exapion fuscirostre	Scotch broom	*Apion fuscirostre*
Exapion ulicis	Gorse	*Apion ulicis*
Botanophila seneciella	Tansy ragwort	*Hylemyia seneciella, Pegohylemyia seneciella*
Aceria chondrillae	Rush skeletonweed	*Eriophyes chondrillae*
Rhinusa antirrhini; R. linariae; R. neta	Toadflaxes	*Gymnetron antirrhini; G. linariae; G. netum*
Spurgia capitigena, S. esulae	Leafy spurge	*Bayeria capitigena*
Pegomya curticornis, P. euphorbiae	Leafy spurge	*Pegomya argyrocephala*
Microplontus edentulus	Scentless chamomile	*Ceutorhynchus edentulus*
Omphalapion hookerorum	Scentless chamomile	*Apion hookeri*

Collection Methods

Some of the most commonly used methods for collecting biocontrol agents are sweep netting with or without aspirating, hand-picking/tapping, vacuuming, and light traps. The effectiveness of each method depends on the type and abundance of biocontrol agents being collected and the habitat. Regardless of the method used, **extraneous debris (e.g., other insects, weed seeds, etc.) must be sorted and removed**. Cooling the collected sample for 10 to 15 minutes reduces insect activity and makes sorting easier. **Any cooling should be done in a refrigerator, not a freezer.**

Sweep netting

Sweep nets are made of cotton or muslin on a hoop 10-15 in (25-38 cm) diameter attached to a handle 3 ft (0.9 m) long. They can be purchased from entomological, forestry, and biological supply companies or you can construct them yourself. As their name implies, these are heavy duty nets used to “sweep” insects off weeds.

Laura Parsons, University of Idaho

A sweep is made by swinging the net through the plant canopy. If insects are suitable for aspiration (see below for a description of aspiration and aspirators), it is best to alternate between sweeping insects off the weed and aspirating them out of the net. Sweep no more than 25 times before aspirating hard-bodied beetles or as few as five times for fragile adult moths and flies. Aspirating or removing insects at regular intervals reduces the potential harm that could result from knocking biocontrol agents around with debris and reduces the opportunity for predator insects swept up with the biocontrol agents from finding and devouring the agents.

Sweep netting is an easy and efficient method for collecting insects from the above-ground portion of plants, and is particularly useful for adult flea beetles. The best time for sweeping is during the warmest part of the day (1 -6 p.m.) as this is when the beetles are most active. In general, adult moths and flies are very delicate, and collecting them with sweep nets can be damaging or fatal. It is best to use other methods for collecting delicate species.

Laura Parsons, University of Idaho

Aspirating

Use an aspirator to suck the biocontrol agents (usually small species) directly from the weed or the sweep net. This provides selective sorting (no unwanted or unknown material is inadvertently collected). 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.

Hand-picking/tapping

Stationary or slow-moving insects can be picked from foliage by hand using forceps or tweezers. When sweeping agents is inefficient or damages tap them onto a beat sheet or tray using a tool such as a racquet. Plants infested with galls or fungal spores can be hand-picked and moved to new infestations. Take care when moving plant material to ensure seeds are not included as as this may introduce new genotypes.

Ray Willard , Washington State Department of Transportation

Vacuuming

Either a leaf blower with reverse capability or an industrial strength wet-dry vacuum cleaner can be equipped with a nylon mesh net on the inside mouth of the blowing tube (held in place with a rubber band or bungee cord) to suck up insects. This is particularly useful for collecting small agents such as flea beetles from weed rosettes. Rocks or debris vacuumed up may harm collected adults, so this method should be applied to foliage collections only. Adding rosette leaves to the net gives agents substrates to crawl and hide on and reduces the suction strength. Net contents should be aspirated to separate agents from unwanted material.

Eric Coombs, Oregon Department of Agriculture

Light trap

Light traps are used to collect nocturnal agents (typically moths) that are otherwise difficult to collect during the day. Construct a wire or wooden framework to support a battery-operated lantern and beneath it a large funnel (with a wide enough opening for large insects) that rests inside a wide-mouth jar with target weed material in the bottom. Place it in a sheltered place near a target weed infestation. Start the light at dusk, and empty it in the morning. Alternatively, prop up a white sheet to serve as a reflecting surface, and place a lantern in front of it on a stool. Hand-collect the insects attracted to the sheet as they land on the surface.

Jerry Payne, USDA ARS

Transport Considerations

Containers

Collected insects must be transferred to containers intended to protect and prevent them from escaping. Containers should be rigid enough to resist crushing but also ventilated to provide adequate air flow and prevent condensation. Unwaxed paperboard cartons are ideal for most biocontrol species. As an alternative, you can use light-colored, lined or waxed-paper containers (e.g., ice cream cartons are particularly suitable) or plastic containers, providing they are ventilated and colored or transluscent. Cut holes in the container or its lid, and cover the holes with a fine mesh screen. These ventilation procedures are not necessary for galls or fungus-infected foliage. Do not use glass or metal containers; they are breakable and make it difficult to regulate temperature, air flow, and humidity.

Again for insects, fill the containers two-thirds full with crumpled paper towels or tissue paper to provide a substrate for insects to rest on and hide in and to help regulate humidity. Include a few fresh sprigs of the target weed foliage (as food) before adding the agents. Sprigs should be free of seeds, flowers, dirt, spiders, and other insects. Do not place sprigs in water-filled containers; they may crush the agents or drown the agents upon leaking. Sprigs are not needed for galls or fungus-infected foliage. Seal the container lids either with masking tape or label tape. Be sure to label each container with (at least) the biocontrol agent(s) name, the collection date and site, and the name of the person(s) who did the collecting.

Transporting Biological Control Agents

When transporting short distances, place the containers in large coolers with sealed ice packs wrapped 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 insect containers. Always keep coolers out of direct sunlight. 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.

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 agents to several sites. In such cases, the containers should be placed in insulated shipping containers with one or more ice packs. The sealed 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 having direct contact with the insect containers and also to prevent crushing should they move about during shipping. Empty spaces in the shipping container should be loosely filled with crumpled paper, packing peanuts, etc. Enclose all paperwork accompanying the agents (including any needed permits) before sealing the shipping container with tape.

Other factors to consider

- Make your shipping arrangements well before you collect the agents, and make sure the carrier you select can guarantee overnight delivery as well as the proper treatment of the package contents.
- Plan collection and packaging schedules so that overnight shipments can be made early in the week rather than delivery on Friday-Sunday.
- Clearly label the contents of containers and specify that they are living insects.
- Contact personnel at the receiving end, tell them what you are shipping and when it is due to arrive, provide a tracking number, verify that someone will be there to accept the shipment, and instruct them not open the container prior to releasing the agents.

Regulations for the Transfer of Biological Control Agents

USA, intrastate Generally, there are few if any restrictions governing collection and shipment of approved biological control agents 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. The state of California regulates release permits at the county level.

USA, interstate The interstate transportation of biological control agents is regulated by the U.S. Department of Agriculture (USDA), and a valid 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—but 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, PPQ Form 526 at the USDA-APHIS-PPQ website. The ePermit process can be accessed at http://www.aphis.usda.gov/plant_health/permits/organism/biological_control/index.shtml. 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 biological control agents within a province is generally not an issue; however, you should consult with provincial authorities and specialists prior to moving any biological control agent across provincial boundaries.

Releasing Biocontrol Agents

Select release site

Survey prospective release sites early to ensure the targeted agent is not already present. Release sites should typically contain large (4,000 m^2, 1 acre) patches of the target weed. Different agents will have different habitat preferences, so select sites on an individual basis. Avoid transferring agents to areas with high disturbance, other control methods (e.g. mowing, insecticide/herbicide use), or with a large number of ant mounds or ground dwelling animals which may predate the biocontrol agents. Good sites should be readily accessible year after year. To reduce mortality or injury, it is best to redistribute the agents the same day they are collected. Releases of all biocontrol agents should be made under moderate weather conditions (mornings or evenings of hot summer days, mid-day for cold season releases). Avoid making releases on rainy days. If you encounter an extended period of poor weather, however, it is better to release the biocontrol agents than wait three or more days for conditions to improve, as the agents' vitality may decline with extended storage.

Establish permanent location marker

Place a steel fence post or plastic/fiberglass pole at least 4 ft (1.2 m) tall as a marker at the release point. 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. Where conspicuous posts may encourage vandalism, mark your release sites with short, colorful plastic tent/surveyor's stakes or steel plates that can be tagged with release information and located later with a metal detector and GPS.

Record geographical coordinates at release point using GPS

Geonarva

Map coordinates of the site marker should be determined using a global positioning system (GPS) device of a GPS capable tablet/smartphone. Coordinates should complement but not replace a physical marker. Accurate coordinates will help re-locate release points if markers are damaged or removed. Along with the coordinates, be sure to record what coordinate system and datum you are using, e.g., Latitude/Longitude in WGS 84 or UTM in NAD83.

Prepare map

The map should be detailed and describe access to the release site, including roads, trails, and relevant landmarks. The map should complement but not replace a physical marker and GPS coordinates. Maps are especially useful for long-term biological control programs 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 or places physically difficult or confusing to access.

Complete relevant paperwork at site

Your local land management agency may have standard biocontrol agent release forms for you to complete. Typically, the information you provide includes a description of the site's physical location, including GPS-derived latitude, longitude, and elevation; a summary of its biological and physical characteristics and land use; the name(s) of the agent(s) released; date and time of the release; weather conditions during the release; and the name(s) of the person(s) who released the agents. The best time to record this information is while you are at the field site. Consider using a smartphone and reporting app. Once back in the office, submit the information to your local weed control authority or land management agency. Keep a copy for your own records.

Set up photo point

A photo point is used to visually document changes in weed infestations and the plant community over time following the release of biocontrol agents. Use a permanent feature in the background as a reference point (e.g., a mountain, large rocks, trees, or a permanent structure) and make sure each photo includes your release point marker. Pre- and post-release photographs should be taken from roughly the same place and at the same time of year. Label all photos with year and location.

Photo point with photos spanning three years, Rachel Winston, MIA Consulting

Release as many agents as possible

As a general rule of thumb, it is better to release many individuals of a biocontrol agent species at one infestation than it is to spread those individuals too thinly over multiple infestations. Releasing all agents within a release container in one spot will help ensure that adequate numbers of males and females are present for reproduction and reduce the risks of inbreeding and other genetic problems. If you have more than one release container, be sure to put some distance between the two releases; 1 km (⅔ mile) is ideal.

Monitoring Biocontrol Agents

Documenting outcomes (both successes and failures) of biocontrol release programs will help generate a more complete picture of biocontrol impacts, guide future management strategies, and serve education and public relations functions. Monitoring can help determine:

- If the biocontrol agents have become established at the release site
- If biocontrol agent populations are increasing or decreasing and how far they have spread from the initial release point
- If the biocontrol agents are having an impact on the target weed
- If/how the plant community or biotic/abiotic factors have changed over time

Monitoring can provide critical information for other land managers by helping them predict where and when biological control might be successful, helping them avoid releasing ineffective agents or the same agent in an area where they were previously released, and/or helping them avoid land management activities that would harm local biocontrol agent populations or worsen the weed problem.

Monitoring methods can be simple or complex. A single year of monitoring may demonstrate whether or not the biocontrol agents established, while multiple years of monitoring may allow you to follow the population of the biocontrol agents, the decline of the target weed, changes in the plant community, and other biotic and abiotic (e.g. climate, soil) changes.

Monitoring: a) checking biocontrol agent abundance, b) measuring vegetation along a transect, c) measuring vegetation in a more systematic grid (all Rachel Winston, MIA Consulting)

Assessing biocontrol agent populations

If you wish to determine whether or not biocontrol agents have established after initial release, you simply need to find the agents in one or more of their life stages, or evidence of their presence. Recommendations for the best stages to monitor are given for each biocontrol agent in the following section of this guide. Begin looking for biocontrol agents where they were first released, and then expand to the area around the release site.

Populations of some biocontrol 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 agents failed to establish. Revisit the site at least once annually for three years. If no evidence of biocontrol agents is found, 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 assistance.

To determine the changing densities of biocontrol agent populations, a systematic monitoring approach is needed. The Standardized Impact Monitoring Protocol (SIMP) is one such approach to monitoring biocontrol agent populations, weed populations, and the surrounding plant community over time. This simplified protocol was developed through cooperation among the Bureau of Land Management, the University of Idaho, Forest Health Protection, the Nez Perce Biocontrol Center, and the Idaho State Department of Agriculture. SIMP monitoring forms and additional information regarding this method can be found at www.agri.state.id.us/Categories/PlantsInsects/NoxiousWeeds/Bio_Control.php.

Assessing the status of the target weed and co-occurring plants

The ultimate goal of a biological control program is to permanently reduce the abundance of the target weed and enable the recovery of more desirable vegetation on the site. To determine the efficacy of biocontrol efforts, there must be monitoring of plant community attributes, such as target weed distribution and density. Ideally, monitoring begins before biological control efforts are started (pre-release) and at regular intervals after release. There are many ways to qualitatively (descriptively) or quantitatively (numerically) assess weed populations and other plant community attributes at release sites.

Qualitative (descriptive) vegetation monitoring

Qualitative monitoring uses subjective measurements to describe the target weed and the rest of the plant community at the management site. Examples include listing plant species occurring at the site, estimates of density, age and distribution classes, visual infestation mapping, and maintaining a series of photos from designated photo points. Qualitative monitoring provides insight into the status or change of target weed populations. However, its descriptive nature does not generally allow for detailed statistical analyses. Data obtained in qualitative monitoring may trigger more intensive monitoring later.

Quantitative vegetation monitoring

The purpose of quantitative monitoring is to measure changes in the target weed population as well as the vegetative community as a whole before and after a biocontrol agent release. It may be as simple as counting the number of stems of the target weed in an area, or as complex as measuring plant height, flower and production, biomass, species diversity, and species cover. If designed properly, quantitative data can be statistically analyzed and give measurable information on plant community changes. Pre- and post-release monitoring should follow the same protocol and be employed at the same time of year. Post-release assessments should be planned annually for at least three to five years after the initial biocontrol agent release. The SIMP approach is a combination of qualitative and quantitative elements and can be easily modified to meet your personal or agency needs.

Assessing impacts on nontarget plants

To address possible nontarget attacks on species related to the target weed, you must become familiar with the plant communities present at and around your release sites and be aware of species closely and distantly related to the target weed. You may have to consult with a local botanist or herbarium records for advice on areas where nontarget plants might be growing and how you can identify them. Care should be taken in the management of your weed biocontrol program to ensure that all closely related native species are identified and monitored along with the target weed.

If you observe approved biocontrol agents feeding on and/or developing on nontarget species, the vegetation sampling procedures described above can be easily modified to monitor changes in density and/or cover of the nontarget species. Concurrently, you may wish to collect additional data, such as the number of agents observed on nontarget plants, the amount of foliar feeding observed, or the presence of characteristic biocontrol agent damage. Collecting this data for subsequent years can help determine if there is a population level impact or if the nontarget feeding is temporary or of minor consequence to the nontarget species.

If you observe approved biological control agents feeding on and/or developing on native species, collect samples and take them to a biocontrol specialist in your area. Alternatively, you may send the specialist the site data so he or she can survey the site for nontarget impacts.

Additional Considerations

Avoiding Parasitism

Some biocontrol agent populations are plagued by parasitoids that reduce their numbers and, consequently, their impact. When redistributing such species, it is important to ensure that parasitoids are not transferred along with the desired biocontrol agent. This can be accomplished by collecting plants infested with the desired biocontrol agents in the fall and storing them at 39-46°F (4-8°C) over the winter. Two to three weeks prior to their normal emergence time, bring them to room temperature in rearing cages or breathable, clear containers. Any parasitoids that emerge should be separated and destroyed. Emerging biocontrol agents can be transferred to new target weed patches during the appropriate plant stage.

Houndstongue

Cynoglossum officinale L.

SYNONYMS: gypsy flower, beggar's lice

ORIGIN: Native to Eurasia; first recorded in North America in Ontario in 1859.

DESCRIPTION: Upright, herbaceous biennial or short-lived perennial typically growing 1-4 ft tall (⅓-1.2 m) from a stout taproot. Leaves are grayish green, have smooth margins, and are softly to roughly hairy on both surfaces. Basal leaves are up to 12 in long (30 cm); stem leaves are smaller, without stalks, and grow alternately. An individual plant may have one to several rosettes on one root system. Flowering stems are cymes with 10-35 flowers, though usually 2-3 flowers are open at once. Flowers have five reddish-purple petals, turning blue with age. Each flower produces up to four nutlets, each densely covered with small hooks.

HABITAT: Capitalizes on disturbance to invade areas with a wide variety of

a) plant (Robert Vidéki, Doronicum Kft., www.bugwood.org), b) infestation (Rachel Winston, MIA Consulting)

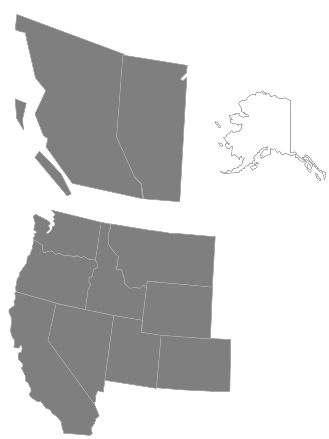
c) rosette (Rachel Winston, MIA Consulting), d) flowers (Fornax), e) nutlets (Richard Old, XID Services, Inc, www.xidservices.com, www.bugwood.org)

conditions. Can be found in rangeland, pastures, abandoned crops, roadsides, and other waste places, but does especially well in forest clearings opened by logging operations and road construction.

ECOLOGY: Spreads only by seed. The barbed hooks on the surface of nutlets readily adhere to animal fur, feathers, machinery or human clothing. Seeds only remain viable in the soil for up to three years. Germination typically occurs in early spring. Plants are rosettes the first year, not producing flowering stems until the second year. Flowering occurs throughout summer. Most plants die following flowering, but some continue to flower for one or two more years.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: There are no approved biocontrol agents; CAN: *Longitarsus quadriguttatus* and *Mogulones crucifer* (=*Mogulones cruciger*).

NOTES: All parts of the plant contain pyrrolizidine alkaloids that are toxic to livestock and humans.

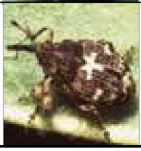


Houndstongue Biological Control

HISTORY IN THE NORTHWEST: European exploration for potential biological control agents began in 1988. Following the testing of six species, *Mogulones crucifer* and *Longitarsus quadriguttatus* were approved for release in Canada in 1997 and 1998, respectively. A petition for the release of *M. crucifer* in the USA was denied due to concerns about the agent's host specificity. Despite its denial in the USA, *M. crucifer* naturally migrated there from Canadian release sites and is presently established in three states. The USDA APHIS issued a pest alert in 2010 which outlines the legal penalties that can be imposed on any individual who is affiliated with the unauthorized collection, transportation, and release of *M. crucifer* within and to the USA.

CURRENT STATUS: Both *M. crucifer* and *L. quadriguttatus* established in Canada, though *M. crucifer* has proven to be a far superior agent. Its high impact has negatively affected populations of *L. quadriguttatus,* which is now only confirmed established in low numbers in BC where it has limited impact. *M. crucifer* is established in AB, BC, ID, MT and WA. At sites where *M. crucifer* has been present for multiple years, houndstongue is now typically rare or completely absent. Nontarget attack has been documented in both Canada and the USA, though to date this attack appears to be only minor, sporadic, and temporary spillover. It should be noted that *M. crucifer* has been shown capable of developing on several plant species that are considered threatened and endangered in the USA. To date, *M. crucifer* does not yet occur in areas of the USA with populations of these protected species. In addition, there are regions of the USA not yet established by *M. crucifer* where there exists large populations of related plant species known to be more prone to *M. crucifer* attack. Both are significant concerns for the future. The incidence of nontarget feeding is still being monitored in both Canada and the USA.

RECOMMENDATIONS: USA: **Both *L. quadriguttatus* and *M. crucifer* are not approved for release. Though *M. crucifer* naturally migrated from Canada, its redistribution within the USA is illegal and is punishable with steep penalties.** CAN: Due to the high impact of *M. crucifer*, continued use of *L. quadriguttatus* is not recommended in Canada. Redistribution of *M. crucifer* is recommended and is best accomplished using an industrial strength wet-dry vacuum cleaner from April to May.

AGENT	ADULT	IMPACT	RECOMMENDATION
Longitarsus quadriguttatus		Defoliation and root- feeding now have limited impact in CAN due to success of *M. crucifer*.	Not released in USA. No longer recommended for redistribution in CAN due to tremendous success of *M. crucifer*.
Mogulones crucifer		Root-feeding extremely effective throughout weed range in Canada, causing high mortality.	Naturally spread to USA; illegal to redistribute. Increasingly distributed in CAN, but recommended where not already established.

Longitarsus, Mogulones: Mark Schwarzländer, University of Idaho

Longitarsus quadriguttatus (Pontoppidan)

Houndstongue flea beetle

DESCRIPTION: Eggs are elliptical, yellowish-orange, and laid at houndstongue leaf petiole bases, on root crowns or into the soil within 2 cm from first year rosettes. Larvae are 1-4 mm long, have short legs, a white body and yellow head with thick head capsule. Adults are up to 3 mm long, shiny black, and have long antennae. Both wing covers have 2-4 reddish spots that vary in size and shape. It is the reddish spots that gives this agent its Latin name, and helps differentiate this species from other *Longitarsus*.

Longitarsus quadriguttatus: a) adult (Mark Schwarzländer, University of Idaho), b) feeding damage (© Province of British Columbia. All rights reserved. Reproduced with permission of the Province of British Columbia)

LIFE CYCLE: Eggs hatch in spring; emerging larvae feed on secondary roots and the main tap root cortex. Larvae overwinter in plant roots and resume feeding in early spring. There are three larval instars. Pupation occurs in the soil. Adults emerge in late spring, feed, mate, and oviposit within a week of emergence. There is one generation per year.

DAMAGE: Adults feed on foliage leaving a characteristic shot-hole appearance over the entire leaf that provides little control of the weed. Larvae feed on roots, often leading to plant mortality.

PREFERRED HABITAT: Hot, dry sites with a mild continental climate.

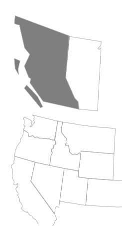
HISTORY: Introduced from Austria to Canada (BC 1998, AB 1999).

CURRENT STATUS: Established in AB and BC initially, but *Mogulones crucifer* subsequently destroyed all known houndstongue at the AB release sites. *L.*

quadriguttatus is now only confirmed established in low numbers in BC where it has limited impact.

REDISTRIBUTION: In Canada, given the high success of *M. crucifer*, continued use of *L. quadriguttatus* is not recommended.

NOTES: **This agent is not approved for release in the USA.** Typical of all flea beetles, adults are capable of jumping great distances and do so when disturbed.



Mogulones crucifer (Pallas)

Houndstongue root weevil

SYNONYMS: *Mogulones cruciger* Herbst

DESCRIPTION: Eggs are white (turning yellow-orange with age) and laid at the bases of houndstongue leaf petioles. Larvae are white with brown head capsules, 1-4 mm long, and have the typical weevil "C-shape." Adults are 2-3 mm long and a mottled dull brown with a white cross pattern on their wing covers.

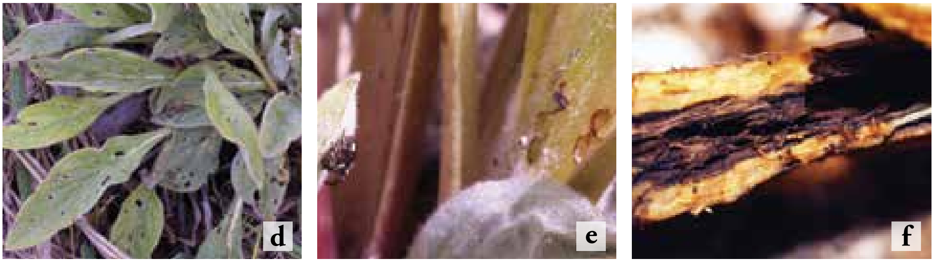
Mogulones crucifer: a) eggs, b) larva (a,b Rachel Winston, MIA Consulting), c) adult (Mark Schwarzländer, University of Idaho)

LIFE CYCLE: Overwintering adults emerge in spring from the soil litter and feed on houndstongue rosette leaves prior to mating and laying eggs from April-May. Hatching larvae feed on roots and develop through three instars. Mature larvae exit roots to pupate in the soil in prepared silk oval cocoons covered in soil particles. New adults emerge in late summer and early fall and feed on houndstongue foliage prior to mating and laying eggs. Autumn oviposition is typically much less frequent than in spring. Adults may live 1-2 years, so overlap in generations has been documented, and larvae can typically be found throughout the year. Overwintering can occur in three forms: mature adults in soil, pupae and new adults in cocoons, or larvae in roots.

DAMAGE: Adults feed on foliage, leaving characteristic circular and oval feeding holes over the entire leaf and petioles. Feeding larvae consume roots which, in turn, may kill plants outright, prevent rosettes from flowering, or decrease the reproductive output of already-flowering stalks.

PREFERRED HABITAT: Does well at all houndstongue sites in BC and AB at which it has been released.

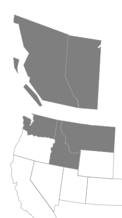
HISTORY: Introduced from Hungary and Serbia to Canada (BC 1997, AB 1998). Spread naturally to the USA by 2008.



Mogulones crucifer damage to d) leaves, e) leaf petioles, f) roots (all Rachel Winston, MIA Consulting)

CURRENT STATUS: Though this agent is approved for use in Canada, it was rejected for release in the USA due to concerns of nontarget attack. It has since migrated naturally from Canada to bordering states in the USA. This agent has been very effective in Canada and in the portions of the USA to which it has naturally migrated. At sites where the agent has been present for multiple years, houndstongue is now typically rare or completely absent. Nontarget attack has been documented in both Canada and the USA, though to date this attack appears to be only minor, sporadic, and temporary spillover. *M. crucifer* has been shown capable of developing on several plant species considered threatened and endangered in the USA. To date, *M. crucifer* does not yet occur in areas of the USA with populations of these protected species. In addition, there are regions of the USA not yet established by *M. crucifer* where there exists large populations of related plant species known to be more prone to *M. crucifer* attack. Both are significant concerns for the future. The incidence of nontarget feeding is still being monitored in both Canada and the USA

REDISTRIBUTION: **It is illegal to release or redistribute this species within the USA**. The USDA APHIS issued a pest alert in 2010 which outlines the legal penalties that can be imposed on any individual who is affiliated with the unauthorized collection, transportation, and release of *M. crucifer* in and to the USA. In Canada, adult field collections can be difficult as adults drop easily from leaves and are readily camouflaged in the soil. The most efficient method is to aspirate adults from leaves, petioles, the root crown and surrounding soil by using an industrial strength wet-dry vacuum cleaner (with a catchment container) from April through May and sieving the resulting material. Adults are most active following periods of sunny, warm days and in the morning to early afternoon. Releases of 300 individuals should be made on patches of at least 400 m² (1/10 acre) containing plants in a variety of stages. Establishment can be monitored the following spring.

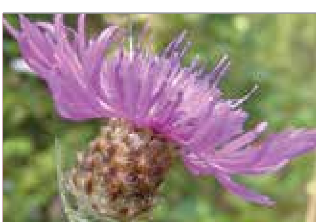
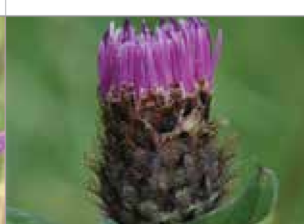


Knapweed species comparison (*Centaurea*)

Diffuse and spotted knapweed are the most common knapweed species in North America and the primary targets of knapweed biological control efforts. Below is a comparison of these two species, as well as four others that are typically considered less problematic in North America but are occasional hosts to knapweed biocontrol agents. Russian knapweed is in a different genus, *Rhaponticum*, and comprises its own, distinct biocontrol program. It is treated separately in this guide.

Trait	Diffuse *Centaurea diffusa*	Spotted *Centaurea stoebe*	Squarrose *Centaurea virgata* ssp. *squarrosa*
Life History	Annual to short-lived perennial (usually biennial)	Short-lived perennial	Long-lived perennial
Preferred Habitat	Disturbed initially; Dry	Disturbed initially; Dry to mesic	Disturbed initially; Dry
Average Height	1½' (0.45 m)	2½' (0.75 m)	1½' (0.45 m)
Basal Leaf Description	4-8" long (10-20 cm); Deeply divided into linear lobes; Gray-green; Densely hairy	4-8" long (10-20 cm); Deeply divided into elliptic lobes; Gray-green; Densely hairy	4-8" long (10-20 cm); Deeply divided into fine lobes; Gray-green; Densely hairy
Capitulum Diameter	0.25-0.4" (7-10 mm)	0.25 - 0.6" (6-15 mm)	0.12-0.25" (3-6 mm)
Bract Description	Narrow; Fringed by sharp spines; Terminal spine longer than laterals and not curved backward	Fringe short and rigid; Dark brown triangular tip	Narrow; Fringed by sharp spines; Terminal spine longer than laterals and strongly curved backward
Capitulum			

Credits: Diffuse: Richard Old, XID Services, Inc, www.xidservices.com; Spotted: Michael Shephard, Forest Service, www.bugwood.org; Squarrose: Steve Dewey, Utah State University, www.bugwood.org; Meadow: Eric Coombs, Oregon Department of Agriculture; Black: Mikrolit; Brown: Cindy Roche, www.bugwood.org

Meadow *Centaurea jacea* nothosubsp. *pratensis*	**Black** *Centaurea jacea* ssp. *nigra*	**Brown** *Centaurea jacea* ssp. *jacea*
Perennial	Perennial	Perennial
Moist sites	Mesic to moist	Disturbed initially; Mesic to Moist
2’ (0.6 m)	1½’ (0.45 m)	2’ (0.6 m)
6” long (15 cm); Entire margins (sometimes tiny teeth or lobes); Tapered both ends, widest past middle; Green; Less hair	6” long (15 cm); Entire margins (sometimes tiny teeth or lobes); Wide at base then taper near stem; Green; Fine hair	6” long (15 cm); Entire margins (sometimes tiny teeth or lobes); Tapered both ends, widest past middle; Green; Less hair
0.5-0.75” (12-18 mm)	0.6-1” (15-25 mm)	0.5-0.85” (12-22 mm)
Bearing papery, deeply fringed margins	Tipped with comb-like, black teeth	Bearing papery, translucent margins
		

Diffuse knapweed

Centaurea diffusa Lam.

SYNONYMS: white knapweed, tumble knapweed

ORIGIN: First recorded in North America in 1907 in an alfalfa field.

DESCRIPTION: A winter-hardy forb that usually grows as a biennial but may at times grow as an or short-lived perennial. Stems are 1-3½ ft tall (⅓-1 m) with numerous, spreading branches that give the plant a ball-shaped appearance and tumble-weed mobility when broken. Rosette leaves are deeply divided, gray-green, and covered in small hairs. Stem leaves are stalkless, getting smaller and less divided higher up the stem. Flower heads have white (sometimes pink or lavender) florets that occur at the ends of branches and produce numerous bristle-topped seeds. Receptacle bracts are edged with a fringe of spines; the terminal spine is distinctly longer. This plant has a deep and fibrous taproot.

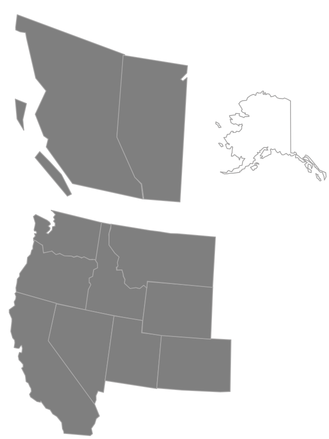
a) plant (K. George Beck & James Sebastian), b) infestations (Eric Coombs, Oregon Department of Agriculture) (both www.bugwood.org)

c) leaf (K. George Beck & James Sebastian), d) capitulum with white florets (Richard Old, XID Services, Inc, www.xidservices.com, e) capitulum with pink florets (Steve Dewey, Utah State University) (all www.bugwood.org)

HABITAT: Rapidly colonizes roadsides and disturbed lands, especially dry sites. It prefers habitats in the shrub-steppe zones and dry, open forests.

ECOLOGY: Spreads only by seeds. Unlike other knapweeds, the flower heads of diffuse do not open to shed seeds. Instead, seeds are shed as the mature plants tumble in the wind after the stiff central stalk breaks. Seeds are also spread by vehicles, animals, and people and can remain viable for many years. Flowering occurs from June through October. Seeds germinate throughout the growing season.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Agapeta zoegana, Bangasternus fausti, Cyphocleonus achates, Larinus minutus, L. obtusus, Metzneria paucipunctella, Pelochrista medullana, Pterolonche inspersa, Sphenoptera jugoslavica, Urophora affinis,* and *U. quadrifasciata*; CAN: *A. zoegana, C. achates, L. minutus, M. paucipunctella, P. medullana, P. inspersa, S. jugoslavica, U. affinis*. and *U. quadrifasciata*.



NOTES: A diploid, fertile hybrid between diffuse knapweed and spotted knapweed has been identified and is known as *C.* x *psammogena.*

Spotted knapweed

Centaurea stoebe L. sensu latu

SYNONYMS: bushy knapweed; *Centaurea biebersteinii* DC, *Centaurea stoebe* L. subsp. *micranthos* (Gulger) Hayek, *Centaurea maculosa* Lam.

ORIGIN: Introduced in contaminated hay from Europe and Asia as early as 1890.

DESCRIPTION: A bushy, winter-hardy, biennial or perennial forb. This upright plant is often found in dense infestations. Plants grow from 1-3½ ft (⅓-1 m) in height and are supported by a deep taproot. Rosette leaves are gray-green, woolly, and deeply divided. Stem leaves are pinnately divided, becoming smaller and less divided towards the tips of multiple woolly, hairy stems. Mid-plant branches are topped by a few to many pink or lavender flower heads producing numerous tiny, bristle-topped seeds. Receptacles are covered by shortly fringed bracts with dark brown tips which give the plant its common name of "spotted knapweed."

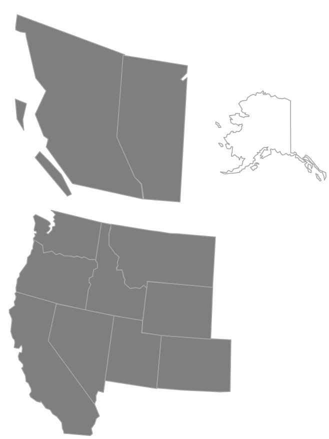
a) plant (Angelica Velazquez, Cowlitz County Noxious Weed Control Board), b) infestation (Jennifer Andreas, Washington State University Extension)

c) rosette (Jennifer Andreas, Washington State University Extension), d) leaf (John Cardina, The Ohio State University), e) flower head (Michael Shephard Forest Service) (d,e www.bugwood.org)

HABITAT: Rapidly colonizes roadsides and disturbed lands, especially dry sites, then invades adjacent undisturbed grasslands and open forests.

ECOLOGY: Spreads only by seeds, which are equipped for dispersal by wind, water, livestock, wildlife, and human activity and which can remain viable in the soil for many years. Flowering occurs from June to October. Seeds germinate throughout the growing season. Heads persist on the stiff stems through the winter, eventually breaking off when new rosette growth appears the following spring.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Agapeta zoegana, Bangasternus fausti, Chaetorellia acrolophi, Cyphocleonus achates, Larinus minutus, L. obtusus, Metzneria paucipunctella, Pelochrista medullana, Pterolonche inspersa, Sphenoptera jugoslavica, Terellia virens, Urophora affinis,* and *U. quadrifasciata*; CAN: *A. zoegana, C. acrolophi, C. achates, L. minutus, L. obtusus, M. paucipunctella, P. medullana, P. inspersa, S. jugoslavica, T. virens, U. affinis*, and *U. quadrifasciata*.



NOTES: *Centaurea stoebe* L. is the appropriate name for the diploid form present throughout Europe; the nomenclature for the tetraploid form invasive in North America remains to be resolved. Spotted knapweed has the widest distribution in North America of all knapweed species.

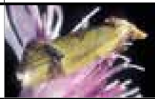
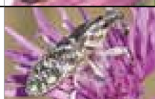
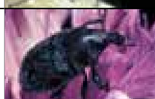
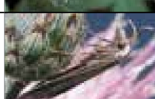
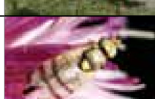
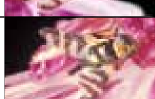
Knapweed Biological Control

HISTORY IN THE NORTHWEST: Six knapweed species (genus *Centaurea*) are highly problematic in North America, though diffuse and spotted are by far the most common. Knapweed biological control began in North America in 1970 with the importation of the knapweed banded gall fly, *Urophora affinis*. Since then, an additional 12 insect species have been introduced to North America as classical biological control agents of knapweed. Diffuse and spotted knapweed are the primary targets, though other knapweed species serve as occasional hosts to established agents.

CURRENT STATUS: All 13 knapweed insects have established in North America, though at varying levels. The eight seed-feeding agents reduce seed production. This does not kill existing plants, but does help reduce the rate of spread of weed populations. Unfortunately most knapweed species are not seed-limited, so seed-feeding agents alone typically do not provide control. The five root-feeding agents decrease plant function, stature, reproductive output, and sometimes density. However, populations of root-feeding insects are typically much less abundant than their seed-feeding counterparts. While they may have significant impacts locally, they typically do not provide control overall when used alone. The seed-feeding *Larinus* beetles have proven to be some of the most effective knapweed biocontrol agents because in addition to larval feeding reducing seed production, adult feeding defoliates leaves and stems. This defoliation can be severe, which can stunt and even kill affected plants. The most successful North American knapweed biocontrol programs to date utilize a combination of insects attacking seeds, foliage and roots of knapweed plants. In this manner, diffuse and spotted knapweed have reportedly been controlled in certain portions of their invaded range, though certain other infestations persist.

RECOMMENDATIONS: USA: The most effective agents established on diffuse knapweed include *Larinus* spp. (especially *L. minutus*), *Sphenoptera jugoslavica*, and *Urophora* spp. *Cyphocleonus achates* is becoming increasingly important on diffuse knapweed at some locations. Both *Urophora* flies are largely already distributed throughout knapweed ranges in North America. Adult *Larinus* and *S. jugoslavica* can be collected using a sweep net when plants are in early flowering. Both favor hot, dry climates. The most effective combination of agents for spotted knapweed include *Larinus* spp. (especially *L. obtusus*), *C. achates*, and *Urophora* spp. Adult *C. achates* can be netted or hand-picked in late summer when plants are mature flowering, and released at hot sites with sandy, coarse soil. CAN: The same combinations of insects are also the most effective against diffuse and spotted knapweed in Canada and can be redistributed in the same manner.

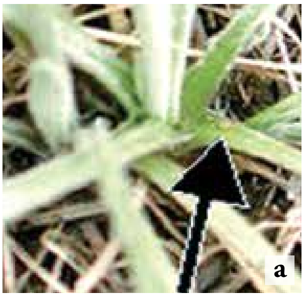
Credits for photos at right: See individual agent pages

Agent	Adult	Impact	Recommendation
Agapeta zoegana		Prefers spotted. Established USA, CAN. Root feeding low to moderate impact overall.	Abundance generally low in USA, CAN. Not high priority for redistribution.
Bangasternus fausti		Reduces seed production diffuse, spotted, squarrose in USA. Limited impact overall.	Not released in CAN. Limited abundance and impact in USA so not high priority agent.
Chaetorellia acrolophi		Prefers spotted. Reduces seed production but limited impact overall.	Abundance generally low in USA, unknown (likely rare) in CAN. Not high priority agent.
Cyphocleonus achates		Often prefers spotted. Root feeding effective at hot, sandy sites in USA, CAN; less elsewhere.	Recommended for redistribution to hot, sandy sites USA/CAN; Especially with *Larinus* spp.
Larinus minutus		Prefers diffuse. Reduces seed production & plant function in USA, CAN. Impact high.	Recommended for redistribution to hot, dry sites in USA, CAN.
Larinus obtusus		Often prefers spotted. Reduces seed production & plant function in USA, CAN. Impact variable.	Recommended for redistribution to mesic sites in USA, CAN.
Metzneria paucipunctella		Prefers spotted. Reduces seed production in USA, CAN. Limited impact overall.	Abundance generally low in USA and CAN. Not high priority for redistribution.
Pelochrista medullana		Established only in USA. Prefers diffuse. Root feeding, low impact overall.	Populations very limited. Not high priority for redistribution.
Pterolonche inspersa		Established only on diffuse in USA, CAN. Root damage moderate but only locally.	Populations low in USA, CAN. Not high priority for redistribution.
Sphenoptera jugoslavica		Prefers diffuse. Established USA, CAN. Root damage moderate locally.	Recommended for redistribution to hot, dry diffuse sites. Spotted sites typically too moist.
Terellia virens		Established only in USA and on spotted. Reduces seed production but limited impact.	Abundance and impact low. Not high priority for redistribution in USA.
Urophora affinis		Established on diffuse, spotted USA, CAN. Ineffective alone; okay in combination.	Typically already widespread in USA, CAN. Moderate priority where not established.
Urophora quadrifasciata		Established on diffuse, spotted USA, CAN. Ineffective alone; okay in combination.	Typically already widespread in USA, CAN. Moderate priority where not established.

Agapeta zoegana (L.)

Sulfur knapweed moth

DESCRIPTION: Larvae are white with brown mouthparts and can be up to 7 mm long. Adults are usually 11 mm long with a wingspan measuring 15-23 mm. Forewings are bright yellow with brownish band markings; hind wings are dark gray. Females have a larger, more rounded abdomen than males and lay white, flattened eggs that turn yellow-red in a few days.



Agapeta zoegana: a) egg (Nez Perce Biological control Center Archive), b) larva and root damage (USDA ARS), c) adult (Laura Parsons & Mark Schwarzländer, University of Idaho) (all www.bugwood.org)

LIFE CYCLE: Larvae overwinter in roots, and feed in those roots the following spring. Pupation occurs in the roots; adults emerge from summer to early fall when knapweeds are in bud and flowering. Adults mate within 24 hours of emergence and are short-lived. They are most active in early morning or evenings, and rest low on the plants or on the soil surface during the day. Females deposit eggs on knapweed stem crevices and leaves as early as the following day. A single adult female lays 21-78 eggs in her lifetime. Larvae hatch in 7-10 days and migrate to the crown area and mine roots, and develop through six instars. As they mine the outer root layers, larvae produce a whitish web tunnel that encloses them. They create a spiral trail downward before they turn back towards the top of the root. There is usually only one generation per year.

DAMAGE: When larvae feed within roots, root tissue can be completely consumed. This reduces knapweed biomass and density and may kill small plants.

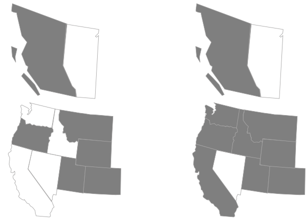
PREFERRED HABITAT: Found mostly in dry, well-drained, open sites with loamy soil. It survives in areas characterized by a moderately humid climate or in areas with arid, subcontinental climates. It can tolerate cold winter temperatures, but requires a long growing season. Suitable host plants have root diameters of at least 0.1 in (2½ mm).

HISTORY: Introduced from Austria and Hungary and released on spotted and diffuse knapweed in the USA from 1984 (CA, ID, MT, NV, OR, WA). Redistributions attempted to squarrose knapweed in UT in 1994. Austrian and Hungarian populations were also used for releases on spotted and diffuse knapweed in Canada (AB 1989, BC 1982).

CURRENT STATUS: In the USA, it is unknown if the redistributions to squarrose knapweed were successful. Can cause significant reduction of spotted knapweed above-ground biomass and number of capitula per plant, but has not demonstrated any obvious effect on plant density. Expected to primarily affect large plants. Damages diffuse knapweed to an even lesser extent than spotted. Abundance is limited on both species so overall impact is low. In Canada, high populations may have significant impact on diffuse and spotted knapweed populations, especially in conjunction with other biocontrol agents. Although widely distributed, abundance is typically low because densities decrease as distribution/dispersal increase.

REDISTRIBUTION: Adult moths are delicate so are best transferred as larvae. Infested plants can be dug up (including the roots) and transferred to new sites in late fall or early spring. Alternatively, roots can be collected in fall and stored at 39-46°F (4-8°C). Two to three weeks prior to their normal emergence time, bring them to room temperature in rearing cages or breathable, clear containers. Once they emerge, adults can be transferred to new knapweed infestations. Releases of 100-200 individuals should be made on continuous, nonlinear patches of knapweed in loamy soil. Establishment can be monitored the following spring by dissecting roots for feeding larvae or observing adults in low foliage during late summer. Note that root damage without larvae present can be difficult to distinguish from other root-feeding insects.

NOTES: Multiple larvae may attack the same root. In one observation, more than 50 *Agapeta zoegana* larvae and 20 *Cyphocleonus achates* larvae were found attacking one very long segment of knapweed root.



diffuse spotted

Bangasternus fausti (Reitter)

Broad-nosed knapweed seedhead weevil

DESCRIPTION: Eggs are yellow ovals covered with dark egg caps. Larvae are white, C-shaped grubs with brown head capsules and can be up to 8 mm long. Pupae are white and up to 5 mm long. Adults are small and gray to brown/black. They can be 4 mm long and have shorter, more blunt snouts compared to the *Larinus* weevils.

Bangasternus fausti: a) pupa (USDA ARS European Biological Control Laboratory), b) adult (Laura Parsons & Mark Schwarzländer, University of Idaho) (both www.bugwood.org)

LIFE CYCLE: Overwintering adults emerge from soil and plant litter in spring and feed on knapweed foliage prior to egg laying. Eggs are laid from late spring through summer, individually on the underside of leaflets or on stems below the developing flower head. Eggs are covered with masticated plant tissue (which forms a black egg cap) and hatch in 8-12 days. Depending on the egg placement, hatching larvae either mine into the midrib of the leaflet or into the stem prior to tunneling into the flower head. Larvae develop through four instars and feed on developing seed tissue throughout the summer. Pupation occurs in the flower head within a chamber made of frass and fused seeds. Adults emerge in late summer or early fall when knapweeds are senescing. Adults drop to the ground to overwinter. There is one generation per year.

DAMAGE: Larval feeding destroys seeds and receptacle tissue. Seed consumption does not kill existing plants, but does help reduce the rate of spread of knapweed populations.

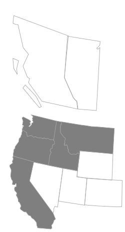
PREFERRED HABITAT: Prefers hot, dry areas and does not do well in areas with prolonged rain or at high elevations.

HISTORY: Introduced from Greece and originally released on diffuse knapweed in the USA from 1990 (CA, CO, ID, MT, OR, WA). Successfully redistributed to spotted knapweed from 1992 (CO, ID, MN, OR, WA) and squarrose knapweed from 1993 (CA, UT). Failed redistributions were attempted on meadow knapweed from 1998 (CA, OR) and on purple starthistle in CA in 1999.

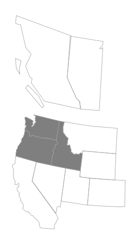
CURRENT STATUS: Larvae can consume up to 100% of seed in attacked capitula of diffuse, spotted, and squarrose knapweed, though a proportion of seeds often escape attack in large flower heads. Abundance is low in the USA, but not likely due to interspecific competition. Overall impact is limited.

REDISTRIBUTION: Though populations are typically low in the USA, some populations in OR and WA are reportedly large enough for redistribution. Adults can be collected with a sweep net (with or without an aspirator) during summer when plants are in early bud to early flowering. Releases of 200 individuals should be made on patches of at least 2,000 m² (½ acre). Establishment can be monitored the following summer by checking for adults and/or feeding larvae within capitula. Note that feeding larvae can be difficult to distinguish from other knapweed weevil species.

NOTES: **This agent is not approved for release in Canada.**



diffuse



spotted

Chaetorellia acrolophi White & Marquardt

Knapweed peacock fly

DESCRIPTION: Eggs are shiny white, elongate, and have a long filament thickened at one end. First generation larvae and pupae are white and barrel-shaped. Second generation larvae and pupae are more yellowish-brown in color. Adults are 4-5 mm long and have bright green eyes, orange-yellow colored abdomens, and overall spotting on the thorax. Wings are clear with light brown bands.

Chaetorellia acrolophi: a) larva (Rachel Winston, MIA Consulting), b) adult (USDA APHIS PPQ Archive, www.bugwood.org)

LIFE CYCLE: There are usually two generations per year; however, a rare third generation is possible under ideal conditions. Adult flies emerge in early summer as knapweed buds form. Mating occurs immediately and oviposition starts within two days. Females lay eggs individually or in small groups of 2-4 underneath the bracts of unopened buds. A single female may lay 70 eggs in her lifetime. Larvae hatch in 4-5 days and penetrate the buds, and feed on immature florets until they reach the developing seeds, where they feed through three instars. Pupation occurs in the flower head 10-15 days after larvae hatch. Typically, first generation adults emerge throughout July, mate and lay eggs. New larvae of this generation continue to feed on developing seed tissue. Third instar larvae overwinter. Pupation occurs within the flower head the following spring.

DAMAGE: Larval feeding destroys some developing seeds. This does not damage existing plants, but helps reduce the rate of spread of knapweed populations.

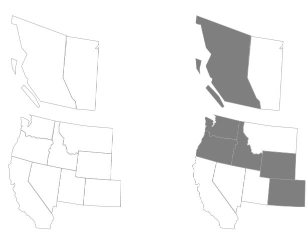
PREFERRED HABITAT: Most effective in areas with low density knapweed, which is less preferred by other capitulum feeders. It generally does better at higher elevations and in regions with high rainfall.

HISTORY: Introduced from Switzerland and released on spotted knapweed in the USA from 1992 (CO, MT, OR, WA, WY). Introduced from Austria and Switzerland and released on spotted knapweed in Canada (BC 1991, AB 1995).

CURRENT STATUS: Established only on spotted knapweed in North America. In the USA, larval feeding reduces seed production, however populations are limited throughout its established range so overall impact is minimal. Diffuse and squarrose knapweed may occasionally be attacked, though damage is likely even less significant than on spotted. Initially believed to have failed establishment on spotted knapweed in Canada, but establishment was confirmed in BC in 2008. Abundance and impact in Canada are currently unknown.

REDISTRIBUTION: Sweeping adult flies is possible, though this is not always the best stage for collection as flies are fragile and can be damaged during collection. Consequently, the species is best transferred by placing plants with infested capitula into uninfested patches during late fall or early spring. Transferring infested seed heads may also transfer unwanted parasitoids, other seed head insects, or knapweed seeds. To avoid this, plants with infested capitula can be collected and adults reared out indoors. Refer to Additional Considerations in the Introduction for instructions on how to do so. Once they emerge in spring, flies can be transferred to new spotted knapweed infestations in groups of 50-100. Establishment can be monitored by observing adults on knapweed foliage the following summer during the heat of the day or by dissecting capitula for larvae from summer throughout the following spring. Note that feeding larvae can be difficult to distinguish from other knapweed fly species. *Urophora* species can be distinguished by their dark brown anal plates and by their presence within galls.

NOTES: In ID, populations do not vary with abundance of other agents; at some OR sites interspecific competition limits populations.

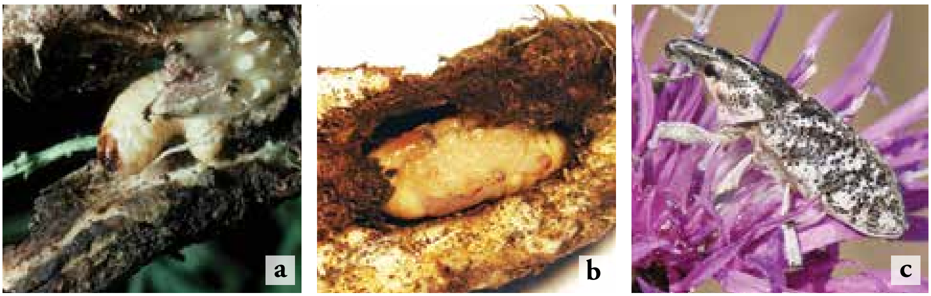


diffuse spotted

Cyphocleonus achates (Fåhraeus)

Knapweed root weevil

DESCRIPTION: Eggs are <2 mm in diameter and white or pale yellow initially, but darken during incubation. Larvae are plump, creamy white or yellowish, with large, light brown head capsules. They can be up to 13 mm long. Similar to most weevils, they are C-shaped. Adults are large, 13–15 mm long, brown-gray mottled, and have short, thick snouts. Females have rounded abdomens, while the males' are flattened.



Cyphocleonus achates: a) larva and root damage (Laura Parsons & Mark Schwarzländer, University of Idaho, www.bugwood.org), b) pupa in root, c) adult (b,c Jennifer Andreas, Washington State University Extension)

LIFE CYCLE: Adults emerge in late summer through early fall and spend most of their life on the root crown, just below the surface. On hot, sunny days they climb to the tops of plants in search of mates. Females lay their eggs in notches they excavate on the root crowns, just below the soil surface. A typical female may lay over 100 eggs. Larvae hatch in 10-12 days and mine towards the center of the roots. They develop through four instars, with third- and fourth-instar larvae often causing a gall-like enlargement of the root. Larvae overwinter in the roots, and pupation occurs in the root over a two-week period in early summer. New adult weevils chew through the root and crawl to the surface. They live for 8-15 weeks but do not overwinter. There is one generation per year.

DAMAGE: Small plants can be killed by larval feeding. Most damage is done when multiple larvae occupy a root, which leads to a reduction in the plant biomass and density of knapweed populations. Tunneling in the root also exposes the plant to bacterial and fungal infection that can cause secondary injury.

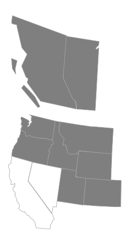
PREFERRED HABITAT: Prefers hot and dry sites, with loose well-drained coarse soils in temperate areas. It establishes in undisturbed bunchgrass habitat, but favors bare soil surfaces where grasses do not crowd the target plants. Sites need to be somewhat large with a corridor of plants, into which the weevil disperses by walking.

HISTORY: Introduced from Austria, Hungary and Romania and released on both spotted and diffuse knapweed in the USA from 1988 (CA, CO, ID, MT, NV, OR, UT, WA, WY) and in Canada (AB, BC) from 1987. Successfully redistributed to squarrose knapweed in UT in 1995. Attempted redistributions to meadow knapweed in OR (1998), CA (2001) and WA (2007) failed to establish.

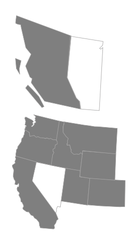
CURRENT STATUS: In the USA, the principal host is spotted knapweed, on which its abundance and impact vary. In some locations, it has been attributed with reducing plant longevity, reproductive output, and density. In other studies, reproductive output remains unchanged as does the weed population overall. Numerous studies claim the agent can be effective, but largely in combination with *Larinus* spp., with high plant competition, under dry conditions, and in loose soil. Damage to diffuse knapweed is usually less extensive and its abundance is also typically decreased on this species. However, diffuse knapweed is the primary host for *C. achates* in WA, and increasing populations are being recovered from diffuse knapweed in ID. Established on squarrose knapweed in UT, but only in limited numbers and with unknown impact. Spotted knapweed is also the preferred host in Canada, on which high weevil populations can decrease plant density and stature, though evidence supporting this is anecdotal. Impact is greatest in conjunction with other biocontrol agents. Weevil populations are much smaller on diffuse knapweed in Canada.

REDISTRIBUTION: Adults can be can be netted in late summer, but are large enough to be hand-picked as well. They are most apparent on sunny days and in the heat of day. Releases of 50-100 individuals should be made at large sites with hot climates and loose, well-drained soil. Establishment can be monitored by observing adults the following late summer or dissecting roots for feeding larvae the following autumn through early summer. Note that root damage without larvae present can be difficult to distinguish from other root-feeding insects.

NOTES: Multiple larvae are often found attacking the same root, along with other species.



diffuse

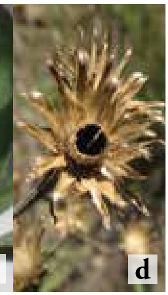


spotted

Larinus minutus Gyllenhal

Lesser knapweed flower weevil

DESCRIPTION: This species is very similar to *Larinus obtusus.* Eggs are elongate, yellow, and often clustered in the flower head between pappus hairs. Larvae are white, C-shaped grubs with brown head capsules. They are approximately 8 mm long. Pupae are 6 mm long and white, turning brown shortly before emergence. Adults are 4-5 mm long, a mottled-brown color, and have a large, bent snout.



Larinus minutus: a) pupa (Gary Brown, USDA APHIS PPQ), b) adult (Laura Parsons & Mark Schwarzländer, University of Idaho), c) adult feeding damage to stem and leaves (Rachel Winston, MIA Consulting), d) emergence hole (Jennifer Andreas, Washington State University Extension)

LIFE CYCLE: Overwintering adults emerge from soil litter throughout the summer. Mating occurs continuously during this long period. Adults feed on the leaves of rosettes and flowering plants, outer stem tissue, and flowers prior to laying eggs. Up to five eggs are deposited in a flower head between pappus hairs; females lay 28-130 in a lifetime. Larvae hatch in three days and feed on pappus hairs before consuming seeds and receptacle tissue. Larvae feed through the entire flowering period of knapweeds and develop through three instars in four weeks. The number of larvae per flower head depends on the size of the flower head and the knapweed species. Pupation occurs in chambers made of chewed seeds and pappus hair within the flower head. New adults emerge by chewing their way out, leaving behind the now-open pupal chamber. They feed on foliage and florets before moving to overwintering sites at plant bases. There is one generation per year.

DAMAGE: Defoliation by adults can be severe, which can stunt and even kill affected plants. Larval feeding consumes large portions of developing seeds, reducing the rate of knapweed spread even further.

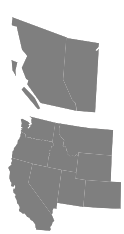
PREFERRED HABITAT: Typically prefers sites more dry and hot than those tolerated by *Larinus obtusus*. It favors dense knapweed stands with little plant competition and requires well-drained, coarse soils. Compacted sites (especially those grazed with livestock during the bolting stage) or places with prolonged rainfall are not suitable for this insect.

HISTORY: Introduced from Greece and Romania and originally released on diffuse and spotted knapweed in the USA from 1991 (CA, CO, ID, IN, MT, NV, OR, WA, WY). Spread naturally and via intentional redistributions to meadow knapweed from 1998 (CA, OR, WA) and squarrose knapweed in CA from 1997. A failed redistribution to purple starthistle was attempted in CA in 1998. Introduced from Greece and released on diffuse and spotted knapweed in Canada from 1991 (AB, BC).

CURRENT STATUS: Larval feeding decreases knapweed seed output while adult feeding decreases plant function. In the USA, causes widespread decreases in density of diffuse knapweed, which is the preferred host over spotted. Impact on spotted knapweed is variable; it can reportedly be high, but is typically less dramatic than on diffuse. Established at lower densities on meadow knapweed in CA, OR and WA and on squarrose in CA and UT. Impact on both species in CA can be high locally, but elsewhere is typically much less than that observed on diffuse knapweed. In Canada, diffuse is typically the preferred host as well. High weevil populations correspond to widespread decreases in density and cover of diffuse knapweed, with less impact on spotted. In Canada, more than five years are generally required post release before reductions are noticeable.

REDISTRIBUTION: Adults can be collected with a sweep net (with or without an aspirator) during summer when plants are in early flowering. Releases of at least 200 individuals should be made on patches of at least 2,000 m² (½ acre). Establishment can be monitored the following summer by checking for adults and/or feeding larvae within capitula. Note that feeding larvae can be difficult to distinguish from other knapweed weevil species.

NOTES: *Larinus minutus* reportedly prefers diffuse knapweed while *L. obtusus* prefers spotted. Both are difficult to differentiate with the naked eye, with some evidence pointing to them being variants of the same species. Many releases of either agent likely contained a mixture of both. Rodent predation can be high at some sites.



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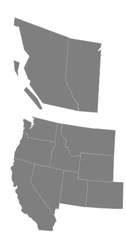


spotted

Larinus obtusus Gyllenhal

Blunt knapweed flower weevil

DESCRIPTION: This species is very similar to *Larinus minutus*. Eggs are elongate, yellow, and deposited in the flower head between pappus hairs. Larvae are white, C-shaped grubs with brown head capsules. They are approximately 8 mm long. Pupae are 6 mm and white, turning brown shortly before emergence. Adults are 5-7 mm long, a mottled brownish-black, and have a large, bent snout.

Larinus obtusus: a) adult (Laura Parsons & Mark Schwarzländer, University of Idaho), b) adult feeding damage (Rachel Winston, MIA Consulting), c) larval feeding damage (Montana State University Archive, www.bugwood.org)

LIFE CYCLE: Overwintering adults emerge from soil litter throughout the summer. Adults feed on knapweed foliage and flowers prior to laying eggs. Eggs are deposited in the flower head between pappus hairs. Larvae hatch in three days and feed on pappus hairs and developing seeds. Larvae feed through the entire flowering period of knapweeds, and develop through three instars in 3-4 weeks. Pupation occurs in 9 days in pupal chambers made of chewed seeds and pappus hair within the flower head. New adults emerge in late summer by chewing their way out, leaving behind the now-open pupal chamber. They feed on foliage and senescing florets before moving to overwintering sites at the base of plants. There is one generation per year.

DAMAGE: Defoliation by adults can be severe, which can stunt and even kill affected plants. Larval feeding consumes large portions of developing seeds, reducing the rate of knapweed spread even further.

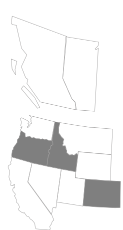
PREFERRED HABITAT: Favors more moist sites with cooler temperatures than those tolerated by *Larinus minutus*. It establishes on south and west slopes with well-drained coarse soils, often near water. Excess competing vegetation may discourage establishment.

HISTORY: Introduced from Romania and Serbia and originally released on diffuse and spotted knapweed in the USA from 1992 (CO, ID, MT, OR, WA, WY). Spread naturally and via intentional redistributions to meadow knapweed from 1999 (CA, OR, WA) and spread naturally to black and brown knapweed in OR by 2004. Introduced from Romania and released on spotted knapweed in BC, Canada from 1992.

CURRENT STATUS: Larval feeding decreases knapweed seed output while adult feeding may decrease plant function. In the USA, spotted knapweed is typically the preferred host, on which it successfully reduces abundance in parts of the Pacific Northwest. In other areas, even high weevil densities and attack rates have little to no impact on knapweed infestations. The distribution listed below for spotted knapweed in the USA is likely incomplete. Populations are much more limited and with less impact on diffuse knapweed. May provide moderate control to meadow (CA, OR, WA), black (OR), and brown knapweed (OR), largely via seed reduction. In Canada, it is well established on spotted knapweed in BC where it frequently occurs in mixed populations with *L. minutus.* Similar to the USA, larval feeding decreases seed output while adult feeding decreases plant function. High weevil populations correspond to widespread density decreases of spotted knapweed. Prefers moister conditions, so has smaller distribution than *L. minutus* and overall impact in Canada is moderate.

REDISTRIBUTION: Adults can be collected with a sweep net (with or without an aspirator) during summer when plants are in early flowering. Releases of at least 200 individuals should be made on patches of at least 2,000 m² (½ acre). Establishment can be monitored the following summer by checking for adults and/or feeding larvae within capitula. Note that feeding larvae can be difficult to distinguish from other knapweed weevil species.

NOTES: *Larinus obtusus* reportedly prefers spotted knapweed while *L. minutus* prefers diffuse. Both are difficult to differentiate with the naked eye, with some evidence pointing to them being variants of the same species. Many releases of either agent likely contained a mixture of both. Rodent predation can be high at some sites. The number of larvae per seed head is often correlated with seed head diameter; up to 6 larvae have been observed in a large capitulum of meadow knapweed compared with the single larvae typically observed in diffuse knapweed seed heads.



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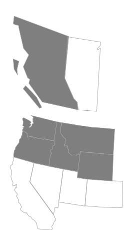


spotted

Metzneria paucipunctella Zeller

Spotted knapweed seedhead moth

DESCRIPTION: Eggs are elongate, oval, and reddish-brown when first deposited, but turn yellowish as they mature. Larvae are 4-5 mm long, white with dark brown head capsules, distinct body segments, and several pairs of prolegs. Pupae, enclosed in a cocoon, are brown with appendages fused to the body. Adult moths are small (8 mm long). Their front wings are slightly fringed and light gray with peppery spotting and dark tips. When at rest, the wings are folded over their backs, giving them a slender appearance.

Metzneria paucipunctella: a) larva and pupa, b) adult (all Norman Rees, USDA ARS www.bugwood.org)

LIFE CYCLE: Adults begin emerging and mating in late spring and early summer when knapweeds are in the rosette and bolting stages. They fly at dusk and are rarely seen. Female moths may lay 60-100 eggs, beginning in early summer. Eggs are placed singly on the bracts at the base of young flower heads, or on the stems just below the capitula. Larvae hatch in 10-12 days as flower heads are opening. Larvae enter the opened capitula and feed on florets, seeds, and receptacle tissue (which reduces the viability of uneaten seeds). There are five instars total. Several young larvae can occupy a flower head early in the season, but only one larva survives beyond the third instar. Larvae overwinter in the flower heads. Pupation occurs in the capitulum in spring and lasts 3-4 weeks. There is one generation per year.

DAMAGE: Feeding larvae can destroy eight seeds per larva (on average) and reduce the viability of others. Older larvae bind seeds together, preventing seeds from dispersing over long distances.

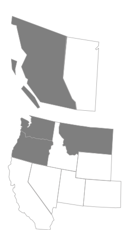
PREFERRED HABITAT: Does not tolerate severe winter temperatures. Favored sites are south slopes in dry, mild-winter climates. Snow cover during winter enhances larval survival. It appears to do best in areas where spotted knapweed flowers early in the season.

HISTORY: Introduced from Switzerland and released on spotted knapweed in AB and BC, Canada from 1973; redistributed to diffuse knapweed from 1981. Redistributed from Canada to spotted knapweed in the USA from 1980 (CO, ID, MT, OR, WA, WY). Spread naturally and via intentional redistributions to diffuse knapweed from 1980 (MT, OR, WA). Redistributed within OR to meadow knapweed in 1983 in releases intended to contain *Urophora quadrifasciata.*

CURRENT STATUS: Spotted knapweed is the preferred host, though even on this species abundance is rarely high. Seed reduction is typically insufficient to impact knapweed populations. Attack to diffuse and meadow knapweed (OR) is far less common; impact is insignificant on these species. In Canada, populations are moderate on spotted knapweed but have only limited impact on plant populations. Diffuse knapweed is rarely attacked- largely only when growing amongst spotted infestations.

REDISTRIBUTION: Sweeping adults is possible though it would be difficult to collect many, and this method is not recommended due to the likelihood of causing damage during collection. Consequently, the species is best transferred by placing plants with infested capitula into uninfested patches during early spring. Transferring infested seed heads may also transfer unwanted parasitoids, other seed head insects, or knapweed seeds. To avoid this, plants with infested capitula can be collected and adults reared out indoors. Refer to Additional Considerations in the Introduction for instructions on how to do so. Once they emerge in spring, adults can be transferred to new knapweed infestations in groups of 50-100. Establishment can be monitored by dissecting capitula for larvae from late summer throughout the following spring.

NOTES: Populations in both the USA and Canada are limited by overwintering mortality, parasitism, and predation (frequently deer mice).



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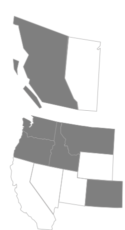


spotted

Pelochrista medullana (Staudinger)

Brown-winged knapweed root moth

DESCRIPTION: Eggs are oval, somewhat flattened, and have a strong outer shell with distinct ribs. Initially they are white, but gradually turn dark yellow during incubation. The segmented larvae are whitish-yellow with brown head capsules. They are usually less than 10 mm long. Adult moths are tan to gray with mottled wings fringed at their tips. They can be up to 10 mm long.

Pelochrista medullana: a) larva in root (USDA APHIS PPQ Archive), b) adult (Bob Nowierski, Montana State University) (both www.bugwood.org)

LIFE CYCLE: Adults emerge throughout summer when knapweed is bolting and flowering. They mate within 24 hours of emergence and lay eggs primarily on the lower surface of rosette leaves. Females can lay up to 120 eggs in warm dry weather, but this can be greatly reduced by cold, rainy conditions. Larvae hatch 7-9 days after oviposition, move to the center of the rosette and mine into the root crown. Larvae feed on the outer layers of root tissue, similar to *Agapeta zoegana*. Webbed tubes are produced along feeding tracks, which can be irregular, downward or spiralling, and the tunnels are lined with a silken web. There are six larval instars. This species seems to prefer rosette plants; larvae that feed on the roots of flowering plants develop poorly. Larvae overwinter in the roots and complete development in the spring or early summer. Pupation occurs within the webbing inside the root. There is one generation per year.

DAMAGE: Larval damage to the roots is similar to that caused by *Agapeta zoegana*. Larvae reduce root storage capacity and expose the plant to pathogens, but only the third to sixth instars cause measurable damage. Small plants with <0.4 in (10 mm) root diameter can be completely destroyed. Plants that survive insect attack are usually smaller and produce fewer flower heads than uninfested plants.

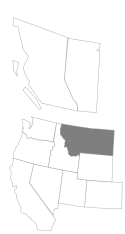
PREFERRED HABITAT: Prefers hot, dry areas and dense knapweed patches. Populations growing in poor, coarse, or gravel soils are ideal.

HISTORY: Introduced from Austria and Hungary and released in the USA from 1984 on diffuse (MT) and spotted knapweed (MT, OR). Introduced from Austria and released in BC on diffuse knapweed (from 1982) and spotted knapweed (from 1986 in rearing tents).

CURRENT STATUS: Preferred host is diffuse knapweed, though it is established on both diffuse and spotted knapweed in the USA. Populations remain limited for unknown reasons, causing minimal damage at localized sites. Failed to establish on either diffuse or spotted knapweed in Canada.

REDISTRIBUTION: Populations are so small as to likely preclude redistribution. Where established, infested plants can be dug up (including the roots) and transferred to new sites in late fall or early spring. Alternatively, roots can be collected in fall and stored at 39-46°F (4-8°C). Two to three weeks prior to their normal emergence time, bring them to room temperature in rearing cages or breathable, clear containers. Once they emerge, adults can be transferred to new knapweed infestations. Releases of 50-100 individuals should be made on continuous, nonlinear patches of knapweed. Establishment can be monitored the following spring by dissecting roots for feeding larvae. Note that root damage without larvae present can be difficult to distinguish from other root-feeding insects.

NOTES: Usually only one larva develops per root, likely due to intraspecific competition. Very large roots have been observed to contain up to four.



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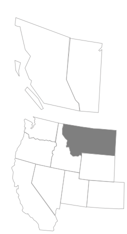


spotted

Pterolonche inspersa Staudinger

Grey-winged knapweed root moth

DESCRIPTION: Eggs are black and oval-shaped with a slightly depressed center. Larvae are pearly white with inflated segments and have small, brown head capsules. Adult moths can be up to 8 mm long. Their wings are light brown, exhibiting a silvery sheen. Wingspans are up to 20 mm. When at rest, the wings are held close to their sides.

Pterolonche inspersa: a) larva and root damage (Eric Coombs, Oregon Department of Agriculture), b) silken chimney tube (USDA ARS European Biological Control Laboratory), c) adult (USDA APHIS PPQ Archive) (all www.bugwood.org)

LIFE CYCLE: Adults emerge from late summer through early fall, mate and lay eggs during their short, 15-20 day life span. Eggs are laid singly or in small groups on the under-surfaces of rosette leaves. A single female may lay 140+ eggs in her lifetime. Larvae hatch within 12 days and mine down the root, feeding on the woody central portion of the root or the soft tissue near the outer edges, causing galls to form. There are five larval instars; third instars typically overwinter within the root and resume feeding the following spring. Larvae construct silken “chimney” tubes that extend from the galls upward to 20 mm above the soil surface, where they pupate. The chimneys provide easy exits for the emerging adults. Pupation is 15 days and occurs in early summer. There is one generation per year.

DAMAGE: Larvae feed on roots, which interrupts the vascular flow of nutrients to the plants, thereby decreasing the plant’s biomass and flowering ability. Damaged roots become spongy and fragile and easily break apart. Damage attracts other predators, which move into the roots and provide secondary attack.

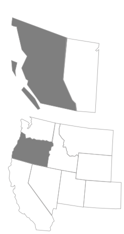
PREFERRED HABITAT: Prefers hot, dry sites with low to moderate plant density. Requires a period of drought during summer, so it is only suited to more arid environments. Preferred soils consist of loosely compacted sand or gravel.

HISTORY: Introduced from Austria, Hungary and Greece and released in the USA on diffuse knapweed from 1986 (ID, MT, OR, UT, WA). Reintroduced from Hungary and released on spotted knapweed from 1988 (CO, MT, OR). Eggs imported from Greece were distributed on squarrose knapweed in UT in 1990. Introduced from Austria and Hungary and released in BC, Canada on diffuse knapweed from 1986 and spotted knapweed in 1987.

CURRENT STATUS: Established on diffuse knapweed in one region in OR, USA where insect populations are now rare and provide no impact because of dramatic control of diffuse knapweed by *Larinus* spp. Releases on spotted and squarrose knapweed failed. In Canada, it is established only on diffuse knapweed, even in patches with spotted and diffuse knapweed interspersed. Populations on diffuse knapweed are moderately abundant and may stunt plants, though evidence is anecdotal, and impact due to this agent alone remains unclear.

REDISTRIBUTION: Populations are so small as to likely preclude redistribution. Where established, infested plants can be dug up (including the roots and any attached larval chimneys) and transferred to new sites in late fall or early spring. Alternatively, roots can be collected in fall and stored at 39-46°F (4-8°C). Two to three weeks prior to their normal emergence time, bring them to room temperature in rearing cages or breathable, clear containers. Once they emerge, adults can be transferred to new knapweed infestations. Releases of 50-100 individuals should be made on continuous, nonlinear patches of knapweed. Establishment can be monitored the following spring by dissecting roots for feeding larvae. Note that root damage without larvae present can be difficult to distinguish from other root-feeding insects.

NOTES: Usually only one larva of this species develops per root, due to aggressive intraspecific competition. However, very large roots have been observed containing up to four. The moth can co-occur with *Sphenoptera jugoslavica* by feeding below *S. jugoslavica* galls.



diffuse

spotted

Sphenoptera jugoslavica Obenberger

Bronze knapweed root borer

DESCRIPTION: Eggs are flat and white when first laid, but change to dark bluish-purple after five days. Larvae have an enlarged head and a long, thin, cylindrical body that tapers to the end. They are whitish with dark brown head capsules. Pupae are initially white, but later darken. Adults can be up to 10 mm long. They are a metallic bronze color and somewhat flattened, with their bodies tapering towards the narrowed abdomen tip.

Sphenoptera jugoslavica: a) eggs, b) larva in root (a,b Eric Coombs, Oregon Department of Agriculture), c) adult (Laura Parsons & Mark Schwarzländer, University of Idaho) (all www.bugwood.org)

LIFE CYCLE: Adults emerge in summer with the onset of knapweed flowering. They feed on knapweed leaves for 2-3 days before mating. During late summer, females lay multiple eggs between the bases of rosette leaves. Leaf stems with diameters of 3-6 mm are preferred over smaller leaves. Females lay an average of 50 eggs during their lifetimes. Larvae hatch after two weeks and feed between leaf stalks. As knapweed sets seed, second instar larvae mine into the upper root; their feeding creates swollen galls and tunnels often filled with frass. Larvae overwinter in roots. Pupation (nine days) occurs within the feeding chamber during early summer the following year. There is one generation per year.

DAMAGE: Adults feed on foliage, leaving characteristic circular and oval feeding holes over the entire leaf. Feeding larvae consume roots which, in turn, may kill plants outright, prevent rosettes from flowering, or decrease the reproductive output of already-flowering stalks.

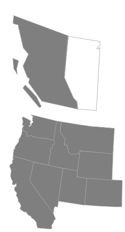
PREFERRED HABITAT: Prefers arid environments with a period of drought in summer. Thrives in well-drained, coarse soils with southern aspects. Exposed soil between plants increases the soil temperature, making sites even more suitable.

HISTORY: Introduced from Greece and released in the USA on diffuse knapweed from 1980 (CA, CO, ID, MT, NV, OR, UT, WA, WY). Spread naturally and via intentional redistributions to spotted knapweed from 1987 (CO, ID, MT, OR). Redistributed to squarrose knapweed from 1996 (CA, UT). Attempted redistributions to meadow knapweed in 1998 (OR) failed to establish. Introduced from Greece and released in BC, Canada on diffuse knapweed from 1976. Redistributed from diffuse to spotted knapweed in BC from 1987.

CURRENT STATUS: In the USA, causes some reductions in diffuse knapweed density and seed output, especially among competing vegetation. Overall impact on diffuse is moderate as the agent is largely restricted to hot, dry sites. Diffuse is the preferred host; while spotted can be attacked, agent distribution and impact are typically very limited on spotted knapweed compared to diffuse. Moderately effective on squarrose in CA, but populations are limited in UT. In Canada, diffuse is again the preferred host, on which high agent populations can be found throughout the driest part of the weed's range. High beetle numbers can decrease weed stature, seed production, and rosette density though most impact is only localized rather than widespread throughout the province. Best in combination with other agents. Can decrease seed production and plant stature of spotted knapweed growing in hot dry areas, but most spotted infestations are too moist to support beetle populations.

REDISTRIBUTION: Adults can be collected with a sweep net (with or without an aspirator) during summer when plants are in flower. Releases of 50-200 individuals should be made at large sites with hot climates and loose, well-drained soil. Establishment can be monitored by observing adults the following summer or dissecting roots for feeding larvae the following autumn through early summer. Note that root damage without larvae present can be difficult to distinguish from other root-feeding insects.

NOTES: Plants rarely support more than one larva; if two develop on a single root, the larva feeding lowest in the root is usually smaller.



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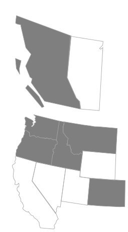


spotted

Terellia virens (Loew)

Green clearwing knapweed fly

DESCRIPTION: Eggs are elongate, about 1 mm long, and shiny white. Larvae are a plump barrel shape and white, but turn yellow-brown as they mature. Pupae are yellow-brown. Adults are approximately 5 mm long. They have clear wings and large, bright green, and iridescent eyes.

Terellia virens: a) larva, b) adult (both Eric Coombs, Oregon Department of Agriculture)

LIFE CYCLE: Adults emerge in spring when knapweed is still in the rosette or bolting stages. Adults feed heavily on nectar when knapweed flower heads bloom. Mating begins with the onset of warm weather and continues throughout summer. In the summer and fall, females lay one to several eggs between florets in young flower heads. The female lays an average of 80 eggs in her lifetime and often marks the bracts of the flower head with a substance to discourage egg laying by other females. Eggs hatch in 3-5 days, and larvae feed on ripening seeds and receptacle tissue through three instars. Larvae overwinter within capitula, then pupate in chambers made of pappus in spring. Weather conditions determine the number of generations (one or two) of *Terellia virens*; however, only one generation has been confirmed at most North American sites.

DAMAGE: Larvae can consume up to 90% of seed in flower heads. Seed consumption does not damage existing plants, but does reduce knapweed's rate of spread.

PREFERRED HABITAT: Prefers plants on south-facing slopes and dry locations.

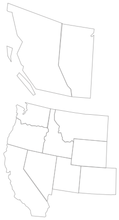
HISTORY: Introduced from Austria and Switzerland and initially released in the USA on spotted knapweed from 1992 (CA, CO, MT, OR, WA, WY).

Redistributions were attempted on purple starthistle and squarrose knapweed in CA in 1998 but failed to establish. Introduced from Austria and Switzerland to spotted knapweed in Canada (BC 1991, AB 1995) but failed to establish.

CURRENT STATUS: Established only in the USA and only on spotted knapweed. Populations are limited, likely due to competition with *Urophora* spp. and *Larinus* spp. Causes only minor reductions in seed production with minor impact overall.

REDISTRIBUTION: Sweeping adult flies is possible, though this is not always the best stage for collection as flies are fragile and can be damaged during collection. Consequently, the species is best transferred by placing plants with infested capitula into uninfested patches during late fall or early spring. Transferring infested seed heads may also transfer unwanted parasitoids, other seed head insects, or knapweed seeds. To avoid this, plants with infested capitula can be collected and adults reared out indoors. Refer to Additional Considerations in the Introduction for instructions on how to do so. Once they emerge in spring, flies can be transferred to new knapweed infestations in groups of 50-100. Establishment can be monitored by observing adults on knapweed foliage the following summer during the heat of the day or by dissecting capitula for larvae from summer throughout the following spring. Note that feeding larvae can be difficult to distinguish from other knapweed fly species. *Urophora* species can be distinguished by their dark brown anal plates and by their presence within galls.

NOTES: May attack diffuse knapweed, but to a much smaller extent than spotted.



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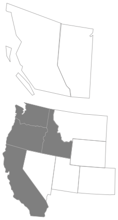


spotted

Urophora affinis (Frauenfeld)

Banded knapweed gall fly

DESCRIPTION: Eggs are white and elongate. Larvae are creamy white, barrel-shaped, and with heads that retract slightly. Larvae of flies do not have head capsules but do develop dark brown anal plates by the end of the feeding period. The pupa is brown, barrel-shaped, and 3 mm long. Adults can be up to 4 mm long. They have dark bodies and clear wings marked with faint horizontal bars. Females have long, pointed, black ovipositors.

Urophora affinis: a) larva in gall (Eric Coombs, Oregon Department of Agriculture), b) multiple galls (Jim Story, Montana State University), c) adult (Laura Parsons & Mark Schwarzländer, University of Idaho) (all www.bugwood.org)

LIFE CYCLE: There is usually one generation per year, though in warm climates, a second generation may occur. Overwintering as third instar larvae, flies pupate for about 14 days in the spring and emerge as adults at the time knapweed is in the bud stage. Females lay up to 120 eggs in groups of 1-5 among immature florets inside closed flower heads. After 3-4 days, larvae hatch and tunnel into the base of the capitulum where they feed on receptacle tissue. Larval feeding triggers the formation of a hard, woody gall which surrounds the larva. The majority of larvae require a cold period to induce pupation, and thus overwinter in flower heads; 10-25% of larvae may pupate early in suitable climates, with second generation adults emerging in early fall.

DAMAGE: Larval feeding directly destroys some seeds, reducing the rate of knapweed spread. In addition, galls drain nutrients from other parts of the plant, which causes stunting and reduces the number of flower heads produced. Between 2-4 galls in a single capitulum are common, though this depends on capitulum size (often directly related to the species attacked).

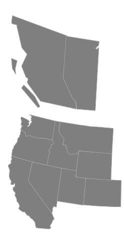
PREFERRED HABITAT: Well adapted to a variety of environmental conditions and can be found throughout the majority of spotted and diffuse knapweed infestations in North America. Shows a preference for mesic sites and appears to do better on dense weed populations.

HISTORY: Introduced from Austria, France and Russia (some via Canada) and released in the USA on diffuse and spotted knapweed from 1973 (CA, CO, ID, MT, NV, OR, WA, WY). Spread naturally and via intentional redistributions to squarrose knapweed in CA, OR, UT from 1988. Introduced from France and Russia to Canada and released on diffuse and spotted knapweed in BC from 1970 (redistributed to AB from 1976).

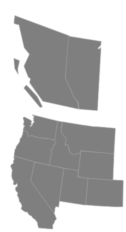
CURRENT STATUS: Well established on diffuse and spotted knapweed in the USA. With *U. quadrifasciata* contributes to seed reduction of >50% at some sites. Seed reduction may retard rate at which weed spreads, but has not appreciably lowered stand density because sufficient seeds remain. At other sites, the direct effect of *Urophora* galls on seed production is negligible. Not considered as important or effective as other knapweed agents. Established in only limited amounts on squarrose knapweed (CA, OR, UT), on which it is not effective. In Canada, high fly populations stunt plant growth and decrease seed production but result in no apparent decline in knapweed density.

REDISTRIBUTION: Sweeping adult flies is possible, though this is not always the best stage for collection as flies are fragile and can be damaged during collection. Consequently, the species is best transferred by placing plants with infested capitula into uninfested patches during late fall or early spring. Transferring infested capitula may also transfer unwanted parasitoids, insects, or knapweed seeds. To avoid this, plants with infested capitula can be collected and adults reared out indoors. Refer to Additional Considerations in the Introduction for instructions on how to do so. Once they emerge in spring, flies can be transferred to new knapweed infestations in groups of 50-100. Establishment can be monitored by observing adults on knapweed foliage the following summer or by dissecting capitula for larvae from summer throughout the following spring. Note that feeding larvae can be difficult to distinguish from other knapweed fly species. *Urophora* species can be distinguished by their dark brown anal plates and their presence within galls.

NOTES: It does not disperse as rapidly as *Urophora quadrifasciata*, but is often the dominant species at sites where both flies coexist. Deer mice feed heavily on *Urophora* larvae, and mice populations are known to increase as a result.



diffuse



spotted

Urophora quadrifasciata (Meigen)

UV knapweed seedhead fly

DESCRIPTION: Eggs are white and elongate. Larvae are creamy white, barrel-shaped, and with heads that retract slightly. Larvae do not have head capsules but do develop dark brown anal plates by the end of the feeding period. The pupa is brown, barrel-shaped, and 3 mm long. Adults can be up to 4 mm long. They have dark bodies and clear wings marked with distinctive dark bands forming a "UV" pattern on each wing. Females have long, pointed, black ovipositors.

Urophora quadrifasciata: a) larva (USDA ARS), b) adult (Laura Parsons & Mark Schwarzländer, University of Idaho) (both www.bugwood.org)

LIFE CYCLE: There are usually two generations per year. Overwintering as third instar larvae, flies pupate for 14 days in spring, and adults emerge as knapweed is budding. Females lay up to 120 eggs in groups of 1-5 among immature florets inside closed flower heads. Unlike *Urophora affinis, U. quadrifasciata* females prefer well-developed capitula. After 3-4 days, larvae hatch and tunnel into the base of the capitulum where, through three instars, they feed on receptacle tissue. Larval feeding induces the formation of a papery gall which surrounds the larva. Pupation occurs in galls in late summer. Second generation adults emerge in early fall, attacking late-developing seed heads. Larvae overwinter in capitula.

DAMAGE: Larval feeding directly destroys some seeds, reducing the rate of knapweed spread. In addition, galls drain nutrients from other parts of the plant, which causes stunting and reduces the number of flower heads produced. Between 2-4 galls in a single capitulum are common, though this depends on capitulum size (often directly related to the species attacked).

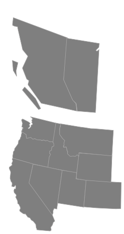
PREFERRED HABITAT: Well adapted to a variety of environmental conditions and can be found throughout the majority of spotted and diffuse knapweed infestations in North America. Tolerant of severe winter conditions and requires considerably more protective snow cover than *U. affinis*.

HISTORY: Introduced from Russia and released in BC, Canada on diffuse knapweed in 1972 and meadow knapweed in 1987. Spread naturally to spotted knapweed by 1975. Spread to the USA naturally by 1979 (diffuse and spotted knapweed) from releases made in Canada and likely redistributed accidentally in seed heads thought to contain only the approved *Urophora affinis*. Spread naturally to bachelor's button as well as brown, meadow and squarrose knapweed Many intentional redistributions made on these species post 1979. Officially approved for redistribution in the USA in 1989.

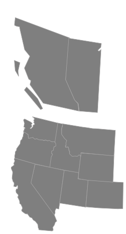
CURRENT STATUS: Well established on diffuse and spotted knapweed in the USA. More widely distributed than *U. affinis* but less abundant. Together seed reduction can be >50% at some sites, but negligible at others. Seed reduction may retard rate at which weed spreads, but has not appreciably lowered stand density because sufficient seeds remain. Not considered as important or effective as other agents. Established in smaller amounts on bachelor's button (*Centaurea cyanus* in OR, WA) and brown (OR, WA), meadow (CA, OR, WA) and squarrose knapweed(CA, OR, UT) on which it is even less effective than on diffuse. In Canada, high fly populations stunt plant growth and decrease seed production but result in no apparent decline in knapweed density. Established on meadow knapweed in BC, on which impact is even less.

REDISTRIBUTION: Sweeping adult flies is possible, though may be damaging. Instead, place plants with infested capitula into uninfested patches during fall or early spring. Transferring infested capitula may also transfer unwanted parasitoids, insects, or knapweed seeds. To avoid this, plants with infested capitula can be collected and adults reared out indoors. Refer to Additional Considerations in the Introduction for instructions on how to do so. Once they emerge in spring, flies can be transferred to new knapweed infestations in groups of 50-100. Establishment can be monitored by observing adults on knapweed foliage the following summer or by dissecting capitula for larvae from summer throughout the following spring. Note that feeding larvae can be difficult to distinguish from other knapweed fly species. *Urophora* species can be distinguished by their dark brown anal plates and their presence within galls.

NOTES: Disperses more rapidly than *U. affinis*, but *U. affinis* is often the dominant species at sites where both flies coexist. Deer mice feed heavily on *Urophora* larvae, and mice populations are known to increase as a result.



diffuse



spotted

Russian knapweed

Rhaponticum repens (L.) Hidalgo

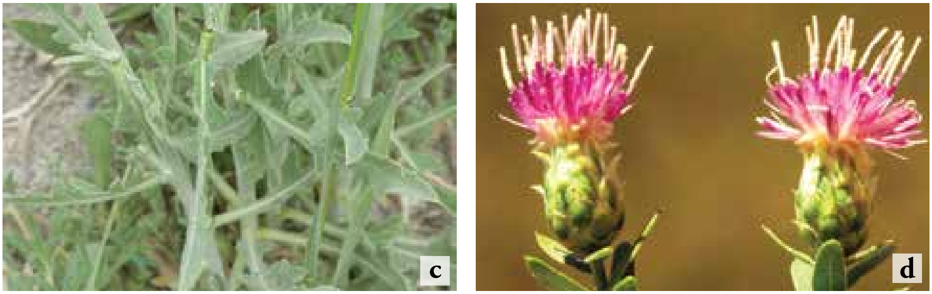
SYNONYMS: *Centaurea repens* L., *Acroptilon repens* (L.) DC.

ORIGIN: Native to central Asia; introduced to North America as a contaminant in alfalfa by 1898.

DESCRIPTION: An upright perennial forb often found in dense infestations. Plants grow from 1-3 ft (⅓-0.9 m) in height and are supported by creeping horizontal roots. Rosette leaves are gray-green, woolly, and deeply divided. Stem leaves are oblong and toothed, becoming smaller towards the tips of multiple woolly, hairy stems. Mid-plant branches are topped by a few to many flower heads with pink, purple, or sometimes blue florets. Flower heads are 0.2-0.4 in (½-1 cm) in diameter and produce numerous tiny, bristle-topped seeds. Receptacles are covered by bracts with thin, papery margins.

HABITAT: A problematic weed of arid regions, it is widespread in rangelands,

a) plant (Eric Coombs, Oregon Department of Agriculture), b) infestation (Norman Rees, USDA ARS) (both www.bugwood.org)



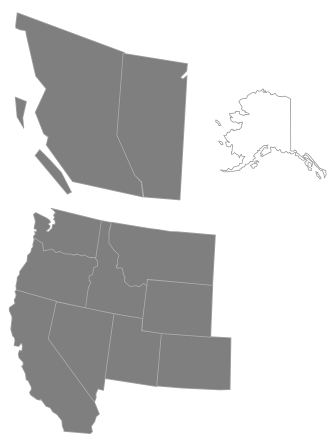
c) leaves (Bonnie Million, National Park Service), d) flower heads (Steve Dewey, Utah State University) (both www.bugwood.org)

grazing land, grain and other crops, waste places, roadsides, and ditches.

ECOLOGY: Reproduces both vegetatively through its roots and by seed. Seeds are equipped for dispersal by wind (short distances), water, livestock, wildlife, and human activity and can remain viable in the soil for up to years. Flowering occurs from June to September with the majority of germination occurring in spring.

APPROVED BIOLOGICAL CONTROL AGENTS: USA and CAN: *Aulacidea acroptilonica, Jaapiella ivannikovi* and *Subanguina picridis*.

NOTES: Horses feeding on Russian knapweed can develop a fatal nervous disorder called chewing disease.

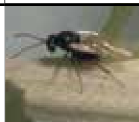
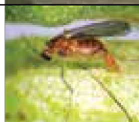
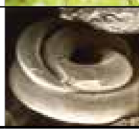


Russian Knapweed Biological Control

HISTORY IN THE NORTHWEST: Exploration throughout the 1970s resulted in the release of *Subanguina picridis* in North America beginning in 1977. Impact of this agent was lower than expected so two additional agents have since been released (*Aulacidea acroptilonica* and *Jaapiella ivannikovi* in 2008 and 2009, respectively).

CURRENT STATUS: *Subanguina picridis* is widespread in both the USA and Canada, but abundance and impact are limited to areas with high soil moisture. It is too early following release to determine the overall impact of *A. acroptilonica* and *J. ivannikovi* in the USA, though early results indicate *A. acroptilonica* populations may remain limited and are already hindered by parasitism. Populations of *J. ivannikovi* are also slow to increase, but at the original USA release sites they are significantly reducing seed output and above-ground biomass. Establishment of *A. acroptilonica* and *J. ivannikovi* have yet to be officially confirmed in Canada.

RECOMMENDATIONS: USA and CAN: *Subanguina picridis* is not a cost-effective agent. Its inability to spread unaided and restriction to moist sites make it a low priority for Russian knapweed control. More time is needed to fully understand the effects of *A. acroptilonica* and *J. ivannikovi*. Redistributions of both are recommended in the USA, with greater emphasis placed on *J. ivannikovi* whose greater impact and shorter generation time make this species the more encouraging agent. Additional releases of *A. acroptilonica* and *J. ivannikovi* are recommended in Canada utilizing lab colonies. The adventive *Puccinia acroptili* has been observed in Canada with mixed results. ***P. acroptili* is not approved for release in the USA.**

Agent	Adult	Impact	Recommendation
Aulacidea acroptilonica		Galls stunt plants, reduce seed production. Populations still limited in USA with minor impact. Parasitized	Recommended for new releases or redistribution; best done by rearing out adults so parasitoids are excluded
Jaapiella ivannikovi		Larval galls stunt plants, reduce seed production significantly at original USA sites; populations still limited	Recommended for new releases with lab colonies or field redistribution by moving infested plants or rearing adults
Subanguina picridis		Galls reduce biomass and seed production, but impact limited to moist sites and times	Not recommended for redistribution as low impact and inability to spread unaided make this agent not cost-effective

Aulacidea, Jaapiella: Urs Schaffner, CABI-Switzerland, *Subanguina:* Tony Caesar, USDA ARS, www.bugwood.org

Aulacidea acroptilonica Tyurebaev

Russian knapweed gall wasp

DESCRIPTION: Larvae are milky white with a curved body and a small, whitish head capsule. Adults are small, typically around 2 mm long. Females are typically slightly longer than males and have larger abdomens. Both males and females have dark bodies with brown slender legs and lighter colored transparent wings. Antennae are long and dark brown.

Aulacidea acroptilonica: a) adult, b) galls (both Urs Schaffner, CABI-Switzerland)

LIFE CYCLE: Adults emerge in early spring. More females than males typically emerge and do so with all eggs fully developed. Oviposition begins immediately, regardless of whether they have mated or not. Unfertilized eggs are typically male. Eggs are laid in meristematic tissue of stems and leaves. Within a few weeks, galls become noticeable around feeding larvae. There are three larval instars, with the third instar becoming dormant during summer. The third instar larvae overwinter, and pupation occurs inside the galls in early spring. A small number of larvae remain in hibernation after the first winter, pupating only after the second winter.

DAMAGE: Gall development diverts nutrients from flower formation, seed production, and plant growth. Under some conditions, galls may stress plants sufficiently to reduce their competitive ability.

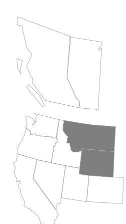
PREFERRED HABITAT: Well adapted to a variety of environmental conditions in its native range, including roadsides, irrigated croplands, wastelands and semi-deserts. Most common where disturbance from grazing animals or cultivation is minimal.

HISTORY: Introduced from Uzbekistan and released in MT, USA from 2009 (WY from 2012) and AB, Canada from 2008.

CURRENT STATUS: It is too soon following release to determine its overall impact and abundance in the USA, though populations have already significantly increased at one MT site. The wasp is unlikely to control Russian knapweed alone, and parasitism is already becoming apparent. Establishment has yet to be officially confirmed in Canada.

REDISTRIBUTION: Adults are small and delicate so sweeping is not advised. Instead, place plants with infested galls into uninfested patches during fall or early spring. Transferring galls may also transfer unwanted parasitoids, insects, or Russian knapweed seeds. To avoid this, gall-infested plants can be collected and adults reared out indoors. Refer to Additional Considerations in the Introduction for instructions on how to do so. Once they emerge in spring, the adult wasps can be transferred to new Russian knapweed infestations in groups of 50-100. Establishment can be monitored by observing Russian knapweed foliage for galls one or two years later during summer.

NOTES: Males appear to be rare or uncommon.



Jaapiella ivannikovi Fedotova

Russian knapweed gall midge

DESCRIPTION: Larvae are white with rosy hues and with a small white head capsule. They are curved and legless and up to 2 mm long. Pupae are pale in color and approximately 2 mm long. Adults are light brown with large transparent wings. They have long, slender legs and large eyes. Males are just under 2 mm long while females are just over.

Jaapiella ivannikovi a) galls, b) adult (both Urs Schaffner, CABI-Switzerland)

LIFE CYCLE: Adults are short-lived and mate soon after emergence. Eggs are laid on the tips of growing shoots. Larvae develop through three instars in silky webs between the growing leaves of the infested shoot, causing leaves to grow together. Pupation occurs in this fusion of leaves, with pupae overwintering. First generation larvae emerge in early spring. In its native range there are typically four overlapping generations per year, each typically one month long.

DAMAGE: Larval feeding causes stunted growth of the shoot and a fusion of leaves, resulting in what is referred to as a "rosette gall." This reduces overall seed production and plant height.

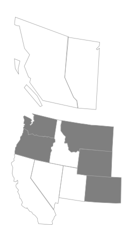
PREFERRED HABITAT: Well adapted to a variety of environmental conditions in its native range, including roadsides, irrigated croplands, wastelands and semi-deserts. Can build up large populations in habitats with high disturbance and irrigation during the summer months. Both factors cause Russian knapweed to produce new shoots, and young shoots are the preferred stage for egg-laying adults. Moist sites appear to have higher establishment success.

HISTORY: Introduced from Uzbekistan and released in MT and WY, USA from 2009 (CA, CO, ID, OR, UT, WA subsequently) and AB, Canada from 2009.

CURRENT STATUS: It is too soon following release to determine its overall impact and abundance in the USA, though initial results from the first WY release site indicate attack reduces seed output per shoot by 91% and above-ground biomass by 34%. Established at several sites in MT, but populations have not significantly increased to date. Establishment has yet to be officially confirmed in Canada.

REDISTRIBUTION: Adults are small and delicate so sweeping is not advised. Instead, place infested plants into uninfested patches throughout the growing season from early spring through fall. Transferring infested plants may also transfer unwanted parasitoids, insects, or Russian knapweed seeds. To avoid this, infested plants can be collected and adults reared out indoors. Refer to Additional Considerations in the Introduction for instructions on how to do so. Once they emerge in spring, midges can be transferred to new Russian knapweed infestations in groups of 50-100. As young shoots are the preferred stage for egg-laying, mowing the release site one week prior to release may increase establishment. This should not be done at overly dry sites where Russian knapweed may be incapable of re-sprouting. Establishment can be monitored by observing gall presence on Russian knapweed foliage later in the same season or in subsequent years.

NOTES: Dissection of field-collected galls revealed up to 14 larvae feeding within. Possibly also established in CA (USA).



Subanguina picridis (Kirjanova) Brzeski

Russian knapweed nematode

SYNONYMS: *Paranguina picridis* (Kirjanova) Kirjanova & Ivanova, *Mesoanguina picridis* (Kirjanova) Chizhov & Subbotin

DESCRIPTION: All stages of this nematode are small and most easily viewed with a microscopic. Both juveniles and adults are long and slim in shape, often curling in on themselves, and are at least partially transparent. Adults can be up to 1½ mm long.

Subanguina picridis: a) galls (Eric Coombs, Oregon Department of Agriculture), b) adult magnified greatly with microscope (Tony Caesar, USDA ARS) (both www.bugwood.org)

LIFE CYCLE: In early spring as stems are bolting, juveniles penetrate rosette leaf stems and shoots. Galls form around their feeding sites. There are two or more generations per year, with all development, feeding, and reproduction occurring in galls. Juveniles overwinter in gall remnants on or just below the soil surface.

DAMAGE: Juveniles and adults cause the formation of galls which reduces above-ground growth and reproduction.

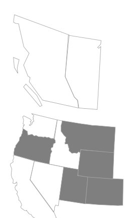
PREFERRED HABITAT: Though it is established in a variety of climates, impact and abundance are limited throughout much of its introduced range. Populations do best in moist areas, especially those regularly irrigated throughout the growing season.

HISTORY: Introduced from Kazakhstan and released in Canada (AB, BC) from 1977. Redistributions from Canada to WA, USA in 1984 failed to establish. A different population sourced from Turkey and Uzbekistan was released in MT, OR, WA in 1990.

CURRENT STATUS: Populations are limited in the USA, and impact has been less than expected. A lack of moisture limits survival, so any infections are not consistent from year to year due to varying moisture conditions. It does not move readily so needs to be propagated and redistributed on a large scale. Consequently, this is not a cost-effective agent. Though initially established in BC, Canada, many release sites were lost due to subsequent land use. No evaluations have been conducted since 2002 to confirm current establishment, abundance and impact. If still present, it is likely limited in establishment and impact, but most promising for spring-moist and irrigated sites.

REDISTRIBUTION: Best redistributed by transferring galls to the soil of uninfested patches during fall. Juveniles will emerge from disintegrating galls in early spring to infect new shoots. Establishment can be confirmed by observing galls on new Russian knapweed foliage throughout the following growing season.

NOTES: Also attacks to a lesser extent the native *Centaurea rothrockii* (whose name has since been changed to *Plectocephalus rothrockii*, the cultivated *Cynara scolymus* (whose name has since been changed to *Cynara cardunculus* subsp. *cardunculus*), and perhaps also the invasive diffuse knapweed.



Russian Knapweed, Unapproved Agents

Puccinia acroptili P. Syd. & Syd. (Pucciniomycetes: Pucciniales)

DESCRIPTION AND LIFE CYCLE: Develops on upper and lower leaf surfaces. Basidiospores germinate in spring, developing club-shaped structures in summer. After pollination, single-celled yellow-brown urediospores are produced. There are multiple generations per season. Thick-walled and medium-brown teliospores overwinter. Spores are wind dispersed.

HISTORY AND CURRENT STATUS: First recorded in BC (CAN) in 1970 as an adventive agent likely originating in South-central Asia. It is currently widespread in AB, BC, SK. At all sites, some plants appear resistant with no negative impact while others adjacent have heavy infection and collapse. In combination with *Subanguina picridis* galls, severely stunted and dying plants have been recorded. **Not approved for release in the USA.**

Purple loosestrife

Lythrum salicaria L.

SYNONYMS: purple lythrum

ORIGIN: Native to Europe, northern Africa, Asia; introduced to North America in the early 1800s in ship ballast, wool, and most likely also as an ornamental or medicinal herb.

DESCRIPTION: Herbaceous, upright perennial typically growing numerous stems 5-9 ft tall (1½-2¾ m) from a spreading, robust taproot. Stems are squarish in cross-section with 4-6 sides. Leaves are lance-shaped, smooth-margined, stalkless, and are 2-5 in long (5-12 cm). Leaves are opposite up the stem, and whorled closer to the base. Flowers are less than 1 in across (2½ cm) with 5-7 pink to purple (sometimes crumpled-looking) petals. Flowers occur in spiked clusters; each flower can produce well over 100 small, light-colored seeds.

HABITAT: An invader of wetlands, can be found along streams, rivers, and

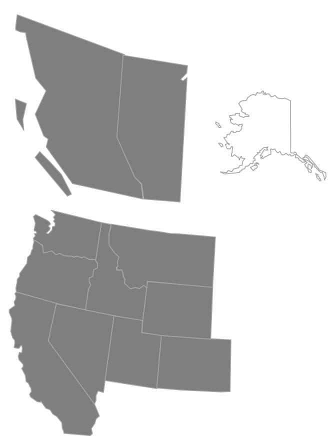
a) plant (K. George Beck & James Sebastian, Colorado State University), b) infestation (Eric Coombs, Oregon Department of Agriculture) (both www.bugwood.org)

c) leaves, e) flowers (both Richard Old, XID Services, Inc, www.xidservices.comd), d) stem e) flowers (K. George Beck & James Sebastian, Colorado State University,) (all www.bugwood.org

irrigation canals, in swamps and freshwater tidal flats, and along lakes and ponds.

ECOLOGY: Spreads primarily by seeds that are easily carried by water, people, and animals, but can also reproduce from root fragments and cut stems. Seeds may remain viable for a few years following dissemination. Seedlings germinate in late spring, and plants may flower the first year. Flowers occur in spiked clusters in late summer to early fall. Plants die back in winter temperatures, with dead stems forming a thick mat persistent for many years.

APPROVED BIOLOGICAL CONTROL AGENTS: USA and CAN: *Galerucella calmariensis, G. pusilla*, *Hylobius transversovittatus* and *Nanophyes marmoratus*.

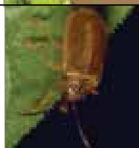
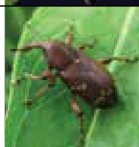
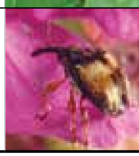


Purple Loosestrife Biological Control

HISTORY IN THE NORTHWEST: European exploration for potential biological control agents began in 1986. Following the testing of six species, four were introduced to North America from 1991: *Galerucella calmariensis, G. pusilla, Hylobius transversovittatus* and *Nanophyes marmoratus.*

CURRENT STATUS: Both *Galerucella* species have established in the USA and CAN and are proving to be the most effective agents in both countries. High densities defoliate plants, reducing seed production, stunting growth, and providing excellent control at many sites. However, some sites in the USA remain unchanged despite high agent numbers. The *Galerucella* beetles often occur in mixed species populations. In both countries, *G. calmariensis* is generally more abundant than *G. pusilla,* but the reverse is true at some USA sites for unknown reasons. Extensive root feeding by *H. transversovittatus* can complement defoliation by *Galerucella* spp., sometimes resulting in plant death. However, *H. transversovittatus* populations are believed to be limited throughout much of its range in USA and CAN. Its establishment and impact are both difficult to assess as larvae are hidden feeders and adults are nocturnal. *Nanophyes marmoratus* is not established in western CAN provinces. In the USA, populations remain limited at many sites due to competition with *Galerucella* spp. *N. marmoratus*, a flower feeder, can help reduce weed population spread at small infestations, but doesn't damage existing plants.

RECOMMENDATIONS: *Galerucella* spp. have the highest priority for redistribution as high populations of these beetles have proven the most effective. *G. calmariensis* appears to be the most important at the majority of sites, though both species often occur in a mix, so should be redistributed as such. They are best collected as adults in spring using sweep nets and aspirators. Alternatively, adults of the new generation can be collected in mid-summer. Though *H. transversovittatus* can be cryptic, if populations can be found or obtained from rearing facilities, its known complementary action with *Galerucella* spp. makes this a medium to high priority agent for redistribution, especially at sites where *Galerucella* spp. do not appear to be abundant or effective. *N. marmoratus* may have the lowest impact of the established species (and thus the lowest priority for redistribution), but it may prove useful at sites with small loosestrife populations or where *Galerucella* spp. are absent or are ineffective.

AGENT	ADULT	IMPACT	RECOMMENDATION
Galerucella calmariensis		Defoliation by both *Galerucella* spp. can decimate weed populations at many sites. Highest abundance and impact of established agents.	Should be redistributed as adults (collected via sweep netting) to new sites or where existing populations have decreased in boom/bust cycles.
Galerucella pusilla		Defoliation by both *Galerucella* spp. can decimate weed populations at many sites. Highest abundance and impact of established agents.	Should be redistributed as adults (collected via sweep netting) to new sites or where existing populations have decreased in boom/bust cycles.
Hylobius tranverso-vittatus		Root-feeding can at high densities result in plant death. Cryptic nature make assessment difficult. Populations appear limited.	Should be redistributed when populations can be found; transfer infested plants. May complement *Galerucella* spp. impact.
Nanophyes marmoratus		Causes flower abortions that do not kill plants, but reduce population spread. Hindered by competition from *Galerucella* spp.	Low impact and poor competitive ability mean this agent should only be redistributed to small infestations or with low *Galerucella* spp.

Galerucella calmariensis: David Cappaert, Michigan State University, www.bugwood.org, *G. pusilla*: Agriculture and Agri-Food Canada Archive, www.bugwood.org, *Hylobius:* Jennifer Andreas, Washington State University Extension, *Nanophyes*: Laura Parsons & Mark Schwarzländer, University of Idaho, www.bugwood.org

Galerucella calmariensis (L.) & *G. pusilla* (Duftschmidt)

Black-margined loosestrife beetle & Golden loosestrife beetle

DESCRIPTION: Larvae of both species are up to 5 mm long. They are greenish-yellow with darkened head capsules and black spots down their back. *Galerucella* species cannot be distinguished in the egg or larval stage. Adults of both species can be 5 mm long. Adult *G. calmariensis* are orange-brown and typically have darkened edges to their hard, outer wings and a dark triangle behind their head. Adult *G. pusilla* are light gold to orange-brown with dark antenna from the middle to the tips. Females of both species are slightly larger than males.

a) *Galerucella calmariensis* adult (David Cappaert, Michigan State University), b) *G. pusilla* adult (Agriculture and Agri-Food Canada Archive) (both www.bugwood.org)

LIFE CYCLE: Overwintering adults feed on leaves and young shoot buds in early spring when purple loosestrife is bolting or resuming growth. Females lay up to 400 eggs in groups of 2-10 on stems and leaves from late spring through summer. Hatching larvae feed on shoot tips and then developing leaves. There are three larval instars. Pupation occurs in soil litter or stem tissue if stems are in standing water. Adults emerge in late summer, resume feeding, then overwinter in soil litter. There is usually one generation per year (two in warm climates).

DAMAGE: Larval feeding strips the photosynthetic tissue off leaves, creating a "window-pane" effect. Adult feeding causes a characteristic "shothole" defoliation pattern. Larval and adult feeding stunt growth, reduce seed production, and may kill plants outright over several years and at high agent densities.

PREFERRED HABITAT: Both species are established in numerous states and provinces, spanning a wide variety of climatic conditions. Both prefer sites without winter flooding and regular water fluctuations (such as via tide or dams).

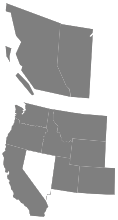
HISTORY: Both species were introduced from Germany and released (often as a

Galerucella spp.: a) eggs and larva (Bernd Blossey, Cornell University), b) larval window-pane feeding, c) adult shot-hole feeding (Eric Coombs, Oregon Department of Agriculture) (all www.bugwood.org)

mix) in the USA from 1992 (CA, CO, ID, MT, OR, UT, WA, WY) and also in Canada from 1992 (AB, BC from 1993 onwards).

CURRENT STATUS: Both species are established in the same states and provinces of northwestern North America. In the USA, they are well established in some states but infrequent in others. *Galerucella calmariensis* is generally more abundant than *G. pusilla,* but the reverse is true at some sites for unknown reasons. High densities have heavy impact by reducing seed production and stunting growth. At some sites, purple loosestrife density has decreased up to 90%; at others purple loosestrife density remains unchanged. Boom-bust cycles are common for this system: as agent populations build, greater dispersal results in increases in weed population, followed by increases in agent populations. Impact is greatest in mixed plant communities that provide competition to recovering loosestrife. In Canada, both *Galerucella* species again often appear in a mix. Together they have provided excellent control throughout majority of purple loosestrife's range. Both *Galerucella* species were initially widespread, but more recent surveys indicate most populations at many sites now consist primarily or wholly of *G. calmariensis*.

REDISTRIBUTION: Best collected in the adult stage in spring using sweep nets and aspirators, though new generation adults can be collected as well in mid- to late summer. Should be transferred to uninfested sites in groups of 100-200. Establishment can be monitored the following year by observing the shot-hole or window-pane feeding characteristic of adults and larvae, respectively. Eggs, larvae, and adults are also readily observed on foliage throughout the growing season.



NOTES: Peak dispersal of overwintered adults is during the first few weeks of spring. Predation may limit some populations.

Hylobius transversovittatus (Goeze)

Loosestrife root weevil

DESCRIPTION: Eggs are white and oval-shaped. Larvae are C-shaped, off-white, and have brown head capsules. They can be up to 10 mm long. Adults are reddish-brown and have two rows of dots on their back which are comprised of white hairs. They are thick insects and up to 12 mm long.

Hylobius transversovittatus: a) eggs, b) larva and root damage (a,b Gary Piper, Washington State University, www.bugwood.org), c) adult (Jennifer Andreas, Washington State University Extension)

LIFE CYCLE: This species often requires two years to complete one generation. Overwintering larvae become active in early spring, feeding on roots and filling feeding tunnels with frass. They develop through three instars and can be present for up to two years. Pupation occurs in the root crown in early summer. Emerging adults feed on leaves. Females lay eggs singly (though up to 300 over two years) in the soil or stems near soil. Larvae emerge in late summer, feed, and overwinter in roots. Adults sometimes overwinter, and can live up to three years.

DAMAGE: Adult feeding is not significant. Roots attacked by larvae have reduced reserve capacity leading to reduced plant vigor, reproductive output, and even death. Large roots can withstand substantial feeding pressure, however, and several larval generations will be necessary before significant impacts are observed.

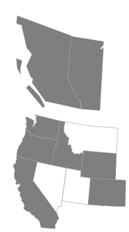
PREFERRED HABITAT: Tolerates a wide range of environmental conditions. Though adults and larvae can survive extended submersion, permanently flooded sites will prevent adult access to plants and will eventually kill developing larvae.

HISTORY: Introduced from Germany and released in the USA from 1991 (from 1992 for western states CA, CO, ID, MT, OR, UT, WA). Introduced from Germany and Finland and released in Canada from 1992 (AB, BC from 1994).

CURRENT STATUS: In the USA it is slower to disperse and reproduce than the other established agents. It is believed to have well established populations in OR and perhaps WA and ID, but is largely limited elsewhere. Extensive root feeding by this agent can complement defoliation by *Galerucella* spp., sometimes resulting in plant death. However, its establishment and impact are both difficult to fully assess as larvae are hidden feeders, and adults are active at night. In Canada, its limited populations and cryptic nature make this species difficult to study so its current status in Canada is largely unknown.

REDISTRIBUTION: Adults can be swept or hand-picked from purple loosestrife foliage in mid- to late summer. Adults are nocturnal, so should be collected at night with the aid of flashlights. Because of the difficulty in this method, infested roots can also be collected and stored in a laboratory setting under conditions simulating the field. Emerging adults can be distributed to uninfested sites in groups of 50-100. Due to the great difficulty of field collections, the majority of released individuals are obtained from laboratory populations. Establishment can be confirmed the following growing season by observing adults on foliage at night, or (more easily) by dissecting roots to find larval damage over the course of the next few growing seasons.

NOTES: Up to 40 larvae have been found per rootstock.



Nanophyes marmoratus (Goeze)

Loosestrife flower-feeding weevil

DESCRIPTION: Larvae are C-shaped, creamy white, and have brown head capsules. They can be up to 2 mm long. Adults are dark brown with orange legs and large whitish-yellow shoulder patches. They are up to 2½ mm long and have a long snout and wide body.

Nanophyes marmoratus: a) egg, b) larva in flower bud (a,b Gary Piper, Washington State University, www.bugwood.org)

LIFE CYCLE: Overwintering adults emerge in late spring and feed on shoot tips, producing a shot-hole appearance in upper leaves. Adults then feed on developing flowering buds. Females lay 60-100 eggs singly inside immature flower buds throughout summer. Hatching larvae develop through three instars and feed on floral parts (one larva per bud). Pupation occurs within the attacked buds, with adults emerging in late summer to overwinter in soil litter. There is one generation per year.

DAMAGE: Adult and larval feeding cause flower-bud abortion, reducing the seed output of purple loosestrife. This does not kill existing plants, but helps reduce the rate of spread.

PREFERRED HABITAT: Well adapted to a variety of environmental conditions throughout the range of the weed in North America. Does not do as well at sites with prolonged flooding or with high populations of *Galerucella* spp. as heavy defoliation by the leaf-feeders reduces food availability.

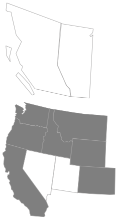
HISTORY: Introduced from France and Germany and released in the USA from 1994 in CA, CO, ID, OR, WA. Introduced from Germany into Canada in 1997, but not in the west (MB only).

Nanophyes marmoratus: c) adult (Laura Parsons & Mark Schwarzländer, University of Idaho), d) damage to lower bud (Gary Piper, Washington State University) (both www.bugwood.org)

CURRENT STATUS: In the USA, feeding on floral buds often results in abortion which helps reduce weed spread. However, weevil populations are typically limited due to interspecific competition with *Galerucella* spp. (defoliated purple loosestrife plants often do not flower, removing *N. marmoratus*' food supply). *N. marmoratus* may be an important agent at sites with decreasing loosestrife and smaller populations of the other agents. Though established in Canada, *N. marmoratus* only occurs in Manitoba, not in the western provinces.

REDISTRIBUTION: During summer, use sweep nets and aspirators to collect adults from loosestrife foliage. A stout beating stick can also be used to dislodge adults from flower spikes before catching them in trays. They can be transferred to uninfested sites in groups of 100-200. Establishment can be monitored the following spring and summer by observing adults on foliage and flowers or dissecting flower buds during the growing season for signs of larval feeding.

NOTES: Has successfully overwintered on exposed islands in an estuary with high tidal exchange where multiple releases of *Galerucella* spp. have failed. The weevils can also persist where plants are scattered at low densities.



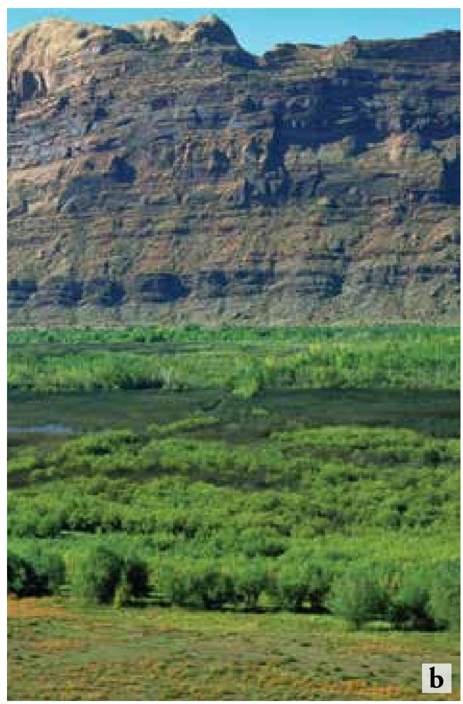
Saltcedar

Tamarix chinensis Willd., *Tamarix ramosissima* Ledeb. & hybrids

SYNONYMS: five-stamen tamarisk

ORIGIN: Both species are geographically isolated in their native Asia (*T. chinensis* in the East, *T. ramosissima* in western Asia), but overlap and hybridize in North America. They were introduced to North America in the 1800s for erosion control and as shade plants.

DESCRIPTION: Both species are very similar in appearance, differing only slightly in the shape of floral parts. In North America, extensive hybridization between these two species has occurred, making separation by appearance difficult to impossible. Both species and their hybrids are perennial shrubs or small trees growing up to 26 ft tall (8 m). Their root system is extensive, with a primary root that grows with little branching until it reaches the water table, at which point secondary root branching becomes substantial. Roots of mature plants are rhizomatous, giving rise to new plants. Leaves are scale-like with salt-secreting glands, and are up to 0.12 in long (3 mm). The foliage is deciduous.



a) plant (Eric Coombs, Oregon Department of Agriculture), b) infestation (Steve Dewey, Utah State University) (both www.bugwood.org)

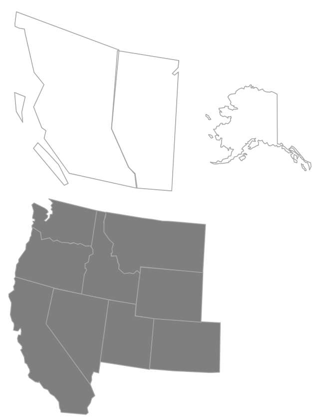
c) leaves and stem (Bonnie Million, National Park Service), d) flowers (Leslie J. Mehrhoff, University of Connecticut)(both www.bugwood.org)

Stems are green and flexible when young, becoming brown and woody with age. Stem fragments can develop adventitious roots and produce new plants if the stem pieces are kept in moist soil. Some plants begin to flower their first year, but most flower in their third. Flowers occur in tight clusters 0.8-3 in long (2-8 cm) on branch ends. Each flower has 5 pink petals ~2 mm long. Fruits are capsules that contain many tiny brown seeds. A large plant may produce several hundred thousand seeds in a single growing season.

HABITAT: Readily invades moist habitats of arid regions, especially in saline soils.

ECOLOGY: Spreads by seed, rhizomes, and sprouting from stem fragments. Seeds are readily transported by wind and water, but are viable for less than 6 months so do not form persistent seed banks. Seedlings germinate rapidly after seeds have direct contact with water. Germination can occur throughout the year. Flowers appear after foliage and are present from spring to fall, decreasing by fall.

APPROVED BIOLOGICAL CONTROL AGENTS: USA and CAN: **None of the species established on *Tamarix* spp. in the USA are currently approved for use.**



NOTES: Both saltcedar parent species and their hybrids are the most invasive *Tamarix* species in North America. They differ from smallflower tamarisk with their flowers appearing after foliage in spring, having 5 petals, and flowering through fall. Smallflower tamarisk flowers have 4 petals, appear before foliage in spring, and are present only in spring.

Smallflower tamarisk

Tamarix parviflora DC.

SYNONYMS: N/A

ORIGIN: Native to southeastern Europe. Introduced to North America in the 1800s for erosion control and as a shade plant.

DESCRIPTION: Perennial shrub or small tree growing up to 16 ft tall (5 m). The root system is extensive, with a primary root that grows with little branching until it reaches the water table, at which point secondary root branching becomes substantial. Roots of mature plants are rhizomatous, giving rise to new plants. Leaves are scale-like with salt-secreting glands, and are up to 0.10 in long (2½ mm). The foliage is deciduous. Stems are green and flexible when young, becoming brown and woody with age. Stem fragments can develop adventitious roots and produce new plants if the stem pieces are kept in moist soil. Some plants begin to flower their first year, but most flower in their third. Flowers occur in tight clusters 0.4 to 0.8 in long (1-2 cm) on branch ends. Each flower has 4 pink petals ~2 mm long. Fruits are capsules that contain many tiny brown seeds. A large plant may produce several hundred thousand seeds in a single

a) plant, b) infestation (both John M. Randall, The Nature Conservancy, www.bugwood.org)

c) resprouting from stem fragment (Joseph M. DiTomaso, University of California-Davis), d) flowers (Barry Rice) (both www.bugwood.org)

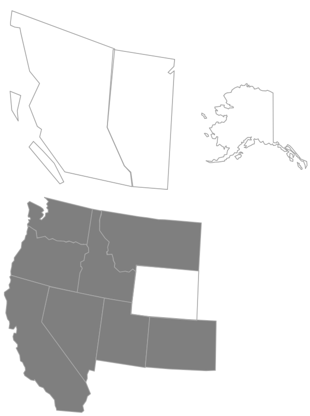
growing season.

HABITAT: Readily invades moist habitats of arid regions, especially in saline soils.

ECOLOGY: Spreads by seed, rhizomes, and sprouting from stem fragments. Seeds are readily transported by wind and water, but are viable for less than 6 months so do not form persistent seed banks. Seedlings germinate rapidly after seeds have direct contact with water. Germination can occur throughout the year. Flowering occurs in spring; flowers appear before foliage.

APPROVED BIOLOGICAL CONTROL AGENTS: USA and CAN: **None of the species established on *Tamarix* spp. in the USA are currently approved for use.**

NOTES: Smallflower tamarisk is the primary invader in CA, USA. Smallflower differs from saltcedar in that its flowers have 4 petals, appear before foliage in spring, and are only persistent through spring. Saltcedar flowers have 5 petals, appear after foliage in spring, and are present from spring through fall.



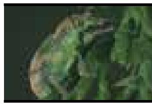
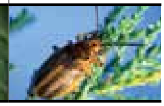
Saltcedar Biological Control

8-12 species of *Tamarix* were intentionally introduced to the USA. Of these, five saltcedar species have become invasive, including *T. parviflora*, *T. canariensis, T. gallica*, and the morphoically similar *T. chinensis* and *T. ramosissima.* The largest invasions in the West consist of *T. chinensis*, *T. ramosissima* and their hybrids. *Tamarix parviflora* is the primary invader in CA. The biocontrol agents thus far established in the USA primarily attack *T. chinensis* and *T. ramosissima* (and their hybrids) and *T. parviflora*. Consequently only these species are described in this field guide.

HISTORY IN THE NORTHWEST: Numerous populations of the defoliating *Diorhabda elongata* were intentionally released in the USA from 2001. *D. elongata* has since been split into 5 species, 4 of which have been released in the USA from 7 different locations, corresponding to 7 different ecotypes. Two ecotypes (Turpan and Posidi Beach) failed to establish. The southwestern willow flycatcher, an endangered bird in the USA, utilizes *Tamarix* spp. in areas where its natural habitat has been encroached by this weed. **Redistributions of *Diorhabda* spp. have been discontinued and are not approved until the legalities of this issue are resolved.** *Coniatus splendidulus* was initially part of a genus of interest for *Tamarix* biocontrol in the USA **but which has never been approved for release.** The species was found established in AZ by 2006.

CURRENT STATUS: Of the 5 *Diorhabda* spp. ecotypes that established prior to the moratorium, the Chilik and Fukang ecotypes originally required long daylight hours in order to avoid premature diapause, which initially prevented them from establishing south of the 38th parallel. They have since evolved, with changing photoperiod requirements now allowing them to persist well below the 38th parallel. Throughout their range, both species are increasing and spreading, providing significant control locally to *Tamarix* populations. The remaining three ecotypes were not ever limited by long daylight hours. The Karshi and Tunisian ecotypes are established and increasing, but are to date restricted to TX and other parts of the Midwest. The Crete ecotype does well on *T. parviflora* in CA. It did well on the widespread saltcedar (*T. chinensis, T. ramosissima* and hybrids) in TX but dispersal was limited. Recent hybridization with *Diorhabda carinata* has led to rapid expansion in TX and other Midwestern states. Flooding and predation limit population growth of all ecotypes. *C. splendidulus* is spreading rapidly in the Northwest and appears to complement *Diorhabda* by attacking foliage before and after *Diorhabda* is active.

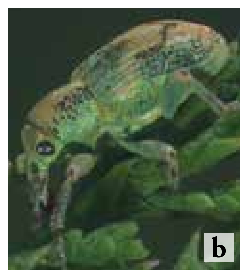
RECOMMENDATIONS: ***C. splendidulus* and *Diorhabda* spp. are not approved for redistribution in the USA. Saltcedar does not occur in Canada.**

Coniatus splendidulus	*Diorhabda* spp.
	

Coniatus: Zeynep Özsoy, Colorado Mesa University, *Diorhabda*: Robert D. Richard, USDA APHIS PPQ, www.bugwood.org

Coniatus splendidulus (Fabricius) (Coleoptera: Curculionidae)

DESCRIPTION AND LIFE CYCLE: Little is known about the biology of this species, and additional molecular work is required to help sort out the identification and taxonomy of the entire genus. Larvae are highly cryptic, closely resembling the scale-like leaves of *Tamarix* spp., albeit with black head capsules. Larvae pupate within woven baskets attached to *Tamarix* leaves. Adults are ~3 mm long with robust bodies, large eyes, thick legs, and thick snouts pointing strongly downward. The elytra have distinct grooves. Adults vary from mottled brown to iridescent green and everything in between. Because larvae and adults can be so difficult to find, searching for the presence of pupal baskets is often the best way to confirm the insect's presence.



Coniatus splendidulus: a) pupal basket, b) adult (both Zeynep Özsoy, Colorado Mesa University)

HISTORY AND CURRENT STATUS: Initially a genus of interest for *Tamarix* biocontrol in the USA, though it was never approved or officially released. The species was first recorded in AZ in 2006 and spread naturally to: CA, NV and UT by 2010, CO by 2011, and TX by 2012. Its mode of introduction to the USA is unknown. Overall abundance and impact are unknown as populations have only recently been reported established throughout southwestern USA, and individuals are cryptic in behavior. In CO, large populations have been observed emerging prior to *Diorhabda* emergence and attacking regrowth of *Tamarix* spp. after *Diorhabda* are in diapause. **Not approved for redistribution in the USA.**

Diorhabda spp.
(Coleoptera: Chrysomelidae)

Robert D. Richard, USDA APHIS PPQ, www.bugwood.org

DESCRIPTION AND LIFE CYCLE: What was released in the USA as *Diorhabda elongata* (Brullé) has since been split into five species, four of which were intentionally released in the USA. All are very similar in appearance, separated out morphologically by differences in genitalia. Eggs of all species are tan, spherical, and laid in masses on *Tamarix* foliage. Hatching larvae develop through three instars. Third instar larvae are up to 9 mm long, black and with distinct yellow longitudinal stripes. Adults are 5½-6 mm long with yellowish tan bodies. Two dark stripes on each elytron are obvious on some species and less distinct on others. Both larvae and adults feed on foliage throughout the growing season. The four species released in the USA originated from seven different habitats, corresponding to seven different ecotypes. The Chilik and Fukang ecotypes (described below) originally required long daylight hours in order to avoid premature diapause. They have since evolved, with changing photoperiod requirements now allowing them to persist further south. These two ecotypes have two generations per year above the 38th parallel. The remaining five ecotypes (Karshi, Turpan, Crete, Posidi Beach, and Tunisian) can produce 3-4 generations per year. Adults of all ecotypes overwinter and emerge in early spring to lay eggs.

HISTORY AND CURRENT STATUS: The southwestern willow flycatcher, an endangered bird in the USA, utilizes *Tamarix* spp. in areas where its natural habitat has been encroached by this weed. In 2009, a lawsuit was filed against USDA APHIS due to the possible negative impacts this biocontrol program could have on the bird by destroying some of its adventive habitat. **Redistributions of *Diorhabda* spp. have been discontinued and are not approved until this is resolved.**

Chilik Ecotype of *Diorhabda carinulata* (Desbrochers): Introduced from Kazakhstan and released in UT from 2001. Successfully established and spread rapidly to AZ, CO and NV. Populations are high but experience heavy bird predation, though they have still increased sufficiently to exert significant control of *Tamarix*. This is especially true along the Colorado River near Moab where extensive defoliation had occurred for at least 18 river miles by 2006, and Delta where 30 ha had been defoliated by 2003. Recent evolution in photoperiod requirements has allowed them to spread south of the 38th parallel. Flooding limits agent populations.

Fukang Ecotype of *Diorhabda carinulata*: Introduced from Fukang, China and released in CA CO NV WY from 2001 (ID MT OR WA subsequently). Established in CA CO ID NV NM OR SD UT WY with heavy defoliation at most release sites, however spread from release sites varies by location. Very successful throughout NV where thousands of ha defoliated by 2006. Repeated defoliation led to death of 70% of plants within 5 years. Also highly defoliating regionally in WY and CO. Populations limited in ID and OR where heavy defoliation only occurs locally. Recent evolution in photoperiod requirements has allowed them to spread south of the 38th parallel. Flooding and heavy predation limit agent populations.

Turpan Ecotype of *Diorhabda carinulata*: Introduced from Turpan, China and released in CO in 2005 but is believed to have failed establishment.

Crete Ecotype of *Diorhabda elongata*: Introduced from Crete, Greece and released in CA and parts of the Midwest from 2003. Does well in CA on smallflower tamarisk, *Tamarix parviflora*, the dominant species in northern and central CA. In general, has had a lower rate of success on the widespread saltcedar (*T. chinensis, T. ramosissima* and hybrids) in CA. Did quite well in TX, though had lower rates of dispersal than that of the Fukang/Chilik ecotypes established in northern regions. Recent hybridization with *Diorhabda carinata* has led to rapid expansion in TX and other Midwestern states. Flooding and predation limit population growth.

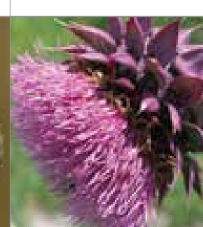
Posidi Beach Ecotype of *Diorhabda elongata*: Introduced from mainland Greece and released in the Midwest from 2005 but eventually died out.

Karshi Ecotype of *Diorhabda carinata* (Faldermann): Introduced from Uzbekistan and released in the Midwest from 2006 where it was localized initially. Hybridization with *D. elongata* (Crete ecotype) has led to rapid expansion in the Midwest. Flooding and predation limit population growth.

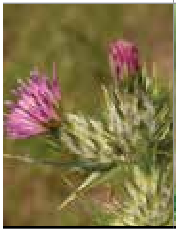
Tunisian Ecotype of *Diorhabda sublineata* (Lucas): Introduced from Tunisia and released in the Midwest (TX) from 2006. The dominant species at the original release location was a hybrid between *Tamarix canariensis, T. gallica, T. ramosissima* or *T. chinensis*, to which the beetles were not strongly attracted in outdoor cage tests. Once liberated they immediately dispersed in search of a better host, thus not establishing. Subsequent releases resulted in populations that expanded rapidly. Still restricted to TX by the end of 2012, but populations are high. Flooding and predation limit population growth.

Thistle species comparison

Bull, Canada and musk thistle are the primary targets of thistle biological control efforts in North America. Below is a comparison of these three species, as well as six others that are occasional hosts to thistle biocontrol agents.

Trait	Bull *Cirsium vulgare*	Canada *Cirsium arvense*	Musk *Carduus nutans*	Marsh *Cirsium palustre*
Life History	Biennial	Perennial	Biennial	Biennial
Preferred Habitat	Various light/ soil conditions; Mesic	Disturbed initially; Moist	Disturbed initially; Fertile soil; Mesic	Acidic soil; Moist
Avg Height	3' (0.9 m)	3' (0.9 m)	5' (1½ m)	4' (1.2 m)
Basal Leaves	3-12" long (7.6-30 cm); Lobed; Coarsely hairy; Yellow spines from midrib and lobes	≤5" long (13 cm); Slightly downy lower surface; Lobed; Prickly, ruffled margins	≤20" long (51 cm); Hairless, waxy, white margins; Coarsely lobed; White spines on margins and lobe tips	≤8" long (20 cm); Deeply lobed, strong midvein; Prominent spines on margins but not leaf surfaces
Stems	Spiny along entire length	Not spiny	Spiny wings along lower sections, not upper	Spiny wings along entire length
Capitulum Diameter	1½" (3¾ cm)	½" (1¼ cm)	3" (7 cm)	½" (1¼ cm)
Bracts	Spiny; Tipped in yellow	Not spiny	End in small spines; Wide, triangular; Purple at maturity	Not spiny; Purplish
Capitulum				

Credits: Bull: Jennifer Andreas, Washington State University Extension; Canada: Richard Old, XID Services, Inc, www.xidservices.com; Musk & Italian: Mary Ellen (Mel) Harte, www.bugwood.org; Marsh: © Malcolm Storey, www.bioimages.org.uk; Plumeless: Becca VanKampen, MIA Consulting; Slenderflower: Washington State Noxious Weed Control Board; Milk: Eric Coombs, Oregon Department of Agriculture; Scotch: Rachel Winston, MIA Consulting

ITALIAN *Carduus pycnocephalus*	PLUMELESS *Carduus acanthoides*	SLENDERFLOWER *Carduus tenuiflorus*	MILK *Silybum marianum*	SCOTCH *Onopordum acanthium*
Annual	Annual	Annual	Annual	Biennial
Disturbed, open; High pH soil; Dry	Disturbed; Well-drained soil; Mesic	Open areas; Fertile soil; Dry	Disturbed initially; Fertile soil; Mesic	Disturbed; Well-drained soil; Dry
4’ (1.2 m)	3½’ (1 m)	3½’ (1 m)	5’ (1½ m)	7’ (2 m)
≤5” long (13 cm); Deeply lobed; Short matted hairs on undersides; Spines on lobe tips and margins	≤8” long (20 cm); Deeply lobed to midvein; Hairy underside; 1-3 spines on margins of each lobe	≤5” long (13 cm); Deeply lobed; Short matted hairs on undersides; Spines on lobe tips and margins	≤20” long (51 cm); Waxy, white marbling along veins; Lobed; Prickly, ruffled margins	≤24” long (61 cm); Woolly above and below; Gray-green; Yellow spines along wavy toothed margins
Slightly winged and spiny along entire length	Leaf-like spines covering stems entire length	Triangular-shaped stem wings tipped with spines along entire length	Not spiny	Spiny wings along entire length
≤ 1” (2½ cm)	≤ 1” (2½ cm)	<1” (2½ cm)	2’ (5 cm)	2’ (5 cm)
Triangular; Long; Have stiff, forward-pointing hairs; Cobwebby	Spiny; Needle-like	Spiny; Triangular but narrow	Tipped in very long stiff spines; Leathery	Spiny; Needle-like; Tipped in yellow
				

Bull thistle

Cirsium vulgare (Savi) Ten.

SYNONYMS: spear thistle

ORIGIN: Native to Europe, Asia, and northern Africa; introduced to North America in the mid 1800s.

DESCRIPTION: An upright forb typically growing as a biennial, but can also behave as an annual or very short-lived perennial. Plants grow from 3-4 ft (1-1.2 m) tall on average. Leaves are long (3-12 in or 8-30 cm), lance-shaped, and lobed, with coarse hairs covering both surfaces. Long, yellow spines extend from the midrib and at each lobe. Stems are stout, hairy, and have spiny wings. Capitula are 1½-2 in (4-5 cm) in diameter, have rows of narrow, spiny bracts tipped in yellow, purplish pink florets, and are solitary at the ends of branches.

HABITAT: Grows best on neutral soils rich in nitrogen and with moderate

a) plant (Marianna Szucs, University of Idaho), b) infestation (Forest and Kim Starr, Starr Environmental, www.bugwood.org)

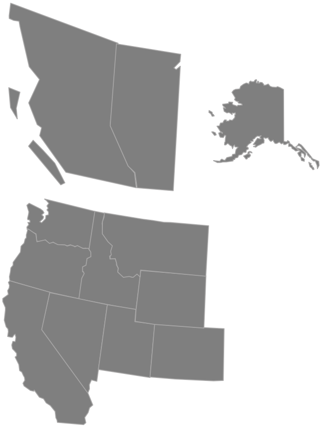
c) leaf (Dan Tenaglia, Missouriplants.com, www.bugwood.org), d,e) stem, flower head (Jennifer Andreas, Washington State University Extension)

moisture. It is not typically found in sand, pure clay, or in soils with high humus content, nor does it grow well in shade and drought. It can be found in almost any type of disturbed area including forest clear cuts, riparian areas, and pastures.

ECOLOGY: Reproduces only by seed. Seeds are readily transported by water, wildlife and human activity and may remain viable in the soil for many years. Seeds germinate and form rosettes whenever moisture is sufficient, but the majority of rosettes form during spring. Bolting occurs in late spring, and plants flower in early to mid-summer (typically June to July).

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Cheilosia grossa, Trichosirocalus horridus* (which is no longer permitted for interstate transport), and *Urophora stylata.* Also attacked by *Rhinocyllus conicus* which was introduced intentionally but is no longer approved for use; CAN: *R. conicus* and *U. stylata.*

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



CANADA THISTLE

Cirsium arvense (L.) Scop.

SYNONYMS: creeping thistle, field thistle

ORIGIN: Introduced from Eurasia in the 1600s.

DESCRIPTION: An upright perennial forb often found in dense infestations. Plants grow from 1-4 ft (⅓-1.2 m) in height with rhizomatous roots. Leaves are irregularly lobed and have very prickly and ruffled margins. They are green on both sides with a slightly downy lower surface. Basal leaves are less than 5 in long (12.5 cm). Leaves grow alternately along the slender, grooved stems which can be finely haired but are not spiny. Upper branches are topped by clusters of small, compact (½ in or 1¼ cm diameter) capitula producing numerous tufted seeds. Receptacle bracts are not spiny. Florets vary in color from white to deep lavender.

HABITAT: Rapidly colonizes disturbed moist sites including prairies, meadows, ditches, stream banks, lawns, and agricultural fields.

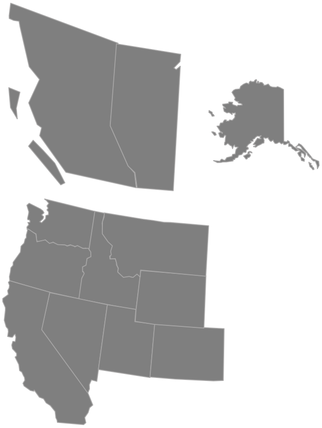
a) plant, b) infestation (both Steve Dewey, Utah State University, www.bugwood.org)

c) leaf (Jennifer Andreas, Washington State University Extension), d) stem (Rob Routledge, Sault College), e) flower head (Richard Old, XID Services, Inc, www.xidservices.com) (d,e www.bugwood.org)

ECOLOGY: Reproduces both vegetatively through its roots and by seed. Seeds are readily transported by water, wildlife and human activity and may remain viable in the soil for many years. Seeds germinate and form rosettes whenever moisture is sufficient, though the majority of rosettes are formed in spring. Stems bolt in late spring with flowering occurring from June to September.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Altica carduorum, Hadroplontus litura* (=*Ceutorhynchus litura*), and *Urophora cardui.* Also attacked by *Rhinocyllus conicus* which was introduced intentionally but is no longer approved for use; CAN: *A. carduorum, H. litura, Larinus carlinae* (=*Larinus planus*), *R. conicus,* and *U. cardui.*

NOTES: 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.



THISTLES

Musk thistle

Carduus nutans L.

SYNONYMS: nodding thistle, nodding plumeless thistle; *Carduus thoermeri* (Weinman)

ORIGIN: Native to Europe, Asia, and northern Africa; introduced to North America in the mid 1800s.

DESCRIPTION: Upright, herbaceous biennial typically growing 5-6 ft tall (1½ to 1.8 m) from a fleshy taproot. Leaves are dark green, hairless, waxy and have characteristic white margins. Leaves are also coarsely lobed with white spines along margins and at lobe tips. Basal leaves are up to 20 in long (50 cm); stem leaves are smaller, grow alternately, and lightly clasp the stem. Stems are stout, highly branched, and have spiny wings along their lower sections but not their upper portions. Flower heads are up to 3 in (7 cm) in diameter, are solitary at the ends of stems, and produce numerous tufted seeds. They droop or "nod" when fully developed and have rows of wide, triangular bracts that end in small spines and are purple at maturity. Florets are magenta.

a) plant (Mary Ellen (Mel) Harte, www.bugwood.org), b) infestation (Marianna Szucs, Colorado State University)

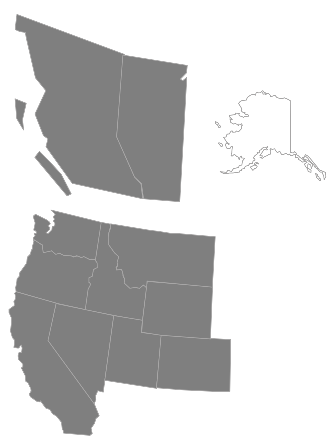
c) leaf (Rachel Winston, MIA Consulting), d) stem, e) flower head (d,e Mary Ellen (Mel) Harte, www.bugwood.org)

HABITAT: Readily invades pastures, roadsides, ditches, and meadows. Grows best in disturbed, neutral to acidic soils with moist conditions.

ECOLOGY: Spreads only by seed. Seeds are readily transported by water, wildlife and human activity and may remain viable in the soil for many years. Rosettes usually form in spring, with plants bolting by early summer. Flowering occurs throughout summer.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Cheilosia grossa, Psylliodes chalcomera, Puccinia carduorum, Trichosirocalus horridus* (which is no longer permitted for interstate transport), and *Urophora solstitialis*. Also attacked by *Rhinocyllus conicus* which was introduced intentionally but is no longer approved for use; CAN: *R. conicus, T. horridus,* and *U. solstitialis*.

NOTES: *Carduus nutans* is part of a variable complex that has been treated as one to several species or, more recently, as a single species with several subspecies. Various intermediates are evident, and many North and South American specimens cannot be reliably assigned. In the USA, subspecies include *nutans*, *leiophyllus*, (which is synonymous with *Carduus thoermeri*) and *macrocephalus*.



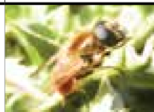
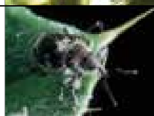
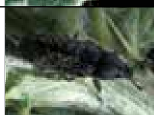
Thistle Biological Control

HISTORY IN THE NORTHWEST: Nine thistle species are highly problematic in North America, though musk, Canada, and bull are typically the most problematic and common. Thistle biological control began in North America in 1969 with the importation of the thistle seed head weevil, *Rhinocyllus conicus.* This agent has since been discovered attacking several species native to North America. Consequently, its USA interstate transport permits were revoked. To aid the thistle biocontrol program, an additional 9 insect species have subsequently been intentionally introduced to North America as classical biological control agents of thistle. Of those currently established, musk, Canada and bull thistle are the primary targets, though other thistle species serve as occasional hosts. An additional six adventive species are present on thistles in North America.

CURRENT STATUS: Six of the 10 intentionally introduced insects have established in North America. The three seed-feeding agents reduce seed production. This does not kill existing plants, but does help reduce the rate of spread of weed populations. This has proven effective for bull and musk thistle when infestations are also subjected to high plant competition. **However, the most effective seed-feeder, *R. conicus*, is no longer approved for any use in the USA**. Seed-feeding is ineffective against Canada thistle as it does not disrupt root reproduction. Both stem-mining species are largely ineffective due to the attacked plant's ability to recover from feeding. The root crown-feeding *T. horridus* is effective on musk and plumeless thistle growing with high plant competition; however, **due to observed nontarget attack, interstate transport of *T. horridus* is no longer permitted in the USA.**

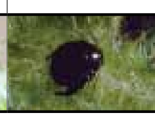
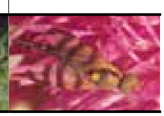
RECOMMENDATIONS: USA: ***R. conicus* is no longer approved for any use. *T. horridus* is no longer approved for interstate transport, and some intrastate redistribution is banned as well.** *T. horridus* is not overly effective against musk or plumeless thistle alone, but can work well in conjunction with the stresses from high competing plant vegetation. Redistributions should only be made in approved locations where nontarget species do not co-occur. The agents currently established are generally not effective against Canada thistle. *Hadroplontus litura* and *Urophora cardui* could be utilized as a last resort in shady or riparian environments where other control methods are not feasible. *U. stylata* is effective against bull thistle stressed by high plant competition, although large populations are difficult to maintain and should be regularly supplemented. Gall-infested capitula can be transferred in fall or spring. CAN: The same combinations of insects are also the most effective against thistles in Canada. In addition, *T. horridus* is approved for use in Canada, as is *R. conicus*. Adult *R. conicus* should be redistributed to new musk infestations in spring using nets.

Established Agents

Agent	Adult	Impact	Recommendation
Cheilosia grossa		Established only in OR, USA. Mines large plants of Italian and slenderflower (rarely plumeless), impact minor.	Not released in CAN. Abundance and impact low in USA. Not high priority for redistribution.
Hadroplontus litura		Well established in USA and CAN. Typically only mines non-essential tissue of Canada; impact limited.	Effective in select settings, but typically low impact overall. Not high priority for redistribution.
Rhinocyllus conicus		Seed-feeding reduces musk density in combination with plant competition. Low impact on late flowering species.	No longer approved in USA; attacks natives. In CAN, can be redistributed to musk infestations with competition.
Trichosirocalus horridus		Best on musk and plumeless in USA, CAN. Root crown-mining complements plant competition, but weak alone.	Interstate transport no longer legal in USA. In CAN, low priority; only for areas with high competing vegetation.
Urophora cardui		Attacks Canada in USA, CAN. Galls can stunt plants and reduce seed production. Impact typically limited.	Could be redistributed to shady, protected areas with other agents. Low priority for redistribution elsewhere.
Urophora stylata		Established on bull in USA, CAN. Seed-feeding reduces production up to 60%. Okay in combination.	Widespread but variable abundance in USA, CAN. Regular redistributions recommended.

Cheilosia: Eric Coombs, Oregon Department of Agriculture, *Hadroplontus, Rhinocyllus, Trichosirocalus,* and *Urophora cardui:* Laura Parsons, University of Idaho, *U. stylata*: Peter Harris Agriculture and Agri-Food Canada, www.bugwood.org

Approved, Non-Established Agents

Altica carduorum	*Lema cyanella*	*Psilliodes chalcomera*	*Urophora solstitialis*
			

Altica: André Gassmann, CABI-Switzerland, *Lema*: Alec McClay, McClay Ecoscience, *Psilliodes:* USDA ARS European Biological Control Laboratory, *Urophora:* Eric Coombs, Oregon Department of Agriculture

Cheilosia grossa (Fallén)

Thistle stem hover fly

SYNONYMS: *Cheilosia corydon* (Harris)

DESCRIPTION: Larvae are tan in color and grub-like, growing up to 19 mm long. Adults are fuzzy with orange-tan hairs, large black eyes, and clearish wings. Adults can be up to 15 mm long, including their wings.

Cheilosia grossa: a) adult, b) larval mining damage, c) capitula death due to mining (all Eric Coombs, Oregon Department of Agriculture, www.bugwood.org)

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, developing through three instars. Pupae overwinter in roots or in soil litter. There is one generation per year.

DAMAGE: Larval mining interferes with plant function and ultimately results in a decrease of seed production, sometimes even death.

PREFERRED HABITAT: 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.

HISTORY: Introduced from Italy and released on musk and slenderflower thistle in the USA in 1990 (MT, NV, OR) and Italian thistle in OR in 1993. Found feeding on bull thistle in OR by 2001.

CURRENT STATUS: Established on Italian and slenderflower thistle in OR, USA, though it is not very abundant on either species. Rarely found on plumeless thistle. Where established on any of the above species, plants with large stem diameters (>10 mm) are often attacked, though overall impact is typically minor. Establishment failed on musk thistle. Occasionally found attacking large rosettes of bull thistle in OR, decreasing plant function and seed production. However, *Carduus* species are preferred over *Cirsium*.

REDISTRIBUTION: Sweeping adult flies is possible in spring when host plants are beginning to bolt, though this may be damaging. Alternatively, pupae can be collected by digging roots in late summer and early fall as the host plants die back with lower temperatures. The infested roots can then be transferred to new infestations. Or they may be stored overwinter at 39-46°F (4-8°C). Two to three weeks prior to their normal emergence time, bring them to room temperature in rearing cages or breathable, clear containers. Once adults emerge, flies can be transferred to new thistle infestations in groups of 50-100. **Damage similar to that caused by this agent has been observed in several native thistles species (*Cirsium edule* group), thus caution should be used when considering introduction of this fly into new areas.** Establishment can be monitored the following summer through spring by dissecting stems and looking for larval damage. Note that feeding damage can be difficult to distinguish from other mining species if larvae are no longer present.

NOTES: **This agent is not approved for release in Canada.**

bull Canada musk

Hadroplontus litura (Fabricius)

Canada thistle stem weevil

SYNONYMS: *Ceutorhynchus litura* (Fabricius)

DESCRIPTION: Larvae are white, grub-like, C-shaped, and may be pointed in the front end. They grow up to 3 mm long and have brown head capsules. Adults are mottled black and white with a "T" shaped marking on their backs. The adults have long snouts and can be up 4 mm long.

Hadroplontus litura: a) larvae in stem, b) adult (Laura Parsons, University of Idaho), c) stem mining damage (a,c Norman E. Rees, USDA ARS) (all www.bugwood.org)

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 new rosette leaves. Emerging larvae mine leaf veins, stems, and root crowns of target plants throughout spring and summer. They develop through three larval instars before pupating in the soil. Emerging adults overwinter in soil litter. There is one generation per year.

DAMAGE: Larval mining and adult feeding do not significantly impact weed populations directly as only non-essential tissues are typically consumed. Feeding does cause secondary damage, however, as pathogens and other organisms enter the stems of target plants via holes made by exiting larvae.

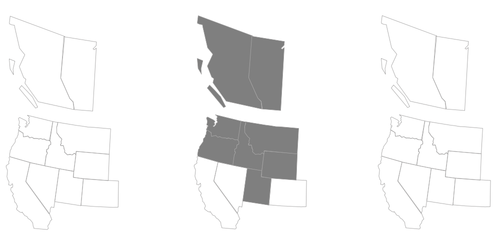
PREFERRED HABITAT: Does well in moist, disturbed areas where target thistles are dense and not stressed by drought, grazing, or other control methods.

HISTORY: Introduced from Germany and released on Canada thistle in the USA from 1971 (CA, CO, ID, MT, OR, WA, WY). Introduced from France, Germany, Italy and Switzerland and released in Canada from 1965 (AB, BC from 1975).

CURRENT STATUS: On Canada thistle in the USA, some reports indicate the agent is very effective due to reduced overwintering survival of the weed; however, most studies show a lack of impact, likely due to only non-essential parenchyma tissue being consumed by larvae, leaving vascular tissues untouched. Though established at most release sites on Canada thistle in Canada, the weevil has low reproductive and dispersal ability so populations are typically limited. Mining over multiple years decreases root biomass, when in conjunction with other stresses. Even in combination with other agents, overall impact is limited.

REDISTRIBUTION: Adults can be collected with a sweep net and aspirator during spring when host plants are bolting. Releases of 200 individuals should be made on patches of at least 2,000 m² (½ acre). Establishment can be monitored the following spring by observing adults on thistle foliage, or during summer by checking for larvae feeding within plant stems.

NOTES: Some populations are infected with *Nosema* pathogens. Infected populations should not be used in redistribution efforts.



bull   Canada   musk

Rhinocyllus conicus (Frölich)

Thistle seedhead weevil

DESCRIPTION: Eggs, laid on buds and stems, are covered with chewed plant material that becomes tan with age, appearing as part of the plant. Larvae are white with brown head capsules, C-shaped, and reach up to 4 mm long. Adults are dark brown or black with yellowish tufts of hair giving them a mottled appearance in spring. As they age, adults lose some of these hairs and turn brownish black. They can be up to 6 mm long.

Rhinocyllus conicus: a) eggs (Whitney Cranshaw, Colorado State University), b) larvae and damage in capitula (Mark Schwarzländer, University of Idaho, c) adult (Laura Parsons, University of Idaho) (a,b www.bugwood.org)

LIFE CYCLE: Overwintering adults emerge in early spring and deposit eggs on bracts of thistle capitula and stems. Larvae hatch in late spring and early summer and develop through four instars. They burrow into seed heads and feed on receptacle tissue and developing seeds. 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.

DAMAGE: Adults feed on foliage and leave signature rounded feed holes over the entire leaf surface, though this damage is typically minor. Larval feeding destroys some seeds. Seed consumption does not kill existing plants, but does help reduce the rate of spread of thistle populations.

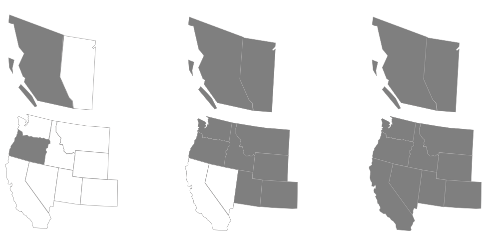
PREFERRED HABITAT: Does best in meadows and moist areas with moderate temperatures. In areas where summer arrives quickly, weevils are unable to utilize later-developing capitula.

HISTORY: Three strains have been collected for use against exotic thistles in the USA, originating from three host species in France and Italy and released from 1969 on musk, plumeless, Scotch (failed), Italian, slenderflower, and milk thistle. The weevil spread naturally to bull and Canada thistle. Introduced from France and released on and redistributed to numerous exotic thistle species throughout Canada from 1968.

CURRENT STATUS: Typically prefers *Carduus* spp. (musk, plumeless, Italian, slenderflower) over other thistles. In the USA, it is abundant on musk thistle on which it is effective when combined with *Trichosirocalus horridus* and plant competition. Abundant on Italian thistle in CA, ID, OR and slenderflower in OR. On both species it can be effective on early-blooming plants but only in combination with plant competition. Established on plumeless thistle in ID, OR, WA though impact is typically low as only early capitula are attacked. It is largely ineffective on Canada thistle (though widely distributed), because seed reduction doesn't hinder the plant's spread via roots. Attacks bull thistle in OR and milk thistle in CA and OR, but overall impact is minimal. **Attacks 22 of 90 *Cirsium* spp. native to the USA. Interstate shipment permits were revoked in 2000, and it is (strongly) not recommended for redistribution within each state.** In Canada, it attacks over 90% of musk thistle capitula, reducing seed production by ~50%. It has been credited with controlling this species when plant competition is present. Established on bull, marsh and plumeless thistle in BC. Reduces seed production of plumeless thistle by 10% as only the early capitula are attacked. Attack to *Cirsium* thistles is even more minor.

REDISTRIBUTION: **This species is no longer approved for redistribution in the USA.** In Canada, adults can be collected in spring with nets and aspirators and transferred in groups of 200 to new thistle infestations. Establishment can be monitored the following summer by dissecting capitula for larvae, or observing adults on foliage in late summer.

NOTES: Adults have shorter snouts than *Larinus carlinae*. Multiple larvae typically occur in the same capitula.



bull Canada musk

Trichosirocalus horridus (Panzer)

Musk thistle crown weevil

SYNONYMS: *Ceuthorhynchidius horridus* (Panzer)

DESCRIPTION: Eggs are opaque white and small. Larvae are creamy white with dark brown head capsules and can be up to 3 mm long. Adults are small (approximately 4 mm long), round and brown with white mottling. They have obvious spines on their thorax and long snouts.

Trichosirocalus horridus: a) larva and root crown damage, b) adult (Laura Parsons, University of Idaho, c) adult feeding damage (a,c Eric Coombs, Oregon Department of Agriculture)

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, developing through three instars. 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.

DAMAGE: Adult feeding in spring has minimal impacts, though larval feeding can weaken, reduce the seed production, and alter the growth of attacked plants.

PREFERRED HABITAT: 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.

HISTORY: Introduced from Italy and released on onto plumeless and musk thistle from 1974. Spread naturally to bull and slenderflower thistle. Redistributed to Italian and Scotch thistle from 1994. Introduced from Germany and released in Canada on musk and plumeless thistle from 1975. Later released on and redistributed to bull, Scotch and marsh thistle.

CURRENT STATUS: In the USA, it prefers musk over plumeless thistle (established on the latter in CO, MT, WA). On both it can be effective when in combination with plant competition and other agents, but is ineffective at many sites. Moderately effective on Italian and slenderflower thistle in OR. Found in limited amounts on bull thistle in WY where impact is minimal. Failed to establish on Scotch thistle in the USA. Established on plumeless thistle in BC, Canada and musk thistle in BC and AB. On both species damage is limited; attacked rosettes frequently survive to produce seed later in the season. Established on bull, marsh, and Scotch thistle in BC with unknown impact.

REDISTRIBUTION: Adults 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. Groups of 100-200 can be released at new sites. Establishment can be monitored the following spring by observing adults on foliage or dissecting root crowns in summer in search of feeding larvae. **Due to observed nontarget attack, interstate transport is not permitted in the USA, and some states have prohibited its redistribution within their borders. Where this agent is approved for redistribution, it is imperative to refrain from making releases at sites where known related or susceptible species co-occur.**

NOTES: A 2002 revision of *Trichosirocalus horridus* concluded this species was in fact a complex of three species, with distinct host plant preferences: *T. horridus, T. mortadelo*, and *T. briesei* with preferences for *Cirsium, Carduus* and *Onopordum* thistles, respectively. Because there is a disagreement for the morphological parameters selected by taxonomists for this separation, molecular studies are currently underway to determine if the species complex is truly a complex, and to what level. For now we refer to all *Trichosirocalus* in North America as *T. horridus.*

bull Canada musk

Urophora cardui (L.)

Canada thistle stem gall fly

DESCRIPTION: Larvae are barrel-shaped, white, and have dark brown anal plates. They can be up to 5 mm 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 long.

Urophora cardui: a) larvae in gall (Eric Coombs, Oregon Department of Agriculture), b) adult (Laura Parsons, University of Idaho), c) gall (Jennifer Andreas, Washington State University Extension)

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 (final) instar, with pupation occurring in early spring as plants start bolting. There is one generation per year.

DAMAGE: Larval feeding causes gall formation. Galls 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.

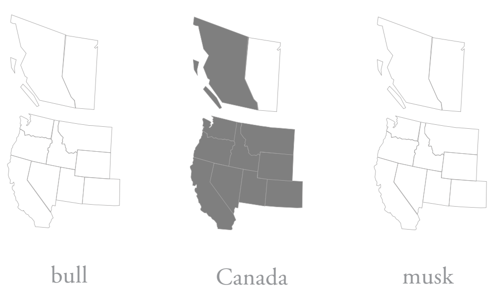
PREFERRED HABITAT: Does well in moist, open and partially shaded areas where its host plant is scattered, especially areas with high grass competition. Areas subject to other means of control (grazing, mowing, chemical treatment, etc.) are not suitable for this fly's survival.

HISTORY: Introduced from Austria and France and released on Canada thistle in the USA from 1977 (CA, CO, ID, MT, NV, OR, UT, WA, WY). Introduced from Austria, France and Germany and released on Canada thistle in Canada (AB, BC) from 1974. An additional strain from Finland was released in BC from 1987.

CURRENT STATUS: Moderately abundant on Canada thistle in the USA. Attacked plants may be stunted and produce fewer seeds, especially when galls occur at terminal growing tips. However the overall impact is largely limited. The species is often restricted to shaded infestations, close to riparian areas. In Canada, populations vary by location and year but are highest in areas with sheltering canopy, near water, and in climates with mild winter temperatures. Under favorable conditions it can reduce density and stature of Canada thistle. In other areas, even in combination with *Hadroplontus litura,* this fly has no measurable impact.

REDISTRIBUTION: Sweeping adult flies is possible, though may be damaging. Instead, place gall-infested plants into uninfested patches during fall or early spring. Transferring infested plants may also transfer unwanted parasitoids, insects, or Canada thistle seeds. To avoid this, gall-infested plants can be collected and adults reared out indoors. Refer to Additional Considerations in the Introduction for instructions on how to do so. Once they emerge in spring, flies can be transferred to new Canada thistle infestations in groups of 50-100. Establishment can be monitored by observing adults on thistle foliage the following spring or by finding the characteristic large, swollen galls created by larval feeding throughout summer and fall.

NOTES: Galls and/or the larvae within them are often preyed upon by rodents, birds, and an unidentified mite. Though *Urophora* larvae can be difficult to distinguish, the characteristic swollen galls help to easily differentiate *U. cardui* from other thistle-attacking *Urophora* species.



Urophora stylata (L.)

Bull thistle seedhead gall fly

DESCRIPTION: Larvae are barrel-shaped, off-white, and have dark anal plates. They can reach lengths of 5 mm 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 long while females can be 7 mm.

Urophora stylata: a) larvae in seed head, b) adult (a,b Peter Harris Agriculture and Agri-Food Canada, www.bugwood.org)

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 (final) instar larvae overwinter within galls. There is one generation per year.

DAMAGE: Larval feeding reduces seed production which can help reduce the rate of spread of thistle populations. Seeds in infested seed heads are physically stuck to gall tissue, thereby reducing dispersal further. Galls from larval feeding act as metabolic sinks, diverting resources away from normal plant development.

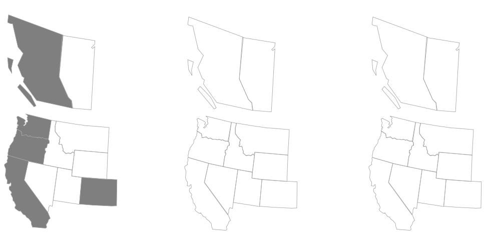
PREFERRED HABITAT: Does best in open meadows with scattered plants. It does not do as well in dense stands of thistle or at sites with flooding and high winds.

HISTORY: Introduced from Germany and Switzerland and released on bull thistle in BC, Canada from 1973. Redistributed from Canada to bull thistle in the USA from 1983 (CA, CO, MT, OR, WA).

CURRENT STATUS: Abundance and impact on bull thistle vary in the USA. Populations are cyclical in OR, and limited in CA, CO and WA. From 60-90% of seed heads are attacked in some areas, which has reduced seed production by up to 60%. However, in general, it is difficult to maintain high fly populations on the short-lived bull thistle. In Canada, it naturally dispersed from all release sites and is now abundant on bull thistle. The weed has decreased at most sites, likely due to a combination of land use and attack by *Urophora stylata* and *Rhinocyllus conicus.*

REDISTRIBUTION: Sweeping adult flies is possible, though may be damaging. Instead, place capitula infested with galls into uninfested patches during fall or early spring. Transferring infested seed heads may also transfer unwanted parasitoids, insects, or thistle seeds. To avoid this, plants with infested capitula can be collected and adults reared out indoors. Refer to Additional Considerations in the Introduction for instructions on how to do so. Once they emerge in spring, flies can be transferred to new thistle infestations in groups of 50-100. Establishment can be monitored by observing adults on thistle foliage the following summer or by dissecting capitula for larvae from summer throughout the following spring. Alternatively, squeezing capitula between the thumb and forefinger from late fall through spring can quickly indicate larval presence. Those infested with galls will feel very firm, while uninfested capitula readily give when pressure is applied, and they easily fall apart.

NOTES: Bull thistle is short-lived and populations follow disturbance patterns, typically not lasting long in the same locations. Consequently, it is difficult to maintain large populations of *U. stylata*.



bull Canada musk

Thistles, Non-Established Agents

Altica carduorum Guérin-Méneville (Coleoptera: Chrysomelidae)

André Gassmann, CABI-Switzerland

DESCRIPTION AND LIFE CYCLE: Adults are metallic blue-black and 4 mm long. They emerge in late spring and feed on young thistle leaves. Oviposition occurs on the underside of thistle leaves. Larvae emerge in mid to late summer, and feed on leaves. When mature, they drop to the soil for overwintering.

HISTORY: Introduced from Switzerland and released on Canada thistle in the USA from 1966 (CA, CO, ID, MT, NV, OR, WA). Establishment failed at all sites. Additional strains from France and Italy subsequently released in eastern states also failed to establish, possibly influenced by predation. Introduced from France and Switzerland and released in Canada from 1963 (AB, BC). Failed to establish as low development in cool summers exposed larvae to high predation.

Lema cyanella (L.) (Coleoptera: Chrysomelidae)

Alec McClay, McClay Ecoscience

DESCRIPTION AND LIFE CYCLE: Overwintering adults emerge in spring and oviposit on leaf undersurfaces and stems. Larvae feed on undersides of leaves, leaving the upper epidermis intact which forms a characteristic feeding window. Mature larvae drop to the soil in mid-summer, pupating within foam cocoons they secrete. Adults emerge in late summer and feed on foliage prior to overwintering in soil.

HISTORY: Introduced from Switzerland and released on Canada thistle in more eastern provinces of Canada from 1983. After establishment failed, a population sourced from Switzerland and France obtained via New Zealand was released in AB from 1993. **One population initially established at low densities, but concerns over nontarget attack led to its eradication.** It is no longer considered established. **Not approved for release in the USA.**

Psylliodes chalcomera (Illiger)
(Coleoptera: Chrysomelidae)

USDA ARS European Biological Control Laboratory (www.bugwood.org)

DESCRIPTION AND LIFE CYCLE: Overwintering adults emerge in spring and oviposit at the bases of plants. They are shiny and dark with a metallic blue-green sheen. Larvae are slender and white with brown head plates. Adults and larvae can be up to 3 mm long. Larvae feed through three instars on leaves, buds, and flowers throughout the growing season. Pupation occurs in the soil litter. There is one generation per year.

HISTORY: Introduced from Italy and released on musk thistle in the USA in 1997 (KS, MD, TX) but failed to establish. It 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. **Not approved for release in Canada.**

Urophora solstitialis (Illiger)
(Diptera: Tephritidae)

Eric Coombs, Oregon Department of Agriculture

LIFE CYCLE: Overwintering larvae are white, barrel-shaped with dark brown anal plates, and can be up to 4 mm long. Adults emerge in later spring and can be 5 mm long. They are brownish black with a yellow head and legs and two black "VII"-shaped markings on wings. Eggs are deposited in developing capitula. Hatching larvae feed on seeds and receptacles, forming hardened galls. Most larvae overwinter in galls, but early maturing larvae may pupate in early summer as a second generation. There are up to two generations per year.

HISTORY: Introduced from Italy and released on plumeless and musk thistle in the USA in 1993 (northwestern releases on musk only and from 1996). USA establishment failed. Introduced from Germany and Austria and released on plumeless and musk thistle in BC from 1990. Established only on plumeless thistle and only in more eastern provinces where overall impact is limited.

Thistles, Unapproved Agents

Six accidentally introduced species are established on thistles in North America. Though some of these have been intentionally redistributed at different times, all six species are not approved for use. **It is illegal to intentionally move these species to new areas in the USA.** Care should be taken when transferring approved agents to ensure that these unapproved species are not also included in transferred material.

Aceria anthocoptes	*Cassida rubiginosa*	*Cleonis pigra*	*Larinus carlinae*	*Puccinia carduorum*	*Terellia ruficauda*

Aceria: Eric Erbe, USDA ARS, www.bugwood.org, *Cassida:* Laura Parsons, University of Idaho, *Cleonis:* Ivo Tosevski, CABI-Switzerland, *Larinus:* Alec McClay, McClay Ecoscience, *Puccinia*: USDA ARS, www.bugwood.org, *Terellia*: Peter Harris, Agriculture and Agri-Food Canada

In addition to the above sprecies, the rust *Puccinia punctiformis* is also widespread on Canada thistle in North America. Though believed to be present inadvertently, it is established throughout much of the world, and questions remain about its native range. While not officially approved for use in the USA, there is recent interest in gaining authorization to utilize it intentionally.

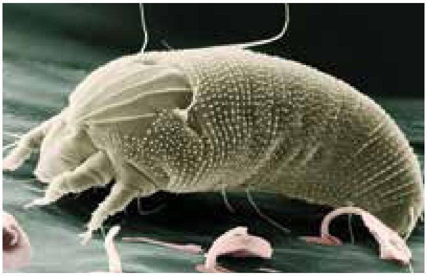
Puccinia punctiformis (F. Strauss) Röhl.
(Pucciniomycetes: Pucciniales)

© Malcolm Storey, www.bioimages.org.uk

DESCRIPTION AND LIFE CYCLE: Teliospores germinate in spring and produce basidiospores. Aeociospores are then produced in a sweet, sticky nectar that attracts flies to disperse spores. Resulting urediospores form densely packed yellow-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, teliospores are produced to overwinter.

HISTORY AND CURRENT STATUS: Believed to have been accidentally introduced to North America by 1890, it is now widespread throughout the USA and Canada. Systemic infection can be lethal but is dependent on suitable conditions. Superficial foliar infections are more common in Canada thistle patches but have little impact on the plant, stunting growth and flowering but not reducing populations. **Not yet approved for redistribution in the USA.**

Aceria anthocoptes (Nalepa) (Acari: Eriophyidae)



Eric Erbe, USDA ARS, www.bugwood.org

DESCRIPTION AND LIFE CYCLE: Mites appear on foliage in spring as plants bolt. Nymphs and adults are white, tan, pink, or yellow, depending on the developmental stage. They are tiny (0.15-0.20 mm long). Females exist in reproductive (summer) and overwintering forms. Feeding mites suck out the contents of leaf cells. There are multiple generations per year; overwintering is likely on roots or root buds.

HISTORY AND CURRENT STATUS: Accidental introduction discovered on Canada thistle in the USA in 1998; now established in CO, MT, WY (USA) and AB (Canada). Can cause thinning and leaf deformation in the lab, but has not been properly evaluated in the field where it appears impact is minimal. Has been collected from numerous thistles native to North America. **Not approved for redistribution in the USA.**

Cassida rubiginosa O.F. Müller (Coleoptera: Chrysomelidae)

Laura Parsons, University of Idaho

DESCRIPTION AND LIFE CYCLE: Adults emerge in early spring and feed on new foliage. They are oval, have black undersides, and a hard, green protective covering and can be up to 7½ mm long. Eggs are laid in spring and summer; emerging larvae feeding on leaves. Larvae are green with spined margins, on which they accumulate molted skins and waste. They grow to 6 mm and pupate in late summer. Adults emerge and feed on young foliage until late fall and overwinter in soil litter. There is one generation per year.

HISTORY AND CURRENT STATUS: Accidental introduction recorded on Canada thistle in North America in 1901; intentionally redistributed in the USA in the 1970s. Established in OR, WA, WY (USA) and AB, BC (Canada). In some areas, can significantly reduce biomass and survival; overall impact is typically minimal, likely hindered by predation and parasitism. Feeds on numerous thistle species, including many natives. **Not approved for redistribution in the USA.**

Thistles, Unapproved Agents

Cleonis pigra (Scopoli) (Coleoptera: Curculionidae)


Ivo Tosevski, CABI-Switzerland

DESCRIPTION AND LIFE CYCLE: Adults emerge in spring and feed on young leaves. They are mottled brown with many shiny black lumps and can be up to 7 mm long. Their wide snouts appear grooved. Larvae hatch throughout summer and bore to the stem base where they feed internally. They are white with a brown head, grub-like, and are up to 3 mm long. Pupation occurs in soil litter. Adults emerge throughout fall and overwinter in soil litter. There is one generation per year.

HISTORY AND CURRENT STATUS: Accidental introduction recorded on Canada thistle in the USA by 1919 and in Canada by 1933. Only established in eastern states and provinces. Larval root mining may kill plants, but regeneration typically observed. Feeds on a wide array of important species; overall impact to exotic thistles is minimal. **Not approved for redistribution in the USA.**

Larinus carlinae (Olivier) (=*L. planus*) (Coleoptera: Curculionidae)


Alec McClay, McClay Ecoscience

DESCRIPTION AND LIFE CYCLE: Adults emerge in early spring and feed on young foliage, resulting in leaf holes, and deformed bracts/seed heads. Adults are elongate (≤8 mm long), have black bodies with mottled tan or yellow hairs, and long snouts. Eggs are laid inside developing capitula. Larvae feed on developing seeds and receptacle tissue throughout summer. Larvae are white, grub-like, and can be up to 5 mm long. Pupation occurs within capitula; adults emerge in late summer and early fall and overwinter in soil litter. There is one generation per year.

HISTORY AND CURRENT STATUS: Accidental introduction recorded in the USA by 1968 and Canada by 1988. Intentionally redistributed within the USA. Established MT, OR, WA (USA) and AB, BC (Canada). Attacks numerous native thistle species; damage to natives often exceeds damage to exotics. **Not approved for redistribution in the USA.**

Puccinia carduorum Jacky
(Pucciniomycetes: Pucciniales)

USDA ARS, www.bugwood.org

DESCRIPTION AND LIFE CYCLE: Overwintering teliospores germinate in spring. Basidiospores infect rosettes and bolting plants. Urediospores are the most characteristic, being gold brown, covered in short spines, round and tiny (25 µ). 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 entire cycle within two weeks.

HISTORY AND CURRENT STATUS: One strain was found present (inadvertently) on slenderflower thistle in CA, USA by 1951. It is specific to that species and established in CA and OR, though its overall impact is unknown. A new strain was introduced on musk thistle in VA in 1987 for experimental field release but quickly spread and is now present and widespread in CA, MT and WY. It is specific to *C. nutans* subsp. *leiophyllus* on which it reduces seed set and quality. **Neither strain is approved for redistribution in the USA.**

Terellia ruficauda (Fabricius)
(Diptera: Tephritidae)

Peter Harris, Agriculture and Agri-Food Canada

DESCRIPTION AND LIFE CYCLE: Adults emerge in early spring, are up to 5 mm long, and yellow-orange with dark spotted abdomens. Wings have 3 black marks along leading margins and fainter marks on hind margins. Eggs are laid in immature female capitula. Larvae feed on seeds and receptacle tissue. They are white, grub-like, and up to 6 mm long. Pupa overwinter in capitula; there is one generation per year.

HISTORY AND CURRENT STATUS: Accidental introduction discovered on Canada thistle in the USA and Canada by 1873. Populations are generally limited. Larvae destroy some seeds, but overall impact is minimal. **Not approved for redistribution in the USA.**

BROOM

Scotch broom

Cytisus scoparius (L.) Link

SYNONYMS: broom; *Cytisus scoparius* (L.) Link subsp. *scoparius, Sarothamnus scoparius* (L.) Wimm. ex W. D. J. Koch

ORIGIN: Introduced as an ornamental from Europe to North America prior to 1850.

DESCRIPTION: Woody shrub typically growing from 3-10 ft tall (1-3 m) from a forked taproot. It can be prostrate or erect, and has numerous slender, dark green branches that are capable of photosynthesis. Stems are hairy when young and less so as the plant ages. Leaves are alternate and three-parted, and are deciduous early in the season and in times of stress. Flowers are yellow, in clusters of two, and are characteristic of the pea family by having petals form a banner and keel (similar to a boat). Seed pods can grow up to 3 in long (7½ cm); they are flattened and have hair on the margins, turning brown at maturity.

HABITAT: Widespread along the Pacific coast. It is particularly problematic in

a) plant, b) infestation (both Jennifer Andreas, Washington State University Extension)

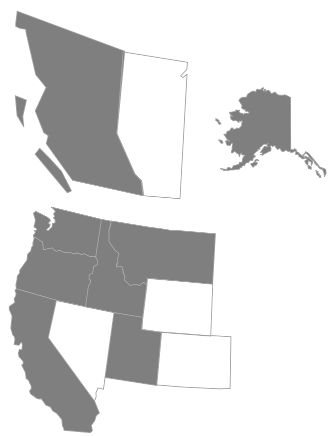
c) leaves (Tom Heutte, Forest Service, www.bugwood.org), d) flower (Jennifer Andreas, Washington State University Extension), e) seed pods (Wendy DesCamp, Washington State Noxious Weed Control Board)

pastures, forests, and wastelands with moister soils. Favors full sunlight.

ECOLOGY: Spreads by seed only, but can also regenerate from the root crown after cutting the stem. Seedlings begin flowering at two years and continue to grow for 25-30 years. Flowering usually occurs in early spring though an occasional plant may bloom in late summer. When seed pods mature and dry, their opening event may scatter seeds great distances. Pods with seeds are also easily transported by humans, birds, and other animals. Seeds may remain viable for more than 60 years.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Bruchidius villosus, Exapion fuscirostre* and *Leucoptera spartifoliella*.

NOTES: Fire may encourage resprouting from root crowns.

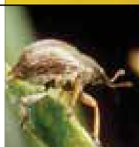


Broom Biological Control

HISTORY IN THE NORTHWEST: *Leucoptera spartifoliella* was the first biological control agent utilized against Scotch broom in North America. Though released in the USA in 1960, it was found to have already been inadvertently established in the Pacific Northwest. *Exapion fuscirostre* was subsequently released in the USA in 1964. An adventive species, *Bruchidius villosus*, was subsequently approved through the proper channels and redistributed in the Pacific Northwest from 1998. Both *E. fuscirostre* and *B. villosus* spread naturally from the USA to Canada.

CURRENT STATUS: USA: Success has not been achieved in the broom biocontrol program to date. All three agents established in the Northwest. *E. fuscirostre* is moderately abundant on Scotch broom however its impact is typically minor, and it appears to be outcompeted by *B. villosus* where both co-occur. Populations of *B. villosus* are increasing on Scotch broom in the Pacific Northwest. Seed destruction can be high at times, which limits the rate of spread of weed populations. It remains unclear whether this will be sufficient to affect stand density in the long term, but studies are underway to measure impact. *Leucoptera spartifoliella* is hindered by heavy parasitism. Where high densities exist, the agent can cause stem dieback, though existing weed stands are not decreased. Furthermore, plants often re-grow below the sites of damage. CAN: **No species were intentionally released in Canada for the control of Scotch broom.** The two broom seed-feeders spread naturally from the USA, though their impact and abundance remain unknown.

RECOMMENDATIONS: USA: Neither *E. fuscirostre* or *L. spartifoliella* cause sufficient damage to Scotch broom populations to warrant widespread redistribution. In addition, the high parasitism rates plaguing *L. spartifoliella* preclude its movement. It is too early to determine if *B. villosus* will have lasting impact, though populations are increasing and efficacy studies are currently underway. In the meantime, redistributions are recommended by collecting adults in early spring for releases at sites with no other control programs in effect. CAN: **Broom biological agents established in Canada were not originally introduced via the proper channels.**

AGENT	ADULT	IMPACT	RECOMMENDATION
Bruchidius villosus		Seed-feeding may help reduce rate of spread of population but doesn't affect existing stands. Overall impact unknown.	Populations increasing and impact studies underway. Recommended for redistribution. Not intentional in CAN.
Exapion fuscirostre		Seed-feeding may help reduce rate of spread of population but doesn't affect existing stands. Overall impact limited.	Low impact makes low priority. May be more effective with complementary control methods and high plant competition. Not intentional in CAN.
Leucoptera spartifoliella		Stem-mining can cause stem dieback, but plants often recover. Many populations heavily parasitized.	Already widely distributed. Not recommended for continued extensive use due to low impact; populations heavily parasitized. Not released in CAN.

Bruchidius: Jennifer Andreas, Washington State University Extension, *Exapion:* Laura Parsons, University of Idaho, *Leucoptera*: Eric Coombs, Oregon Department of Agriculture, www.bugwood.org

Bruchidius villosus (Goeze)

Broom seed beetle

DESCRIPTION: Eggs are tiny, white, and oval-shaped. Larvae are an off-white color with brown head capsules. and can reach up to 2 mm in length. Adults can also be up to 2 mm long. They have gray-black bodies, antennae, and legs. Both their elytra and snouts are short.

Bruchidius villosus: a) four eggs on a Scotch broom seed pod, b) larva feeding completely within the middle seed, c) adult (all Jennifer Andreas, Washington State University Extension)

LIFE CYCLE: Adults emerge from overwintering (away from the host plant) in spring when broom begins to flower. Eggs are laid on the pod, with hatching larvae burrowing in and feeding on developing seeds. A single larva will develop through four instars completely within an individual seed and then pupate within the seed coat. New adults emerge in late summer, leaving behind round emergence holes in seeds. Adults do not chew their way out of the pod, instead relying on the pod to split naturally at maturity (in order to spread its seeds). There is one generation per year.

DAMAGE: Larval feeding on developing seeds reduces viable seed production, leading to possible decreases in the rate of weed spread.

PREFERRED HABITAT: Does best in meadows or on hillsides with southern exposure. May perform poorly in heavily shaded, cold, high elevation, and/or damp sites.

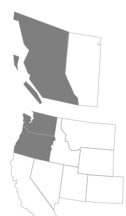
HISTORY: Native to Europe and unintentionally introduced to the eastern USA. First recorded in MA in 1918 but spread along the east coast. Unintentional populations were tested for host specificity following USDA-APHIS TAG protocols and then deliberately transferred from NC to OR, WA onto Scotch broom beginning in 1998. Spread naturally from there to BC, Canada by 2001.

Bruchidius villosus: d) emerged adult and feeding damage, e) adult (right) compared to an adult *Exapion fuscirostre* (left) (both Jennifer Andreas, Washington State University Extension)

CURRENT STATUS: Widespread on Scotch broom in northwestern USA. Abundance is increasing but variable; 10-90% of pods are attacked, and 20-80% of seeds are destroyed within attacked pods. Studies are continuing, but it is unclear if densities and attack rates are high enough yet to decrease plant populations. Parasitism is typically low but may limit populations in some regions. This species appears to outcompete *E. fuscirostre* at sites where they both occur. In Canada, abundance and impact are unknown, though it is more active than the other adventive Scotch broom agent, *E. fuscirostre*.

REDISTRIBUTION: Best collected in the adult stage using a beat net and racket with an aspirator during early spring when plants start flowering and producing seed pods. Can then be transferred to uninfested sites in groups of 100-200. Establishment can be monitored the following growing season by observing adults on foliage and flowers or by dissecting seed pods to find larvae feeding within seeds. Note that first instar larvae can be difficult to differentiate from *E. fuscirostre*.

NOTES: Late instar larvae of *B. villosus* can be differentiated from *E. fuscirostre* in that *B. villosus* larvae feed completely within broom seeds, to the extent their presence can be difficult to detect unless seeds are dissected. Contrary to this, *E. fuscirostre* larvae cause external feeding damage to seeds that is obvious when the pod is first opened. *B. villosus* was observed attacking French broom in OR, USA by 2001 and appears to be spreading, though its impact has not been determined. **This agent was not an intentional introduction in Canada.**



Exapion fuscirostre (Fabricius)

Scotch broom seed weevil

SYNONYMS: *Apion fuscirostre* Fabricius

DESCRIPTION: Eggs are small, white to yellowish, and round. Larvae are an off-white color with brown head capsules. They can be up to 2½ mm in length while adults can be up to 3 mm. Adults have brown bodies with two long, dark gray bands that run down either side of their bodies (one on each side). Their snouts are long and curved, and they have light brown legs.

Exapion fuscirostre: a) larvae in seeds (Eric Coombs, Oregon Department of Agriculture), b) adult (Laura Parsons, University of Idaho) (both www.bugwood.org)

LIFE CYCLE: Adults emerge from overwintering in soil litter in early spring when broom begins to flower. Females must feed on broom flowers in order to produce eggs. Eggs are laid inside the pod, with hatching larvae feeding on developing seeds. Larvae feed half in and half out of attacked seeds, developing through four instars and pupating within the seed pod. New adults emerge in late summer. Adults do not chew their way out of the pod, instead relying on the pod to split naturally at maturity (in order to spread its seeds). There is one generation per year, though generations sometimes overlap as adults are frequently active year-round.

DAMAGE: Larval feeding on developing seeds reduces viable seed production, leading to decreases in the rate of spread of Scotch broom, though the overall efficacy of this species is questionable. Adult feeding causes terminal shoot dieback, but does not kill the plant.

PREFERRED HABITAT: Does best in meadows or on hillsides with southern exposure. Performs poorly in heavily shaded, cold, high elevation, and/or damp sites.

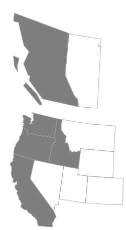
Exapion fuscirostre: c) adult feeding damage (Eric Coombs, Oregon Department of Agriculture), d) emerged adult and feeding damage (Jennifer Andreas, Washington State University Extension)

HISTORY: Introduced from Italy and released on Scotch broom in the USA (CA, ID, OR, WA) from 1964. Spread naturally to BC, Canada by 2007.

CURRENT STATUS: Though moderately abundant on Scotch broom in the USA, impact is generally low. Observed seed reduction rates between 20-60% are insufficient to impart significant control of plant populations alone, but may contribute to a slowed rate of spread. Parasitism is typically low but may limit populations in some regions. This species appears to be outcompeted by *B. villosus* at sites where they both occur. In Canada, abundance and impact are unknown, though it is less active than the other adventive Scotch broom agent, *B. villosus*.

REDISTRIBUTION: This species is a lower priority for redistribution than *B. villosus*. Regardless, it is best collected in the adult stage using a beat net and racket with an aspirator during early spring when plants start flowering. Adults can then be transferred to uninfested sites in groups of 100-200. Establishment can be monitored the following growing season by observing adults on foliage and flowers or by dissecting seed pods to find larvae feeding within. Note that first instar larvae can be difficult to differentiate from *B. villosus*.

NOTES: Late instar larvae of *E. fuscirostre* can be differentiated from *B. villosus* in that *E. fuscirostre* larval feeding damage to seeds is obvious once pods are opened. *B. villosus* larvae feed completely within seeds so individual seeds must be dissected to confirm the species is present. **This agent was not an intentional introduction in Canada.**



Leucoptera spartifoliella (Hübner)

Scotch broom twig miner

DESCRIPTION: Larvae are green-brown, appear somewhat flattened, and can reach 3-4 mm in length. Adults are small (5 mm long) and are seldom seen. They are white with white antennae, feathered wing tips, and have pale gold markings.

Leucoptera spartifoliella: a) pupa, b) adult (both Eric Coombs, Oregon Department of Agriculture, www.bugwood.org)

LIFE CYCLE: Adults lay eggs in late summer when broom is in the late-flowering stage. Larvae hatch and tunnel into young shoots to feed. Larvae develop through six instars over several months and overwinter in the stems of broom. Pupation occurs in spring, with adults emerging in late spring and early summer as broom flowers. There is one generation per year.

DAMAGE: Larval mining causes stem dieback, however, plants often re-sprout below sites of damage.

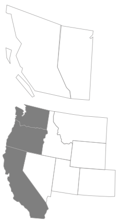
PREFERRED HABITAT: Does best at low-elevation infestations with moderate temperature and ample moisture.

HISTORY: Introduced from France and released on Scotch broom from 1960 in the USA (CA, OR), but was found to have already been present in CA, OR and WA. It was likely imported on ornamental plants prior to 1940. Both populations have since intermixed and are no longer differentiated.

CURRENT STATUS: Widespread in on Scotch broom in CA and OR (USA), but present at only limited sites in WA. High numbers can deform plants and cause stem dieback, but plant density is not affected. Because plants often re-grow below sites of damage, overall impact is negligible. Populations are also heavily parasitized and do not fare well in hot, dry sites.

REDISTRIBUTION: This species is a very low priority for redistribution. Because larvae are heavily parasitized, it is best to collect adults using light traps in spring as plants start flowering. These can be transferred in groups of 50-100 to new infestations. The species is already widely distributed throughout the Northwest, however, so infestations should be checked for its presence prior to redistribution attempts. Established of transferred individuals can be monitored the following growing season by dissecting stems in search of feeding larvae. Adults are cryptic and rarely seen.

NOTES: **This agent is not approved for release in Canada.**



Broom, Unapproved Agents

Three accidentally introduced species are established on broom in North America. **It is illegal to intentionally move these species to new areas in the USA.** Care should be taken when transferring approved agents to ensure that these unapproved species are not also included in transferred material.

Aceria genistae (Nalepa) (Acari: Eriophyidae)

Galls: Jennifer Andreas, Washington State University Extension

DESCRIPTION AND LIFE CYCLE: All stages are tiny and best viewed with a microscope. Larvae and nymphs are pinkish-white and 0.10-0.12 mm long. Adults are light pink and have a worm-like appearance. They have two pairs of developed legs near their heads and can be 0.16-0.225 mm long. All stages feed on stem bud tissue by extracting sap from plant cells. This induces the development of galls 5-30 mm in diameter that serve as protective housing to hundreds of mites. Galls are the best indication of mite presence. As galls grow, they become more hairy until they senesce, at which time mites migrate to new buds to form new galls. Galls may develop faster and have greater impact at hot, dry sites. There can be several generations per year. Mite numbers appear to be greatly reduced during overwintering. All stages are capable of overwintering within new buds.

HISTORY AND CURRENT STATUS: Accidental introduction recorded on Scotch broom in OR and WA (USA) by 2005. Possibly established in CA. Abundant in WA where overall impact is medium as it reduces flowering and plant biomass and in some cases may cause stem and plant mortality. Widespread in OR but only abundant locally with slight impact. Currently undergoing host specificity testing in WA with the intent of future intentional redistribution, if approved. Identified only recently in BC, Canada (2010) where impact thus far is minor. **Currently not approved for redistribution in the USA.**

Agonopterix nervosa (Haworth)
(Lepidoptera: Oecophoridae)

© Donald Hobern, Canberra, Australia

DESCRIPTION AND LIFE CYCLE: Larvae emerge in early spring and feed on feed in lightly spun tubes of plant material on shoot tips of broom and gorse. Larvae vary in color from yellowish-gray to brown and can be up to 15 mm long. Adults are typically 10-15 mm long with variable coloring. Typical adults have white or yellowish wings with gray to brown small mottling, sometimes appearing as stripes on wing veins. Adults appear in early summer and are present throughout the growing season, sometimes overwintering. There is one generation per year.

HISTORY AND CURRENT STATUS: Accidental introduction recorded on gorse in BC, Canada by 1915. Spread to the USA in the 1920s. Attacks both Scotch broom and gorse in CA, NV, OR, WA (USA), though is more effective on gorse. May stunt shoots and reduce seed production, but overall impact is limited. Populations are heavily parasitized. Abundance and impact on gorse in BC are unknown. **Not approved for redistribution in the USA.**

Arytainilla spartiophila (Förster)
(Hemiptera: Psyllidae)

Landcare Research Ltd., New Zealand

DESCRIPTION AND LIFE CYCLE: Overwintering eggs are embedded in broom stems beneath a waxy cap. Tiny, orangey-brown nymphs (<2 mm long) hatch in spring and crawl into new growth buds to feed. Nymphs grow through five instars before developing into pale brown aphid-like adults (2–3 mm long) with clear wings. Adults feed on new growth, lay eggs, and die before winter. There is one generation per year.

HISTORY AND CURRENT STATUS: Accidental introduction recorded on Scotch broom in WA, USA in 1935. Now widespread in CA, OR, WA. High densities may weaken plants stressed from competition, making them vulnerable to pathogens. Overall impact likely limited. Their honeyew interferes with late-season collections of other agents. **Not approved for redistribution in the USA.**

Gorse

Ulex europaeus L.

SYNONYMS: furze

ORIGIN: Native to western Europe; introduced in the late 1800s as an ornamental or hedge plant to contain livestock, but soon escaped cultivation

DESCRIPTION: Woody shrub that typically grows 3-13 ft tall (1-4 m) from a woody, multi-branched root system. It can be prostrate or erect, and has numerous angular branches that end in spines. Stems are hairy when young and less so as the plant ages. Leaves are alternate and three-parted when the plant is young and are reduced to scales or thick spines as the plant ages. Flowers are yellow and occur either singly in leaf axils or in numerous clusters on the ends of older branches. Flowers are characteristic of the pea family by having petals form a banner and keel (similar to a boat). Seed pods are hairy, turning black with age. They grow to 0.8 in long (2 cm).

a) plant, b) infestation (both Wendy DesCamp, Washington State Noxious Weed Control Board)

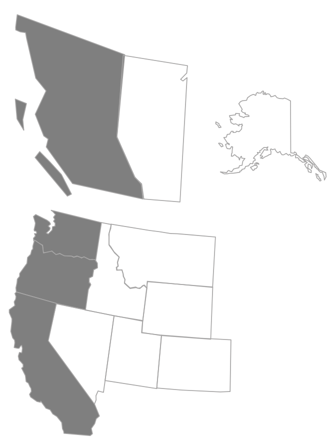
c) leaves (Jennifer Andreas, Washington State Univrsity Extension), d) open flower (Wendy DesCamp, Washington State Noxious Weed Control Board), e) seed pods (Forest & Kim Starr, Starr Environmental GROUP www.bugwood.org)

HABITAT: Widespread along the Pacific coast. It is particularly problematic in open or disturbed places, especially roads, abandoned or overgrazed pastures, old agricultural fields, and sand dunes.

ECOLOGY: Spreads by seed only, but can also regenerate from the root crown after cutting the stem. Seedlings begin flowering at two years and continue to grow for 25-30 years. Flowering occurs in early spring with a smaller secondary bloom in late fall in some locations. When seed pods mature, they dry out and open rapidly, which may scatter seeds great distances. Pods with seeds are also easily transported by humans, birds, and other animals. Seeds may remain viable for 20 years.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Exapion ulicis* and *Tetranychus lintearius*

NOTES: Highly flammable with an oil content of 2 to 4%.



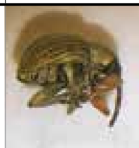
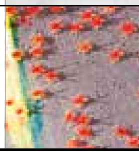
GORSE

Gorse Biological Control

HISTORY IN THE NORTHWEST: Two agents have been released against gorse in the USA since 1953 (*E. ulicis* 1953 and *Tetranychus lintearius* 1994). Neither was released in Canada.

CURRENT STATUS: USA: Success has not been achieved in the gorse biocontrol program. Both of the agents released established in the Northwest. *Exapion ulicis* is moderately abundant on gorse, however its impact is typically minor. While seed destruction can be high at times, this at best limits the rate of spread of weed populations, but does not affect existing stand density. At many sites, seed predation is too low to have any noticeable impact, and gorse seed maturing in autumn/winter escapes attack completely. The gorse spider mite was initially widely distributed, causing a significant reduction of flowering. Populations have since been hindered by heavy predation such that it is now considered an ineffective agent. CAN: **No species were intentionally released in Canada for the control of gorse.**

RECOMMENDATIONS: USA: None of the agents currently established have provided significant long-term impact to gorse. Due to the high predation rates plaguing *T. lintearius* on gorse, it is not a high priority for redistribution. *Exapion ulicis* could be redistributed to uninfested sites, but due to its low efficacy, this should likely only occur at sites where additional control methods will be employed or high plant competition exists. Keep in mind alternative control methods damaging gorse seed pods will also damage *E. ulicis*. CAN: **Gorse biological agents have not been released in Canada, and neither are currently established there.**

AGENT	ADULT	IMPACT	RECOMMENDATION
Exapion ulicis		Seed-feeding may help reduce rate of spread of population but doesn't affect existing stands. Late seeds escape attack. Overall impact limited.	Low impact, so low priority of redistribution. Should only be used with other control methods and/or high competition. Not released in CAN.
Tetranychus lintearius		Stem- and foliage-feeding reduces flowering, decreasing weed rate of spread Severely attacked plants killed. Mites now heavily preyed upon.	Not recommended for continued extensive use as populations heavily preyed upon. Not released in CAN.

Exapion: Forest and Kim Starr, Starr Environmental, www.bugwood.org, *Tetranychus*: Rich Lee, San Juan County Noxious Weed Board

Exapion ulicis (Forster)

Gorse seed weevil

SYNONYMS: *Apion ulicis* (Forster)

DESCRIPTION: Eggs are round, small, and translucent yellow. Larvae are cream colored, C-shaped, and can reach 3 mm in length. Adults are gray with very long, curved snouts and brownish gray legs. Faint stripes are sometimes apparent on their elytra, and they are typically 2-3 mm long.

Exapion ulicis: a) larvae and damage (George Markin, USDA Forest Service) b) adult (Forest and Kim Starr, Starr Environmental) (both www.bugwood.org)

LIFE CYCLE: Adults emerge from overwintering during early spring and deposit eggs into young seed pods. Larvae hatch in late spring and early summer and feed on developing seeds. They develop through four instars. Pupation occurs in seed pods, with adults emerging in late summer. Adults feed on spines and stems of gorse and then overwinter. There is one generation per year.

DAMAGE: Larval seed-feeding may reduce the rate of spread of gorse. Adult feeding leads to destruction of stem tissue but without significantly harming the plant.

PREFERRED HABITAT: Does best in open, sunny sites with dense plants. Distribution is limited in regions with cold winters, shade, only scattered host plants, and in salt spray zones along the coast.

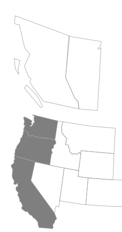
HISTORY: Introduced from England and released on gorse in CA, OR, WA (USA) from 1953.

CURRENT STATUS: Widespread and abundant on gorse in northwestern USA, though overall impact is limited. From 30-95% of seed pods are attacked.

This does not reduce established stand density. It may at best slow the rate of spread of the weed, however it is ineffective on seed maturing in autumn/winter.

REDISTRIBUTION: Best collected in the adult stage using a beat net and racket with an aspirator during early spring when plants start flowering. Can then be transferred to uninfested sites in groups of 100-200. Establishment can be monitored the following growing season by observing adults on foliage and flowers or by dissecting seed pods to find larvae feeding within.

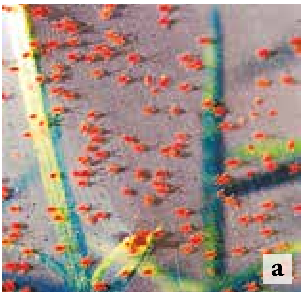
NOTES: **This agent is not approved for release in Canada.**



Tetranychus lintearius (Dufour)

Gorse spider mite

DESCRIPTION: Eggs are tiny, round, and largely transparent. First stage (or larval mites) are light in color and have six legs. Second to fourth stage (nymphal) mites have eight legs, are brown, and resemble small adults. Adults also have eight legs, are brick red in color, and are up to 2 mm long.



Tetranychus lintearius: a) adults, b) webbing with mass of adults (a,b Rich Lee, San Juan County Noxious Weed Board), c) large infested gorse patch (Eric Coombs, Oregon Department of Agriculture)

LIFE CYCLE: Adults form a colony with large amounts of webbing on the terminal branches of gorse. Females lay eggs year-round on infested shoots. Hatching mites complete four immature stages, with larvae and nymphs feeding on plant tissue. Adults feed on stems and spines and live up to four weeks. There are up to six generations per year, with all stages capable of overwintering.

DAMAGE: Larval, nymphal, and adult feeding stunts branch growth and reduces flowering, thus contributing to a reduction in the spread of gorse. Heavily infested plants are killed by the extensive feeding.

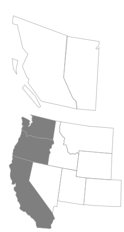
PREFERRED HABITAT: Does best in warm, open gorse patches and away from the ocean. Damp, ocean-side infestations or heavily shaded forest patches are seldom attacked. Can be somewhat cold hardy, but severe winter temperatures limit populations.

HISTORY: Introduced from England, Portugal, and Spain via New Zealand and released on gorse in CA, OR and WA (USA) from 1994.

CURRENT STATUS: Initially widely distributed on gorse in the western USA, even leading to an 80% reduction in flowering in OR. Was most effective in open patches in inland areas susceptible to severe winters. Populations have since decreased significantly due to heavy predation by beetles and predatory mites. It is now considered an ineffective agent.

REDISTRIBUTION: Best redistributed by clipping infested branches and transferring them to uninfested gorse. This can be done throughout the growing season. Establishment can be monitored the same season or in following years by observing new tent webbing on infected plants.

NOTES: **This agent is not approved for release in Canada.**



Gorse, Unapproved Agents

Agonopterix nervosa (Haworth) (Lepidoptera: Oecophoridae)

© Donald Hobern, Canberra, Australia

DESCRIPTION AND LIFE CYCLE: Larvae emerge in early spring and feed on feed in lightly spun tubes of plant material on shoot tips of gorse and Scotch broom. Larvae vary in color from yellowish-gray to brown and can be up to 15 mm long. Adults are typically 10-15 mm long with variable coloring. Typical adults have white or yellowish wings with gray to brown small mottling, sometimes appearing as stripes on wing veins. Adults appear in early summer and are present throughout the growing season, sometimes overwintering. There is one generation per year.

HISTORY AND CURRENT STATUS: Accidental introduction recorded on gorse in BC, Canada by 1915. Spread to the USA in the 1920s. Attacks both Scotch broom and gorse in CA, NV, OR, WA (USA), though is more effective on gorse. May stunt shoots and reduce seed production, but overall impact is limited. Populations are heavily parasitized. Abundance and impact on gorse in BC are unknown. **Not approved for redistribution in the USA.**

Orange hawkweed

Pilosella aurantiaca (L.) F. W. Schultz & Sch. Bip.

SYNONYMS: Grim the Collier, devil's paintbrush; *Hieracium aurantiacum* L.

ORIGIN: Native to Europe. Introduced to North America by 1875 as a garden ornamental.

DESCRIPTION: An upright perennial typically growing 10-24 in (25-60 cm) tall from a fibrous root system. Plants produce short rhizomes as well as stolons that extend 4-12 in (10-30 cm) and form the next generation of plants. Stems are largely unbranched until the tips, which end in 5-30 capitula. Leaves (up to 5 in or 13 cm long) typically occur only in a basal rosette, though 1 or 2 smaller leaves may occur on the plant stem. Stems and leaves are covered with stiff hairs that can be simple, glandular, and/or star-shaped. The entire plant contains a milky latex. Capitula are ½-1 in (1-2½ cm) in diameter and contain reddish-orange florets (all ray). Seed head bracts are covered in glandular hairs. Seeds (achenes) are topped by tufts of pappus, resembling dandelion seeds.

a) plant (Howard F. Schwartz, Colorado State University), b) infestation (Forest and Kim Starr, Starr Environmental) (both www.bugwood.org)

c) leaves (with leaflets), d) flower (Steve Dewey, Utah State University), e) mature seeds (© Keir Morse, www.keiriosity.com)

HABITAT: Prefers full sun or partial shade and soils that are well drained and coarse-textured. Dense infestations often occur in moist meadows, pastures, hay fields, roadsides, gravel pits, forested areas, tree plantations and riparian areas.

ECOLOGY: Reproduces by seed, stolons, and short rhizomes. Plants germinate in spring and flower from mid- to late summer. Seeds are transported by wind, water, or adhering to clothing or fur, and are often moved in contaminated soil associated with transplanting new plants into gardens and flower beds. Seeds remain viable in soil for up to 7 years. Stolons elongate throughout summer, forming daughter rosettes at their tips. Once daughter plants root, the stolons die, and the new plant becomes independent. After flowering, the supporting rosette dies. New plants sprout each year from rhizomes.

APPROVED BIOLOGICAL CONTROL AGENTS: USA and CAN: *Aulacidea subterminalis*

NOTES: Several studies suggest the plant may have allelopathic properties, inhibiting the growth or function of competing species.

Whiplash hawkweed

Pilosella flagellaris (Willd.) Arv.-Touv.

SYNONYMS: *Hieracium flagellare* Willd., *Hieracium ×flagellare* Willd. (pro sp.) [*caespitosum* × *pilosella*]

ORIGIN: Native to Europe. Year of first introduction to North America unknown.

DESCRIPTION: Due to the current confusion and taxonomic flux of hawkweeds in North America (see following pages), the following description may only apply to some populations of whiplash hawkweed: An upright perennial typically growing 2½-8 in (6-20 cm) tall from a fibrous root system. Plants produce rhizomes as well as long, leafy stolons which form the next generation of plants. Stems are largely unbranched until the tips, which end in 2-6 capitula. Leaves typically only occur in a basal rosette. The green leaves are slightly narrow at their bases and more broad toward their tips, usually growing 1-2 in (2½-5 cm) long. Leaves have dense hairs (both simple and star-shaped) along their margins and underside midveins. Stem hairs are simple and star-shaped near

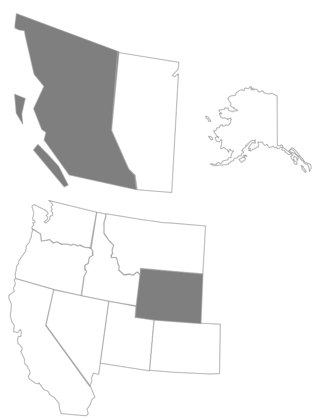
a) plants from side view, b) infestation from above (both Rosemarie De Clerck-Floate, Agriculture and Agri-Food Canada)

c) leaves, d) flower heads, e) underside of flower heads (all Rosemarie De Clerck-Floate, Agriculture and Agri-Food Canada)

the base, becoming glandular near the capitulum. The entire plant contains a milky latex. Capitula are typically ½-1 in (1.3-2½ cm) in diameter and contain yellow florets (all ray). Florets often have a red stripe on their undersides. Seed head bracts are covered in star-shaped and/or glandular hairs. Seeds (achenes) are topped by tufts of pappus, resembling dandelion seeds.

HABITAT: Does well in full sun or partial shade. Can be found in dense infestations in disturbed sites, roadsides, and forest edges.

ECOLOGY: Reproduces by seed, stolons, and short rhizomes. Plants germinate in spring and flower in late spring or early summer. Seeds are transported by wind, water, or adhering to clothing or fur, and are often moved in contaminated soil associated with transplanting new plants into gardens and flower beds. Stolons elongate throughout summer, forming daughter rosettes at their tips. Once daughter plants root, the stolons die, and the new plant becomes independent. After flowering, the supporting rosette dies. New plants sprout each year from rhizomes.



APPROVED BIOLOGICAL CONTROL AGENTS: USA and CAN: *Aulacidea subterminalis*

NOTES: This species likely resulted from a cross between plants of *Pilosella caespitosa* (meadow hawkweed) and *P. officinarum* (mouse-ear hawkweed). It is part of the *P. flagellaris* collective, which also includes *P. macrostolona* and *P. prussica.*

HAWKWEEDS

Hawkweed Biological Control

There are several hawkweeds presently established in North America, including both native and introduced species as well as hybrids. Identification can be difficult, which is compounded by the current state of taxonomic flux for members of this group. Morphometric and molecular studies are underway. To date only one biocontrol agent has been approved for use in North America, *Aulacidea subterminalis*. Though this species is approved for use against orange, whiplash, mouse-ear and king devil hawkweed, to date (April 2014) it has only been released against orange and whiplash hawkweed in North America. Consequently only these two hawkweed species are described in this field guide.

HISTORY IN THE NORTHWEST: Biological control of hawkweeds began in New Zealand where five biocontrol agents have been intentionally introduced since 1997. The early work conducted in New Zealand paved the way for testing undertaken later for North America. However, because North America has several native species related to exotic hawkweeds (unlike New Zealand), many of the previously tested agents were found unsafe for introduction to North America. The gall wasp *Aulacidea subterminalis* has thus far been the only species found safe to introduce. It was imported from Switzerland and released in both the USA (MT) and Canada (BC) on orange hawkweed from 2011. It was also released on whiplash hawkweed in BC repeatedly since 2011.

CURRENT STATUS: Establishment has yet to be officially confirmed in the USA or Canada, but release and monitoring programs in both countries remain active. Orange hawkweed is not its preferred host, so Canadian releases after 2011 have been and will continue to be focused on whiplash hawkweed.

RECOMMENDATIONS: USA and CAN: Additional releases should be made utilizing laboratory populations to increase the chance of establishment. Contact local biocontrol or weed authorities for information on agent availability.

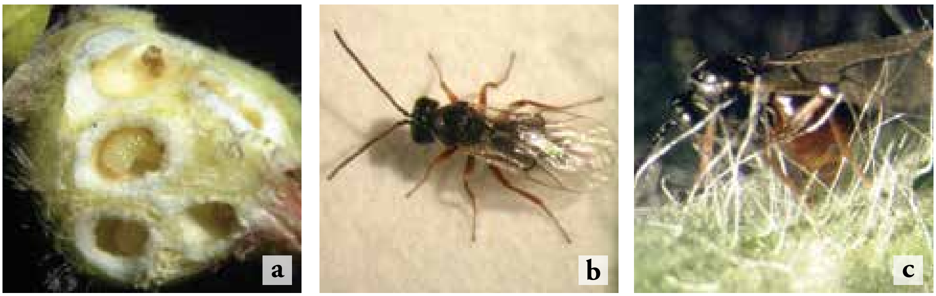
AGENT	ADULT	IMPACT	RECOMMENDATION
Aulacidea subterminalis		Establishment yet to be officially confirmed in USA or CAN. In native range, galling reduces vegetative reproduction.	Additional releases from lab populations recommended to increase chance of establishment.

Aulacidea subterminalis photo Ghislaine Cortat, CABI-Switzerland

Aulacidea subterminalis Niblett

Hawkweed gall wasp

DESCRIPTION: Eggs are tiny and milky-white. Larvae are creamy white and are typically 2-3 mm long. Adults are small (2-3 mm long) with bulbous bodies. They have a brown abdomen and legs, while the thorax and head are typically brownish-black. Antennae are long and brown, and the wings are transparent with darker veins.



Aulacidea subterminalis: a) larvae in galls, b) adult (Ghislaine Cortat, CABI-Switzerland), c) adult ovipositing (a, b Gitta Grosskopf, CABI-Switzerland)

LIFE CYCLE: Overwintering larvae pupate within galls in early spring. Emerging adults lay eggs inside hawkweed stolon tips. This species of wasp is able to lay eggs without fertilization, so there are no males. Hatching larvae feed within the stolons throughout summer. Larval feeding induces the formation of fleshy green galls. Larvae remain in galls through autumn and winter. By spring, the galls dry out and turn brown, and larvae pupate within them. There is one generation per year.

DAMAGE: Galling reduces stolon growth, which reduces the vegetative reproduction of the plant by decreasing the number of daughter plants.

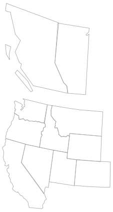
PREFERRED HABITAT: Specific habitat requirements for this species are unknown.

HISTORY: Introduced from Switzerland and released on orange hawkweed in both the USA (MT) and Canada (BC) from 2011. It was also released on whiplash hawkweed in BC, Canada repeatedly from 2011.

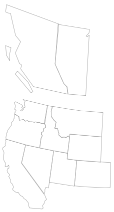
CURRENT STATUS: Establishment has yet to be officially confirmed in the USA or Canada, but release and monitoring programs in both countries remain active. Orange hawkweed is not its preferred host, so Canadaian releases after 2011 have been and will continue to be focused on whiplash hawkweed.

REDISTRIBUTION: New releases should be made in both the USA and Canada, utilizing laboratory material where possible. When field populations are confirmed established and increase sufficiently to warrant redistribution, galls can be collected in late fall and transferred to sheltered positions in new hawkweed infestations. Galls are best transferred in groups of 100 or more. Establishment can be monitored the following growing season by observing galls on new hawkweed stolon growth.

NOTES: In addition to orange and whiplash hawkweed, *Aulacidea subterminalis* is also approved for use against king devil (*Pilosella ×floribunda*) and mouse-ear hawkweed (*Pilosella officinarum*) in North America. To date (April 2014), neither of these hawkweed species has been targeted for release. *A. subterminalis* does not occur naturally on king devil hawkweed in its native Europe so is not believed to be an ideal host in North America. Though the wasp readily attacks mouse-ear hawkweed, this weed presently only occurs in small, isolated patches in BC so is being targeted with other control methods. Whiplash and mouse-ear hawkweed are also not overly abundant in the Northwest of the USA, but infestations of both (and especially mouse-ear) may be targeted for *A. subterminalis* release in the near future.



orange



whiplash

PUNCTUREVINE

Tribulus terrestris L.

SYNONYMS: caltrop, goat head

ORIGIN: Native to the Mediterranean, western Asia and Africa. Introduced to North America accidentally along with livestock by 1900.

DESCRIPTION: A prostrate annual plant growing from a taproot. The stems radiate from the crown, typically growing 2-7 ft (60-200 cm) in diameter to form a mat along the ground. Stems vary from green to reddish-brown and are somewhat hairy. The leaves are opposite and compound with 4-8 pairs of elliptical leaflets. The leaflets are typically dark green and hairy along margins. Leaflets are often ¼-½ in (5-12 mm) long. Flowers appear in leaf axils, where leaves attach to stem branches. They have 5 lemon-yellow petals and are typically less than ½ in (12 mm) in diameter. Mature fruits break apart into 5 burs, each containing 1-4 seeds. Burs are bony and each armed with 2-4 rigid spines.

HABITAT: Often occurs in dense mats along areas of disturbance, including crop

a) plant, b) infestation (both Jennifer Andreas, Washington State University Extension)

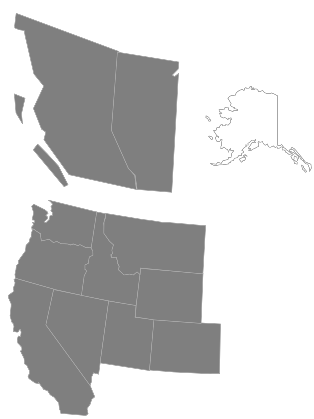
c) leaves (with leaflets), d) flower (c,d Jennifer Andreas, Washington State University Extension), e) fruits (Steve Hurst, USDA NRCS PLANTS Database, www.bugwood.org)

margins, pastures, corrals, roadways, sidewalks and vacant lots. Seems to prefer semi-arid and Mediterranean-like climates.

ECOLOGY: Reproduces by seed only. Plants germinate in spring and summer with sufficient soil moisture and warm temperatures. The plant quickly grows a deep taproot that enables it to tolerate dry soils after establishment. Flowering occurs as quickly as 3 weeks after germination, and continues throughout summer. The sharp spines of burs readily puncture and adhere to tires, clothing, feet and fur, transporting seeds great distances. Seeds typically stay viable for 5 years, though some reports claim up to 20 years.

APPROVED BIOLOGICAL CONTROL AGENTS: USA and CAN: *Microlarinus lareynii, Microlarinus lypriformis*

NOTES: The sharp spines on fruits are injurious to humans and livestock, interfere with agricultural harvesting, and lower the quality of seed, feed, and wool.

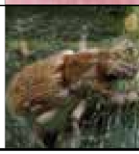


Puncturevine Biological Control

HISTORY IN THE NORTHWEST: Both the weed weevil, *Microlarinus lareynii,* and the stem miner, *M. lypriformis,* were introduced from Italy and released throughout the USA from 1961. Several redistributions followed, often involving a mixture of the two species. After initial releases failed to establish in some cold climates, a second introduction was made using a population of both species from the Abruzzi Mountains, Italy. These individuals were released in more northern areas of CA, but failed to establish. A population containing both species was collected from CO (USA) and redistributed to CAN (BC) in 1986, but failed to establish.

CURRENT STATUS: Both species are established with variable densities on puncturevine in the USA. In combination, they have successfully reduced puncturevine cover and seed production up to 80% in warmer areas of the southwest USA. They are generally ineffective at higher elevations and higher latitudes where cold winter temperatures reduce weevil abundance and impact. Recent redistribution efforts within CA successfully established a population of both species at one high elevation site, indicating establishment is possible when sites have overwintering shelter and limited disturbance. *M. lareynii* is much more successful at high elevation sites compared to *M. lypriformis*, and is established in limited amounts in WA and OR whereas *M. lypriformis* is not, indicating a higher cold tolerance by *M. lareynii*. Populations of both species are limited by parasites and predators at some sites. **Both species have been observed attacking the native *Kallstroemia californica, K. grandiflora,* and one additional native *Kallstroemia* species. Adults have been found on numerous exotic species (some of economic importance), though impact is typically negligible.**

RECOMMENDATIONS: USA: Redistribution of both species is recommended for warmer climate sites where they are not already established. Adults of both can be collected in fall or spring from the soil litter beneath plants using a vacuum or aspirator. They should be transferred in groups of 100-200. They are less recommended for release at cold sites where they are unlikely to establish or have great impact. If other control options are not feasible at cold climate sites, *M. lareynii* is more highly recommended than *M. lypriformis,* and emphasis should be placed on choosing sites with sufficient overwintering shelter and limited disturbance. **Both weevil species should not be released where native *Kallstroemia* species occur.**

Agent	Adult	Impact	Recommendation
Microlarinus lareynii		Established USA only. Larval feeding destroys seeds, reducing puncturevine population spread. Largely limited by cold climates	Recommended in warm climates; low priority for cold. Should not be used near native *Kallstroemia* species.
Microlarinus lypriformis		Established USA only. Stem-mining weakens plant vigor, causes stem breakage, reduces seed production. Largely limited by cold climates	Recommended in warm climates; not recommended for cold. Should not be used near native *Kallstroemia* species.

Microlarinus lareynii: Jennifer Andreas, Washington State University Extension, *M. lypriformis*: USDA ARS European Biological Control Laboratory, USDA ARS-European Biological Control Laboratory (both www.bugwood.org)

Microlarinus lareynii (Jacquelin du Val)

Puncturevine seed weevil

DESCRIPTION: This species is very similar to *Microlarinus lypriformis*. Eggs are dark yellow and cylindrical. Larvae are C-shaped with white to yellow-brown bodies and dark brown head capsules. Pupae are creamy white and up to 4½ mm long. Adults are a mottled brown and covered with erect grayish hairs that make them appear shaggy. Adults are typically 4-5 mm long and have short, broad snouts.

Microlarinus lareynii: a) larva in fruit (L.L. Berry, www.bugwood.org), b) adult (Jennifer Andreas, Washington State University Extension)

LIFE CYCLE: Adults emerge in spring and feed on puncturevine stems, leaves, and flowers. Females chew pits in young fruits and lay eggs before sealing the pit with a dark cement. Hatching larvae feed on seeds and fruit tissue, developing through four instars. They pupate within their feeding cell inside attacked fruits. New adults typically emerge within five days; the period from egg to adult frequently takes 25-30 days. In warm climates, many generations can be produced throughout a growing season, typically one generation per month.

DAMAGE: Larval feeding destroys seeds and may induce seed abortion, though the damaging spines of fruits still develop. Adult feeding is usually insignificant.

PREFERRED HABITAT: Distribution and abundance are limited by cold weather.

HISTORY: Introduced from Italy and released on puncturevine in the USA from 1961 (CA, CO, ID, MT, NV, OR, UT, WA, WY). After initial releases failed to establish in some cold climates, a second population from the Abruzzi Mountains, Italy, was released in more northern areas of CA but failed to establish. A population from CO (USA) was redistributed to CAN (BC) in 1986, but failed to establish.

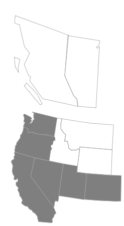
CURRENT STATUS: Established with variable densities on puncturevine in the

Microlarinus lareynii: c) adult feeding scars (Jennifer Andreas, Washington State University Extension), d) adult inside attacked fruit (Eric Coombs, Oregon Department of Agriculture, www.bugwood.org)

USA. In combination with *Microlarinus lypriformis,* it successfully reduced weed cover and seed production up to 80% in warmer areas of the southwest USA, especially CA. It is generally ineffective at higher elevations and latitudes where cold winter temperatures reduce weevil populations. Recent redistribution efforts within CA successfully established a population at one high elevation site, indicating establishment is possible if sites have overwintering shelter and low disturbance. Populations are limited by parasites and predators at some sites.

REDISTRIBUTION: Adults can be collected in fall or spring in the heat of the day from the soil litter beneath plants using a vacuum or aspirator. Alternatively, infested plants and soil litter can be collected in paper bags or cardboard boxes and left in the sun for a short period of time. Any adults present will climb the walls of the container, allowing for easier collection. Adults (without plant material) should be transferred in groups of 100-200 to warm climates or sites with sufficient overwintering shelter and limited disturbance. **They should not be released where native *Kallstroemia* species occur.** Establishment can be monitored the following growing season by observing adults beneath puncturevine foliage during the heat of the day, or finding signs of attack.

NOTES: *Microlarinus lareynii* is slightly larger and has a more tear-shaped body than the similar *M. lypriformis*. *M. lareynii* is much more successful at high elevation sites compared to *M. lypriformis*, and is established in limited amounts in WA and OR whereas *M. lypriformis* is not, indicating a higher cold tolerance by *M. lareynii*. **Also attacks the native *Kallstroemia californica*, *K. grandiflora,* and one additional native *Kallstroemia* species. Adults have been found on numerous exotic species (some of economic importance), though impact is typically negligible.**



Microlarinus lypriformis (Wollaston)

Puncturevine stem weevil

DESCRIPTION: This species is very similar to *Microlarinus lareynii.* Eggs are dark yellow and cylindrical. Larvae are C-shaped with white to yellow-brown bodies and dark brown head capsules. Pupae are creamy white and up to 4 mm long. Adults are a mottled brown and covered with erect grayish hairs that make them appear slightly shaggy. Adults are typically 4-5 mm long and have short, broad snouts.

Microlarinus lypriformis: a) larva in puncturevine stem, b) adult (both USDA ARS European Biological Control Laboratory, USDA ARS - European Biological Control Laboratory, www.bugwood.org)

LIFE CYCLE: Adults emerge in spring and feed on puncturevine stems and leaves. Females chew pits into the root crown or on undersides of stems and lay eggs inside. Hatching larvae mine the stems and root crowns, developing through four instars. They pupate within the stem mines. New adults typically emerge within five days from exit holes in the stems or root crown. The period from egg to adult frequently takes 25-30 days. In warm climates, multiple generations can be produced throughout a growing season, typically one generation per month.

DAMAGE: Larval mining consumes vascular tissue, weakening the plant and often causing stem breakage. This, in turn, reduces the vigor and reproductive output of attacked plants. Adult feeding is usually insignificant.

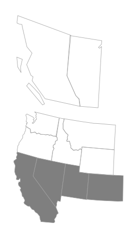
PREFERRED HABITAT: Its distribution and abundance are limited by cold weather.

HISTORY: Introduced from Italy and released on puncturevine in the USA from 1961 (CA, CO, ID, MT, NV, OR, UT, WA, WY). After initial releases failed to establish in some cold climates, a second population from the Abruzzi Mountains, Italy, was released in more northern areas of CA but failed to establish. A population from CO (USA) was redistributed to CAN (BC) in 1986, but failed to establish.

CURRENT STATUS: Established with variable densities on puncturevine in the USA. In combination with *Microlarinus lareynii,* it successfully reduced weed cover and seed production up to 80% in warmer areas of the southwest USA, especially CA. It is generally ineffective at higher elevations and latitudes where cold winter temperatures reduce weevil populations. Recent redistribution efforts within CA successfully established a population at one high elevation site, indicating establishment is possible if sites have overwintering shelter and low disturbance. Populations are limited by parasites and predators at some sites.

REDISTRIBUTION: Adults can be collected in fall or spring from the soil litter beneath plants using a vacuum or aspirator. Alternatively, infested plants and soil litter can be collected in paper bags or cardboard boxes and left in the sun for a short period of time. Any adults present will climb the walls of the container, allowing for easier collection. Adults (without plant material) should be transferred in groups of 100-200 to warm climates or sites with sufficient overwintering shelter and limited disturbance. **They should not be released where native *Kallstroemia* species occur.** Establishment can be monitored the following growing season by observing adults beneath puncturevine foliage during the heat of the day, or by dissecting stems and root crowns to find mining larvae.

NOTES: *Microlarinus lypriformis* is slightly smaller and has a less tear-shaped body (more symmetrical) than the similar *M. lareynii*. *M. lypriformis* is much less abundant at high elevation sites compared to *M. lareynii*, and is not established in WA and OR whereas *M. lareynii* is, indicating *M. lypriformis* has a lower cold tolerance. **Also attacks the native *Kallstroemia californica, K. grandiflora,* and one additional native *Kallstroemia* species. Adults have been found on numerous exotic species (some of economic importance), though impact is typically negligible.**



Tansy ragwort

Jacobaea vulgaris Gaertn.

SYNONYMS: ragwort, tansy, stinking Willy; *Senecio jacobaea* L.

ORIGIN: Native to Europe, Siberia, and Asia. Likely introduced to North America in contaminated ship's ballast; recorded as early as 1850s.

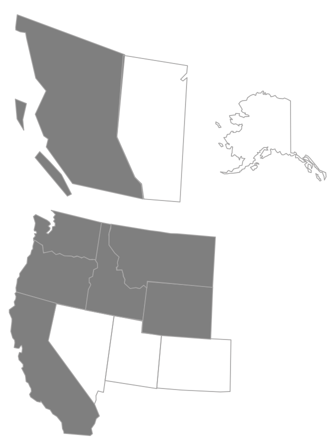
DESCRIPTION: Upright, herbaceous biennial (winter annual or short-lived perennial under certain conditions). Typically grows 1-3 ft tall (⅓-1 m) from one to several soft, fleshy roots. Leaves are deeply lobed to pinnately toothed, alternate, and 3-8 in long (7½-20 cm). Stems arise singly or in clumps and branch near the top with multiple inflorescences. Flower heads consist of yellow disc (center) and ray (outer) florets. Ray flowers (usually 13) resemble petals and grow ⅓-¾ in long (8-20 mm) long. Seeds are topped by a fine pappus.

HABITAT: Especially problematic in open and/or disturbed rangeland, generally with moist soils.

a) plant (Jennifer Andreas, Washington State University Extension), b) infestation (Marianna Szucs, Colorado State University)

c) rosette (Jennifer Andreas, Washington State University Extension), d) stem leaf (Marianna Szucs, Colorado State University), e) flower head (Strobilomyces)

ECOLOGY: Spreads only by seed, which can be dispersed short distances by wind and longer distances by humans, other animals, and water. Seeds produced from both types of florets may remain viable in the soil for up to eight years. The life history varies depending on climatic conditions, with two life cycles predominant in western North America. In the Pacific Northwest, the plant typically acts as a biennial. Rosettes develop and put on considerable growth during the winter with bolting occurring early the following spring. Flowering may occasionally occur the first year, but is usually delayed until the second. Flowering occurs from July to September. In the shorter growing seasons of the Intermountain West, the plant may behave as a short-lived perennial. Seed germination typically begins in spring. Seedlings increase in size throughout the summer, and only the largest successfully overwinter. Bolting typically occurs early the following summer, and flowering takes place from July to October. Cutting or mowing the plant in the either climate may cause it to grow as a perennaial.



APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Botanophila seneciella, Longitarsus jacobaeae,* and *Tyria jacobaeae* (which is no longer permitted for interstate transport); CAN: *B. seneciella, Cochylis atricapitana, L. jacobaeae,* and *Tyria jacobaeae*

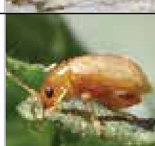
NOTES: The entire plant is toxic to livestock, causing irreversible liver damage.

Tansy Ragwort Biological Control

HISTORY IN THE NORTHWEST: Following a series of lengthy and involved host specificity testing, in 1959 the cinnabar moth, *Tyria jacobaeae*, became the first agent approved and released in North America against tansy ragwort. Though this defoliating moth proved effective at reducing tansy ragwort stands at some locations in the Northwest, the tansy ragwort biocontrol program continued to expand. By 1969, two additional species had been approved for release in both the USA and Canada: *Botanophila seneciella* and *Longitarsus jacobaeae.* In 1990, *Cochylis atricapitana* was approved and released only in Canada.

CURRENT STATUS: *B. seneciella* is moderately abundant in CA, ID, MT, OR, WA (USA), and limited in abundance in BC (CAN). In both countries, it is susceptible to resource competition with the other established agents so is often restricted to small relic populations of tansy ragwort that are less desired by the other agents. It attacks 5-10% of early seed heads; later-developing capitula generally escape attack. *B. seneciella* is unable to control the weed alone. *C. atricapitana* has only established in coastal BC where populations remain limited. Though mining can suppress flower production and plant growth, the low populations likely make overall impact minor. The Italian CPNW strain of *L. jacobaeae* is well established in low-elevation coastal sites in CA, OR, WA and BC where it has proven highly effective in controlling tansy ragwort. The Italian CAD strain is established at colder high elevation sites in OR and MT where it provides local control. The Swiss strain is rapidly increasing in ID and MT at cold sites with heavy snowpack where it provides local control. It remains unknown if recent attempts to redistribute the Swiss strain to BC were successful. *T. jacobaeae l*arvae often cause extreme defoliation to tansy ragwort in CA, MT, OR, WA and BC where populations are typically abundant. In mild climates, plants often recover. At sites with harsh, early winters, frost kills regrowth so plants never fully recover and impact can be high. **Due to observed nontarget attack, interstate transport of *T. jacobaeae* is not permitted in the USA, and some states have prohibited its redistribution within their borders.**

RECOMMENDATIONS: USA: *B. seneciella* has overall low attack rates and is hindered by competition with other agents. Can be utilized as low priority for small, remote populations not desired by other agents and where alternative control methods are difficult to apply. ***T. jacobaeae* is no longer approved for interstate transport, and some intrastate redistribution is banned as well.** Redistributions in approved locations should only be done in areas with cold, early winters, and where nontarget species do not co-occur. In such places, larvae can be transferred during the growing season. *L. jacobaeae* is the most effective of established agents, providing excellent control of tansy ragwort at many sites throughout its invaded range in the Northwest. Three strains are present in the USA with each preferring different climatic conditions. Additional redistributions of adults are recommended throughout the growing season, with emphasis placed on distributing the different strains to the appropriate habitats. ***C. atricapitana* is not approved for release in the USA.** CAN: *B. seneciella* and *C. atricapitana* are both limited in abundance and overall impact and are a low priority for redistribution. Similar to the USA, *B. seneciella* can be utilized in small, remote infestations without other agents present. Plants infested with *C. atricapitana* can be transferred in spring to provide small, localized impact in coastal habitats. *T. jacobaeae* has to date had only minor overall impact in Canada so is also a low priority. Larvae should only be redistributed to areas with harsh, early winters. *L. jacobaeae* is the most effective agent established in Canada and a high priority for continued redistribution. The strain currently established is effective at low-elevation, coastal sites. It is unknown if the Swiss strain successfully established, but additional emphasis should be given to moving this strain to colder, high-elevation sites of the interior. Adults can be transferred throughout the growing season.

Agent	Adult	Impact	Recommendation
Botanophila seneciella		Attacks 5-10% of early capitula only. Due to resource competition, restricted to small weed populations less desired by other agents.	Low impact alone and poor competitor. Low priority for redistribution, except remote populations where difficult to employ other methods.
Cochylis atricapitana		Stem-mining stunts growth, reduces flower production. Populations small and only coastal. Overall impact unknown, likely limited.	Not released in USA. In CAN, not high priority, but can contribute to control in coastal habitats. Transfer infested plants in spring.
Longitarsus jacobaeae		Foliage-feeding, root-mining weaken and kill plants. 3 strains cause heavy impact in different habitats. Most effective agent established.	High priority for redistributing different strains to most appropriate habitats to optimize control. Transfer adults throughout season.
Tyria jacobaeae		Larvae cause extreme defoliation. Plants can recover in mild climates. At cold, harsh sites, frost prevents recovery, killing plants.	Interstate transport no longer legal in USA. In CAN, larvae should be redistributed only to sites with harsh, early winters.

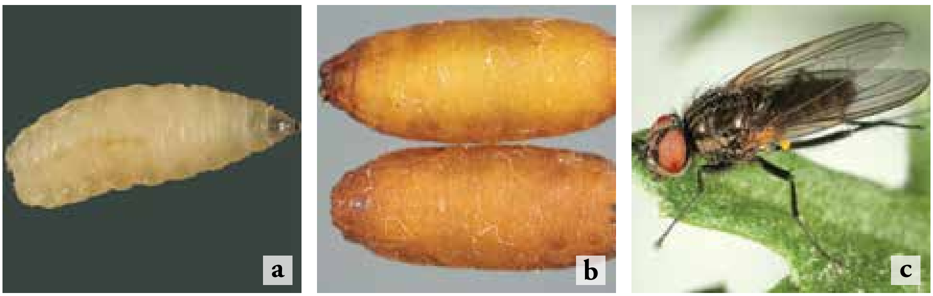
Botanophila: © Malcolm Storey, www.bioimages.org.uk, *Cochylis:* © Geoff Riley, *Longitarsus*: Marianna Szucs, Colorado State University, *Tyria*: Mark Schwarzländer, University of Idaho

Botanophila seneciella (Meade)

Ragwort seedhead fly

SYNONYMS: *Hylemyia seneciella* (Hardy), *Pegohylemyia seneciella* (Meade)

DESCRIPTION: Eggs are small, oval in shape, and off -white in color. Larvae (maggots) are creamy white and narrowed at one end. Late instar larvae can be up to 6 mm long. Pupal chambers are barrel-shaped and brown. Adults resemble house flies with reddish eyes, dark bodies, and slightly clouded wings that extend beyond their body. They are up to 6 mm.



Botanophila seneciella: a) larva, b) pupae, c) adult (a-c © Malcolm Storey, www.bioimages.org.uk)

LIFE CYCLE: Pupae overwinter in loose soil or litter. Adults emerge in spring when tansy ragwort is in the rosette to late bolting stage. Adults lay eggs in young flower buds in late spring and early summer. Hatching larvae burrow into capitula and feed on developing seeds (one larva per seed head). Attacked seed heads are easily identified—initially by a brown discoloration as florets die and later by the presence of frothy spittle. Final (third) instar larvae exit seed heads in late summer, leaving behind characteristic exit holes, and pupate in the soil where they overwinter in puparia. There is one generation per year.

DAMAGE: Larval feeding destroys some or all seeds within attacked seed heads. Seed consumption does not kill existing plants, but does help reduce the rate of spread of ragwort populations.

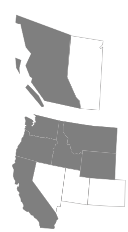
PREFERRED HABITAT: Does well in meadows and forest clearings. Where it is established alongside the cinnabar moth, the ragwort seed head fly is often restricted to scattered tansy ragwort plants growing in habitats less suitable to the moth (e.g. shaded forests or narrow mountain valleys).

HISTORY: Introduced from France and released in the USA (CA, OR, WA) from 1966. Redistributed from CA to BC (CAN) from 1968.

Botanophila seneciella: d) infested seed head, e) spittle on infested seed head (d,e Jennifer Andreas, Washington State University Extension), f) exit hole (Marianna Szücs, University of Idaho)

CURRENT STATUS: Moderately abundant in the USA. Infestation rates of up to 40% of available capitula have been documented in small, isolated tansy ragwort populations, though 5-10% attack rates are more typical. Only early seed heads are utilized; later-developing capitula generally escape attack. This agent is susceptible to resource competition from *Tyria jacobaeae,* which also consumes tansy ragwort seed heads, as well as tansy ragwort mortality caused by *Longitarsus jacobaeae*. Consequently, though the ragwort seed head fly is the most widely distributed, it is usually the least abundant and least effective of the three agents established in the USA. Widely distributed in Canada though abundance is low. Populations are often restricted to small relic populations of weed less desired by other biocontrol agents. Unable to control the weed alone, but contributes to partial control in combination with *Longitarsus* spp. and *Cochylis atricapitana*.

REDISTRIBUTION: Sweeping adult flies is possible, though may be damaging. Moving bouquets of fly-infested seed heads into uninfested patches is effective, but this may inadvertently spread new tansy ragwort seeds (from potentially different genotypes) and make the tansy ragwort problem worse. The safest method is to collect pupae. Bouquets of infested plants can be placed in flasks of water (small-mouth jars prevent emerging maggots from falling in the water and drowning). Flasks are placed in open buckets amid a thick layer of very fine sand or loose peat moss during late summer. Maggots exiting seed heads will burrow into the sand to pupate. Sand can be stored at 4-8 °C (39-46 °F) to overwinter and then be placed into uninfested patches of tansy ragwort in early spring. Establishment can be monitored the following season by dissecting capitula to find feeding larvae or observing frothy spittle on infested seed heads.



Cochylis atricapitana (Stephens)

Ragwort stem and crown boring moth

DESCRIPTION: Larvae are creamy white to tan with small black heads and can be up to 8 mm long. Pupae are yellowish-brown, 7-8 mm long, and enclosed in a white cocoon. Adults are small and tent-winged with a wingspan of 7-16 mm. The forewings have irregular brown marks flecked with black and grey on a white or yellowish-white background. Females are more pink than males. A tuft of dark-colored scales extends from behind the head.

Cochylis atricapitana: a) larva in rosette, b) adult (© Geoff Riley), c) feeding damage (a,c © Province of British Columbia. All rights reserved. Reproduced with permission of the Province of British Columbia)

LIFE CYCLE: There are 2-3 generations per year. Overwintering larvae resume activity in spring, feeding on tansy ragwort stems and root crowns. through five instars. Pupation occurs either in the stem or in surrounding soil litter. Adults emerge in late spring as tansy ragwort is bolting and lay creamy-white eggs on the crown or on the underside of tansy ragwort leaves. Hatching larvae mine leaves and petioles while older larvae mine stems and roots crowns. Pupation of the new generation occurs in the plant. Emerging adults lay eggs in similar locations in mid to late summer. Newly hatching larvae may overwinter, or a third generation may emerge from eggs laid in autumn and overwinter in plant stems.

DAMAGE: Larval mining suppresses flower formation, stunts plant growth, and may kill plants outright.

PREFERRED HABITAT: Adapted to a wide variety of habitats where tansy ragwort grows, including high elevations and sites with early winters, but is to date established best in more mild coastal zones.

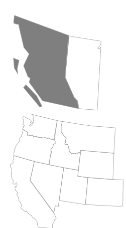
HISTORY: Introduced from Spain via Australia and released in Canada from

1990 (BC from 1991).

CURRENT STATUS: Established in BC (CAN), but populations are small and restricted to coastal regions; introductions into interior climates failed. Though this moth likely contributes to partial control with *Longitarsus* spp., formal evaluation of its impact is lacking.

REDISTRIBUTION: Adults can be collected at night with the use of a black light; however, sufficient numbers can be difficult to find. Consequently, it is easier to redistribute larvae. Infested plants can be dug up and transferred to new sites in groups of 50 during spring, prior to flower maturation. Transplanting in fall is typically less successful for the agent, and also creates the risk of spreading tansy ragwort seeds (from potentially different genotypes) which may make the tansy ragwort problem worse. Establishment can be monitored throughout the following season by dissecting stems and root crowns to find larvae. Note that early instar larvae feeding in the root crown may be easily confused with *Longitarsus jacobaeae* larvae.

NOTES: **This agent is not approved for release in the USA.**



Longitarsus jacobaeae (Waterhouse)

Tansy ragwort flea beetle

DESCRIPTION: There are three strains of *L. jacobaeae* presently established in the USA: two Italian and one Swiss. All strains are morphologically identical. Eggs are small (<1 mm diameter) and whitish-yellow, turning orange with maturity. Larvae are white and may be 1-4 mm long. Last instar larvae have brown head capsules. Pupae are white and 2-4 mm long. Adults are golden brown, 2-4 mm long, and have enlarged hindlegs.

Longitarsus jacobaeae: a) eggs and hatching larva (Ken Puliafico, Montana State University), b) late instar larva (Eric Coombs, Oregon Department of Agriculture), c) pupa (Laura Parsons, University of Idaho)

LIFE CYCLE: The three strains established in the USA differ genetically and in the timing of various stages in their life cycles. All strains have one generation per year, and larvae develop through three instars. Populations established in Canada are aligned with the Italian CPNW strain.

Italian CPNW strain: At low elevations in the Coastal Pacific Northwest (CPNW), adult beetles emerge in late spring and feed briefly on tansy ragwort rosettes before becoming dormant for the summer. Adult beetles become active again and feed on tansy ragwort foliage in the cooler/wetter fall. After 2-3 weeks of feeding, adults mate and females lay eggs around the bases of ragwort rosettes, sometimes laying eggs until early spring. Larvae hatch a couple weeks after eggs are laid and mine the leaf petioles and then root crowns of rosettes throughout winter and early spring. In spring, larvae leave root crowns to pupate in the soil.

Italian CAD strain: A cold-adapted strain of the Italian beetle (CAD) is established in lower numbers at high elevation sites in OR (USA) and the Intermountain West of the North America. At these locations, larvae do not aestivate; they continue feeding throughout summer. Pupation occurs in the soil in summer, and adults emerge soon after, laying eggs by late summer/early autumn. Eggs and larvae overwinter.

Swiss strain: Adult beetles emerge in mid- to late summer and feed on tansy ragwort foliage for 2-3 weeks prior to laying eggs around the bases of rosettes.

Longitarsus jacobaeae: d) adult (Marianna Szucs, Colorado State University), e) adult feeding damage, f) larvae in roots (e,f Jeff Littlefield, Montana State University)

Egg laying may extend into early fall. Eggs overwinter, requiring at least 60 days (80 is optimal) before hatching in the spring. Larvae feed at first in tansy ragwort leaf petioles prior to moving into the root crown. Pupation occurs in the soil in late spring or early summer.

DAMAGE: Adult feeding results in characteristic shot-holes in leaves (typically rosette leaves rather than those of bolting plants). This interferes with photosynthesis and plant metabolism and may decrease the size of tansy ragwort plants. When beetle populations are high and plants are water-stressed, adult feeding can cause plant death, especially to seedlings and rosettes. The larval stage is generally the most destructive. Larval mining of the root crown depletes energy reserves, can reduce plant reproductive output, or cause death.

PREFERRED HABITAT: All strains do better in dense, unshaded tansy ragwort infestations. Flooding interferes with the larval and pupal stages so tansy ragwort infestations in floodplains are less amenable to biological control by this agent. The Italian CPNW strain is best suited for low elevation sites (at or below 400 m or 1,300 ft) with climates characterized by warm summers and mild, moist winters. The Italian CAD strain is hardier than CPNW populations and can survive at higher elevations (1,000-1,600 m or 3,200-5,200 ft). The Swiss strain does well at elevations higher than 400 m (1,300 ft) characterized by warm summers and cold winters with hard frosts and snow cover. It may be found up to 1,675 m (5,500 ft).

HISTORY: Introduced from Italy and released in the USA from 1968 (CA, MT, OR, WA) where it established at low-elevation coastal sites. A cold-adapted strain of this release was later identified by University of Idaho researchers and determined to occur at high elevation sites in OR and the Intermountain

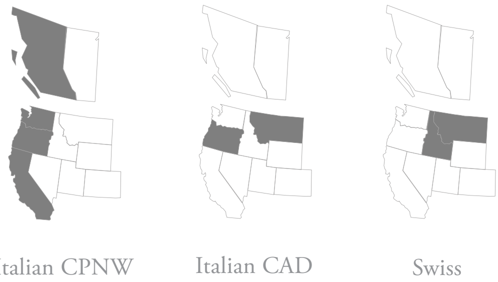
Longitarsus jacobaeae continued

West. A population from Switzerland was released in CA in 1969, but failed to establish. A second Swiss strain was successfully introduced to ID, MT, OR from 2002 to increase establishment in infestations with colder climates. Italian CPNW beetles CA and OR, USA were redistributed to BC, Canada from 1971 and 1976, respectively. A small population from England was also released in BC in 1972. The three different release populations were later not differentiated and redistributed (likely as a mix) throughout BC and to other provinces. A strain from Switzerland was released in BC in 1973 but failed to establish. The Swiss strain that successfully established in the USA in 2002 was redistributed to BC in 2011 in an attempt to increase efficacy in cold habitats.

CURRENT STATUS: The Italian CPNW strain is established in high numbers at low-elevation, coastal locations characterized by warm, dry summers and mild, wet winters. There it has reduced tansy ragwort densities by over 90% at numerous sites. The Italian CAD strain is established in low numbers at high-elevation sites at Mt. Hood OR and in MT where it has heavy impact. The Swiss strain is better suited to climates where the Italian CPNW strain does poorly (inland, colder regions with heavy snowpack). It is rapidly increasing at release sites in the USA though populations are still limited. The strain established in Canada is abundant in cool coastal climates. Establishment failed or is very limited at interior sites. Where populations are large, the beetle controls tansy ragwort well in conjunction with other biocontrol agents. It remains unknown whether the recent attempted release of the Swiss strain successfully established in Canada.

REDISTRIBUTION: Best collected in the adult stage either via sweeping (with or without an aspirator) or with an insect-collecting vacuum. Utilizing a sieve to sift beetles from debris helps make sorting easier. The Italian CPNW strain is best collected in the fall, while both the Italian CAD strain and the Swiss strain can be collected in late summer. All can be transferred to new infestations in groups of 200. **Four non-approved *Longitarsus* species have been identified in mixed populations of *L. jacobaeae* in Canada, and one of these in the northwestern USA. Care should be taken in redistributing this species to ensure only *L. jacobaeae* is collected.** (See page 182 for additional information.) Establishment can be monitored the following year by observing adults on ragwort foliage along with the characteristic shot-hole feeding. Adults of the Italian CPNW strain can be observed in early summer and the fall/early winter. Adults of the Italian CAD strain can be observed in fall. Adults of the Swiss strain can be observed throughout summer. Alternatively, plants can be dissected for evidence of larval feeding. Italian CPNW larvae can be found from fall through spring. Italian CAD larvae can be found from fall through the next summer, and the Swiss strain larvae can be found in spring and early summer. Note that larvae feeding within root crowns may be confused with early instar larvae of *Cochylis atricapitana*.

NOTES: Works well in conjunction with *Tyria jacobaeae*.



Tyria jacobaeae (L.)

Cinnabar moth

DESCRIPTION: Eggs are small (1 mm) and bright yellow when new, but turn black with age. First instar larvae are light brown or orange, while instars 3-6 are banded orange and black. Mature larvae are up to 25 mm long. Adults have black forewings with two red dots and red-lined borders. Hind wings are bright red. Wingspans may be up to 4 cm, and coloring often fades with moth age.

Tyria jacobaeae: a) eggs (Jeff Littlefield, Montana State University), b) early instar larvae (George Markin, U.S. Forest Service), c) late instar larva (Mark Schwarzländer, University of Idaho)

LIFE CYCLE: Pupae overwinter in loose soil or plant litter. Adults emerge in late spring, mate and lay eggs in clusters on the undersides of tansy ragwort rosette leaves. Hatching larvae feed on the undersides of rosette leaves. As plants bolts, later instar larvae feed on stem leaves and developing buds, often in groups of 10-30. Final (sixth) instar larvae leave plants in late summer and pupate in suitable locations before overwintering. There is one generation per year.

DAMAGE: Larvae may completely defoliate tansy ragwort plants, leaving behind only bare stems. In milder climates plants can recover. In colder, harsher climates, frost kills ragwort regrowth before plants can fully recover.

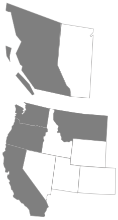
PREFERRED HABITAT: This species does best in warm, sunny areas with dense tansy ragwort infestations. It is less successful in shady habitats, narrow canyons, saturated soils, locations with harsh winters and little protective snow cover, or over-grazed areas. Because pupae overwinter in shallow soil or plant litter, they are highly susceptible to trampling or predation by rodents or other insects.

HISTORY: Introduced from France and released in the USA (CA, MT, OR, WA) from 1959. Introduced from Switzerland and released in BC (CAN) from 1962. A second introduction was made in Canada in 1966 (BC in 1967) using material from the USA, though this failed to establish.

Tyria jacobaeae: d) pupa (George Markin, U.S. Forest Service), e) adult (Mark Schwarzländer, University of Idaho), f) larvae feeding gregariously (Jeff Littlefield, Montana State University)

CURRENT STATUS: Populations fluctuate in the USA. High densities often completely defoliate plants. In mild regions of CA, OR, WA the weed often re-grows and recovers sufficiently to successfully overwinter and reproduce. In the colder, harsher Intermountain West, frosts usually kill regrowth before plants fully recover so the moth is more effective at reducing weed populations. Widespread in Canada (BC) though overall impact is typically minimal. Its complete defoliation of tansy ragwort can lead to decreased winter survivorship and decreased seed production in some locations at some times. However, ragwort populations persist in all major infested areas despite even high cases of defoliation. Weather-induced fluctuations of the weed tend to control insect populations rather than the insect controlling the weed.

REDISTRIBUTION: Best collected in the larval stage by tapping or shaking plants over an open pan throughout the growing season. Larvae can be transferred to new sites in groups of 50-100. Establishment can be monitored the following year by observing feeding larvae throughout the growing season. **Due to observed nontarget attack, interstate transport is not permitted in the USA, and some states have prohibited its redistribution within their borders. Where this agent is approved for redistribution, it is imperative to refrain from making releases at sites where known related or susceptible species co-occur.**



NOTES: *T. jacobaeae* complements the effect of *Longitarsus jacobaeae.* The conspicuous colors of *Tyria* larvae serve as warnings to potential predators. Larvae are capable of sequestering alkaloids from their host for use as toxic defenses against birds and other animals.

Tansy Ragwort, Unapproved Agents

Longitarsus spp.
(Acari: Eriophyidae)

Adult *L. flavicornis:* (Mark Schwarzländer, University of Idaho)

DESCRIPTION AND LIFE CYCLE: The accidental or adventive tansy ragwort flea beetles (*L. flavicornis, L. ganglbaueri, L. gracilis*, and *L. succineus*) very closely resemble and are frequently mistaken for *L. jacobaeae*, especially *L. flavicornis* which differs only in the size of the male genitalia. Though less is known about the biology of the latter three flea beetles, *L. flavicornis* is a highly studied and successful tansy ragwort biological control agent in Australia. It has one generation per year. Larvae mine the petioles, lower leaves, and then root crowns of tansy ragwort where they overwinter. Larvae develop through three instars. They are white with brown head capsules, and may be 1½-4 mm long. Pupation occurs in the soil in late spring or early summer. Pupae are white and 2-4 mm long. Adults emerge in early summer, feed on tansy ragwort leaves, and lay small yellowish eggs (<1 mm diameter) at the base of ragwort rosettes in late summer. Adults are coppery brown and 2½-3½ mm long. They have fully developed wings and are capable of flight, though they more often utilize their enlarged hindlegs to jump. Newly hatching larvae feed on ragwort stems, root crowns, and roots where they overwinter; occasionally the egg stage overwinters in Canada.

HISTORY AND CURRENT STATUS: Since the 1970s, four species of *Longitarsus* have been observed in Canada as either adventive species or as successfully established populations after accidental introductions in contaminated releases of *L. jacobaeae*, likely from Europe. *Longitarsus flavicornis* was initially reported as established only on Vancouver Island in mixed populations with *L. jacobaeae* where it reportedly had limited impact on the weed. Additional evaluation is needed to confirm its presence. *Longitarsus ganglbaueri* is only present in limited numbers in MB and NS, Canada, but has reportedly been documented at some point in the USA in CA, OR, WA. Its current status remains unknown. *Longitarsus gracilis* was identified in NS, Canada, most likely inadvertently introduced in mixed shipments of *L. jacobaeae* from Europe. What was believed to be a population of *L. jacobaeae* was redistributed from NS to BC in 2005. Subsequent monitoring of the BC release site yielded only *L. gracilis.* The species is considered well-established at one site in the Okanagan Valley in

BC. *Longitarsus succineus* is established only in NL, Canada. **These four flea beetles are not recommended for redistribution in Canada or the USA due to their broad host range. Care should be taken to ensure adults or eggs of these unapproved species are not accidentally collected. Check with your local biological control experts for help with identifying flea beetle species.**

Rush skeletonweed

Chondrilla juncea L.

SYNONYMS: skeleton weed, hogbite, nakedweed, gum succory

ORIGIN: Inadvertently introduced into the eastern United States in the 1870s.

DESCRIPTION: Herbaceous perennial usually growing 1-4 ft tall (⅓-1.2 m) and having a rhizomatous root system. Rosettes have deeply lobed leaves. Plants produce multiple stems that are wiry and rigid with alternate, very narrow leaves. The plant has an overall skeleton appearance. Bottom portions of stems are covered with stiff, golden-reddish and downward pointing hairs. Flower heads are ½ in across (1 cm) and consist of 9-12 yellow florets that produce seeds without fertilization. Seeds are small, brown, and topped by tufts of pappus. All parts of the plant exude a milky latex when damaged.

HABITAT: A serious weed of roadsides, rangeland, abandoned cropland, and

a) plant (Rachel Winston, MIA Consulting), b) infestation (Laura Parsons, University of Idaho)

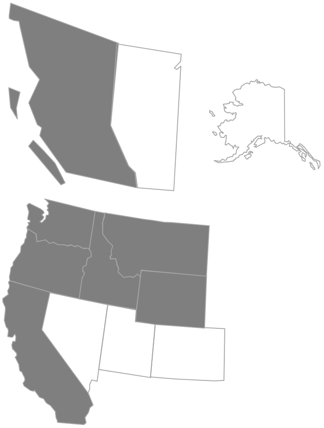
c) rosette leaves (Richard Old, XID Services, Inc, www.xidservices.com, www.bugwood.org) d) stem hairs, e) flower head (both Rachel Winston, MIA Consulting,)

disturbed places. It does best in semiarid conditions with cool, moist winters and warm summers without extensive drought, and in well-drained soils.

ECOLOGY: Spreads by seed and rhizomes. Seeds are readily carried by wind, water, wildlife and human activity. Root pieces less than ½ in long (1 cm) can develop into new plants. Rosettes develop from fall through spring; plants bolt in spring. Flower heads bloom in late summer.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Aceria chondrillae, Bradyrrhoa gilveolella, Cystiphora schmidti,* and *Puccinia chondrillina;* CAN: *B. gilveolella.*

NOTES: Seven genotypes of this weed are recognized in North America; five in the West and two on the East Coast. Two of the genotypes occurring in the West also occur in Midwestern and Eastern North America. Some biocontrol agents behave differently depending on the genotype of the attacked weed. See the following pages for a map of known rush skeletonweed genotypes in western North America.

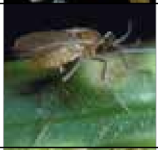


Rush Skeletonweed Biological Control

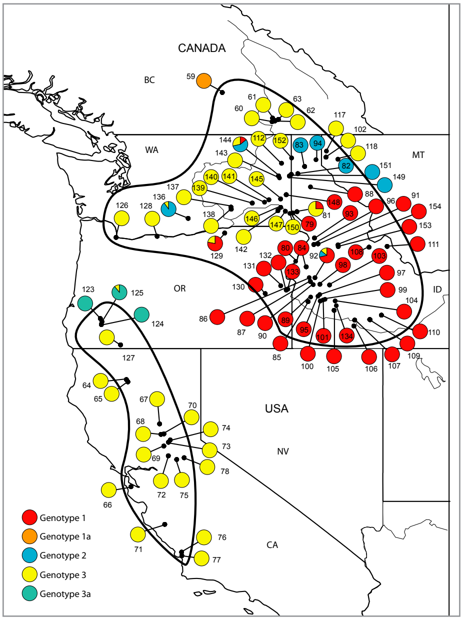
HISTORY IN THE NORTHWEST: Rush skeletonweed is a problematic weed in numerous parts of the world. The call for biological control of this weed first began in Australia in 1936, though the first biocontrol agent was not released there until 1971. To date, a total of one rust fungus, two insects, and one mite species have been released in Australia. The same species were also released in the USA: *Cystiphora schmidti* in 1975, *Puccinia chondrillina* in 1976, *Aceria chondrillae* in 1977, and *Bradyrrhoa gilveolella* in 2002. *B. gilveolella* was intentionally redistributed from the USA to BC (CAN) from 2007 onwards. *A. chondrillae* and *P. chondrillina* spread naturally from the USA to BC.

CURRENT STATUS: *A. chondrillae* is established in CA, ID, MT, OR, WA, WY (USA) where abundance and impact are variable. It reduces flowering and seed production up to 90% in OR and WA, but efficacy is limited in CA due to predation and in ID due to high overwintering mortality. Though it is widespread in BC (CAN), populations are limited and the weed continues to thrive. *B. gilveolella* is confirmed established only in OR and ID (USA) where numbers are increasing at the original release sites. *B. gilveolella* has not officially been confirmed as established in BC (CAN); however, early results look promising and monitoring continues. Additional time is needed in both countries before overall establishment, impact and abundance can be evaluated. *C. schmidti* is established in CA, ID, OR, WA, WY (USA) where infested plants are stunted and produce fewer seeds. Though widespread, populations are limited in abundance due to heavy parasitism and predation. *P. chondrillina* is established in CA, ID, OR, WA, WY (USA) where efficacy varies by weed genotype and site conditions. It is the most effective in WA and CA where it decreases plant size and reproductive output, but is less effective elsewhere, especially hot and dry sites. Though widespread in BC (CAN), overall impact is limited as rush skeletonweed populations are persisting.

RECOMMENDATIONS: USA: High predation and parasitism make *C. schmidti* a low priority for redistribution. *B. gilveolella* is only recently established and additional releases are warranted to help increase populations. These should likely be made from lab colonies as field populations are still limited. *A. chondrillae* and *P. chondrillina* have variable success depending on site conditions and rush skeletonweed genotype. Redistributions of both species should occur at mesic sites (moist for *P. chondrillina*) with mild winters. CAN: Abundance and impact of *A. chondrillae* remain limited. *B. gilveolella* is not yet officially confirmed as established, and additional releases from lab colonies are warranted to increase populations.

Agent	Adult	Impact	Recommendation
Aceria chondrillae		Galling reduces flowering, seed production. Effective at some USA sites. Suffers predation, overwintering mortality elsewhere. Limited in CAN.	Average reduced efficacy makes this only a medium priority for redistribution to mesic sites with mild winters. Not intentional in CAN.
Bradyrrhoa gilveolella		Root- feeding decreases plant vigor, root reserves; kills above-ground portions. Too early to determine impact in USA or establishment in CAN	Additional releases warranted in both USA and CAN. Likely should be sourced from lab colonies as field populations still limited.
Cystiphora schmidti		Galling stunts plants, decreases seed production. Populations typically limited by parasitism, predation.	Due to high levels of parasitism and predation, very low priority for redistribution efforts. Not released in CAN.
Puccinia chondrillina		Rust infection decreases plant size, seed output. Most effective in moist, mesic areas and on certain weed genotypes.	Redistribute in USA to moist sites where genotypes match. Not intentional in CAN where impact low overall.

Credits for photos in table above: *Aceria*, *Cystiphora*: Charles Turner, USDA ARS, www.bugwood.org, *Bradyrrhoa*: Laura Parsons & Mark Schwarzländer, University of Idaho, *Puccinia*: Jennifer Andreas, Washington State University Extension



Rush skeletonweed genotypes in western North America (reprinted with permission from Gaskin, J.F., M. Schwarzländer, C.L. Kinter, J.F. Smith, and S.J. Novak. 2013. Propagule pressure, genetic structure, and geographic origins of *Chondrilla juncea* (Asteraceae): an apomictic invader on three continents. American Journal of Botany 100(9): 1871-1882.)

Aceria chondrillae (Canestrini)

Rush skeletonweed gall mite

SYNONYMS: *Eriophyes chondrillae* (Canestrini)

DESCRIPTION: All stages are tiny and best viewed with a microscope. Nymphs are pale yellow and 0.10 mm long in the first stage. Second stage nymphs are humpbacked, orange, have four legs, and reach 0.17 mm. Adults are worm-like, yellow-orange, and have two pairs of legs. Males are up to 0.18 mm long while females are 0.26 mm.

Aceria chondrillae: a) adult (Charles Turner, USDA ARS), b, c) damage (b Richard Old, XID Services, INC, c Biotechnology and Biological Control Agency) (a,b www.bugwood.org)

LIFE CYCLE: There are multiple generations per year. Overwintering adults attack shoot buds when rush skeletonweed bolts in spring. Feeding leads to the formation of contorted galls; each gall may contain several hundred mites. Females lay 60-100 eggs within the gall they occupy. One generation can be completed in 10-12 days. Mites may spread with wind-dispersed seeds in the fall. Mite populations and galls increase until skeletonweed dies back in the winter.

DAMAGE: Galls induced by mite feeding stunt shoot growth, reduce rosette and seed production, reduce root carbohydrate reserves, and often result in seedling death.

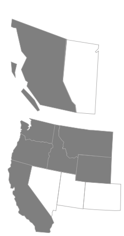
PREFERRED HABITAT: Well adapted to a variety of environmental conditions throughout the Northwest. Rapidly colonizes plants growing in undisturbed, well-drained soils on south- or west-facing slopes. Mite populations do not persist in sites subjected to repetitive soil disturbance, such as cropland. High overwintering mortality occurs in areas with harsh winters and without winter rosettes of rush skeletonweed.

HISTORY: Introduced from Italy and released in CA, ID, OR, WA (USA) from 1977. Spread naturally from the USA to Canada.

CURRENT STATUS: Abundance and impact in the USA are variable. It is widespread in OR and WA where it reduces flowering and seed production by 50-90%, depending on plant size and environmental conditions. Efficacy is limited in CA due to predation and in ID due to high overwintering mortality. Though it is established at multiple locations in BC (CAN), weed populations are persisting. Mite abundance is low and overall abundance is limited.

REDISTRIBUTION: Stems infested with galls can be gathered from late summer through fall. Stems should be placed in direct contact with uninfested stems at new sites (taking care not to spread skeletonweed seeds to new sites as this may introduce new genotypes). As galls dry, mites will relocate to uninfested stems. Establishment can be monitored the following season by observing new galls on growing plants.

NOTES: Different biotypes of the mite show close associations with certain genotypes of rush skeletonweed. **This agent was not an intentional introduction in Canada.**



Bradyrrhoa gilveolella (Treitschke)

Rush skeletonweed root moth

DESCRIPTION: Larvae are 20-25 mm long, off-white, and have brown head capsules. Adults are creamy buff colored and have three brown, horizontal bands on their front wings. They have wingspans up to 28 mm.



Bradyrrhoa gilveolella: a) larva, b) root tunnel, c) adult (all Laura Parsons & Mark Schwarzländer, University of Idaho)

LIFE CYCLE: There are two generations per year in Europe, where adults emerge in spring as rush skeletonweed bolts. Females lay eggs (up to 250 each) on stems or soil near plants. Once in contact with the plant, larvae feed into the stem base, and move downward to attach themselves to the root, feeding on root cortex and spinning feeding tubes made of silk, sand, and frass as they travel. Tubes may be up to 60 mm long and extend to the soil surface as exit chimneys. Pupation occurs in tubes. Adults emerge in late summer and lay eggs. Emerging larvae overwinter in feeding tubes.

DAMAGE: Heavy larval feeding results in death of aboveground plant parts, diminished root reserves, and decreased vigor.

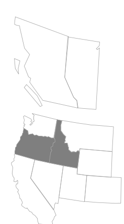
PREFERRED HABITAT: Does best on plants growing in sandy, granitic, or loose-textured soils.

HISTORY: Introduced from Greece and released in CA, ID, OR, WA (USA) from 2002. Redistributed from the USA to BC (CAN) from 2007 onwards.

CURRENT STATUS: In the USA, populations are becoming locally abundant at the original release sites. It is too soon following establishment to determine overall impact. Establishment has not been officially confirmed in Canada, though early results are promising and monitoring continues.

REDISTRIBUTION: Once field populations become larger, adults can be swept from vegetation during the evening in spring and late summer when either generation is peaking. Take care to collect prior to the majority of egg-laying, or redistribution will be fruitless. Also be aware that sweeping can damage these fragile moths. Alternatively, harvest the roots of infected skeletonweed in the fall and store them at 39-46°F (4-8°C). Two to three weeks prior to their normal emergence time, bring them to room temperature in rearing cages or breathable, clear containers. Once they emerge, adults can be transferred to new sites in groups of 25-25. The latter method is only plausible if precise attack symptoms can be recognized. Establishment can be monitored the following year by dissecting stems and roots to observe larvae feeding.

NOTES: Several larvae may feed on the same root simultaneously.



Cystiphora schmidti (Rübsaamen)

Rush skeletonweed gall midge

DESCRIPTION: Larvae are flattened, 1-2½ mm long, and are pink or orange. Adults are light brown and very small, usually 1 to 1½ mm long. Legs are long and delicate. Female abdomens end in a bulbous enlargement.

Cystiphora schmidti: a) larvae (top Eric Coombs, Oregon Department of Agriculture, bottom Gary Piper, Washington State University), b) adult (Charles Turner, USDA ARS) (all www.bugwood.org)

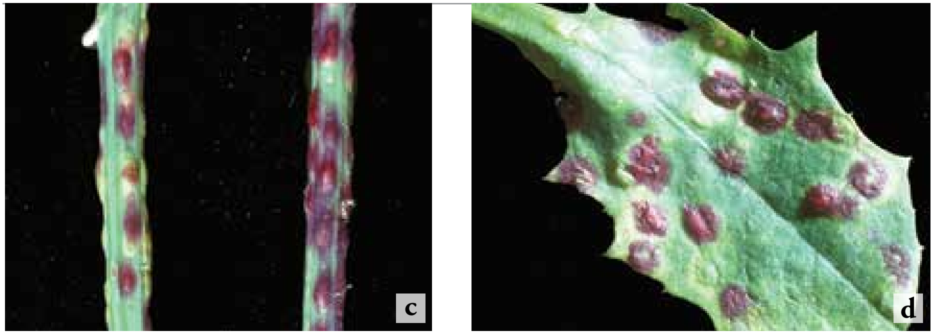
LIFE CYCLE: Adults emerge in spring, and females deposit 60–180 eggs in leaves of rush skeletonweed rosettes. Larvae feed on stem and leaf tissue, inducing the formation of purplish galls. Leaf galls are circular, 3 mm in diameter, and slightly raised, whereas stem galls are elongated and usually more elevated. Pupation occurs within galls with each larva spinning a silky cocoon around itself prior to pupation. Adults emerge from cocoons and galls using pupal head spines, destroying plant tissue in the process. New eggs are laid in stems and stem leaves. There are 4 or 5 generations per year. Larvae or pupae overwinter in galls or soil.

DAMAGE: Attacked tissue is injured or destroyed, leading to fewer branches and flower heads and less viable seeds.

PREFERRED HABITAT: Does best in warm, dry areas and on plants growing in open locations in well-drained soil.

HISTORY: Introduced from Greece via Australia and released in the USA from 1975 (CA, ID, OR, WA).

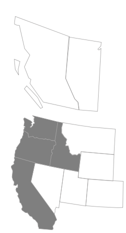
CURRENT STATUS: In the USA, infested plants are stunted and have decreased seed production. Midge populations are generally small, however, being greatly hindered by parasitism and predation.



Cystiphora schmidti: c,d) damage (Gary Piper, Washington State University, www.bugwood.org)

REDISTRIBUTION: Stems infested with *Cystiphora schmidti* galls can be gathered from midsummer through early fall. Stems should be placed in direct contact with uninfested stems at new sites. Many emerging midges will attack the new plants upon emergence. Transferring infested galls may also transfer unwanted parasitoids, other insects, or rush skeletonweed seed from different genotypes. To avoid this, gall-infested stems can be collected and adults reared out indoors. Refer to Additional Considerations in the Introduction for instructions on how to do so. Once they emerge in spring, midges can be transferred to new rush skeletonweed infestations in groups of 50-100. Establishment can be monitored by observing galls on new foliage throughout the following growing season.

NOTES: Attacks all genotypes of rush skeletonweed present in the northwestern USA. **This agent is not approved for release in Canada.**



Puccinia chondrillina (Bubák & Syd.)

Rush skeletonweed rust fungus

DESCRIPTION and LIFE CYCLE: During fall, lesions form at the bases of flowering rush skeletonweed shoots. These form teliospores that overwinter in dormancy. In spring, spores germinate in rosette leaves in clusters of pycnia that yield pycniospores. These lead to aecia and aeciospores on leaves, which germinate to produce uredia and urediospores. Urediospores are the most abundant during the growing season, and are the most distinctive spore. They are round, dark brown, dry and powdery. Urediospores are easily dispersed by both wind and rain, spreading rapidly from plant to plant. Multiple generations are produced per year.

Puccinia chondrillina: a,b) spores on infected leaves (Jennifer Andreas, Washington State University Extension), b) infected rosette (Wendy DesCamp, Washington State Noxious Weed Control Board), c) infected stems (Eric Coombs, Oregon Department of Agriculture, www.bugwood.org)

DAMAGE: Pustules reduce rush skeletonweed photosynthetic capabilities and deplete root nutrient storage, leading to plant weakening and even death. Small rosettes and seedlings are often destroyed by heavy rust infestations. If larger plants are infected sufficiently early in the season, flowering stems are stunted and deformed and produce few viable seeds.

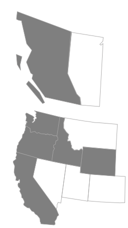
PREFERRED HABITAT: Does best in mesic climates with regular dew periods. Hindered by overly harsh winters that kill infected hosts.

HISTORY: Introduced from Italy and released in CA, ID, OR, WA (USA) from 1976. A different strain was introduced along with its rush skeletonweed host in eastern USA (MD) in an unknown year. The intentionally introduced strain spread naturally from the USA to BC (CAN) by 1976.

CURRENT STATUS: In the USA, efficacy varies by weed genotype and site conditions. It is considered the most effective agent in WA and CA where it decreases plant size and reproductive output. It is less effective in ID and OR. The rust fares poorly on hot and dry sites. One strain is parasitized. Widespread in BC (CAN) where it has been observed stunting and reducing the density of young plants. It is most effective in high moisture areas and in regions where infected overwintering rosettes are not killed by harsh temperatures. Despite being abundant in BC overall impact is considered limited as rush skeletonweed populations are persisting.

REDISTRIBUTION: Should be collected by vacuuming urediospores from infected leaves throughout the growing season, suspending the spores in water, and spraying them on new foliage prior to a dew period. Alternatively, transfer infected stems to new sites in the evening during summer, and spray uninfested plants with water. In fall and spring, whole infected plants can be transplanted to new sites. Take care not to spread rush skeletonweed seeds to new sites as this may introduce new genotypes. Establishment can be monitored by observing pustules on new rush skeletonweed foliage throughout the following growing season.

NOTES: **This agent was not an intentional introduction in Canada.** The three most prevalent genotypes of rush skeletonweed in the western USA differ in their susceptibility to the two different rust strains. Genotype 2 is resistant to both strains, genotype 1 is resistant to one strain but not the other, and genotype 3 is susceptible to both strains.



STARTHISTLE

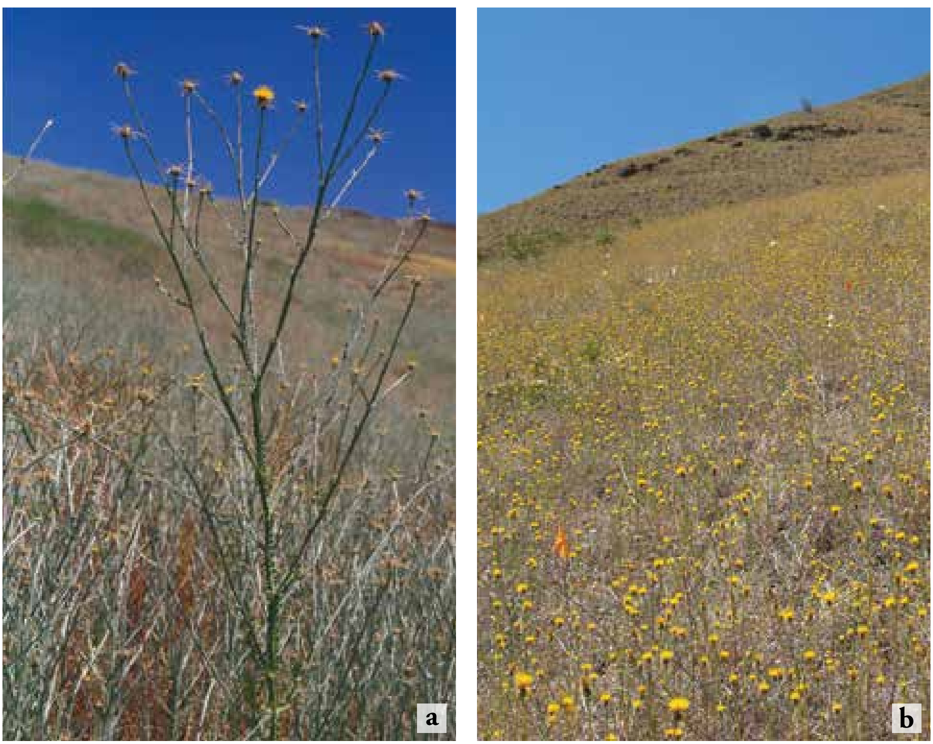
Yellow starthistle

Centaurea solstitialis L.

SYNONYMS: St. Barnaby's thistle

ORIGIN: Introduced from the Mediterranean in the mid-1800s as a contaminant in hay and imported seed.

DESCRIPTION: Winter annual usually growing between ½-6 ft tall (15 cm -1.8 m) and having a deep taproot. Rosettes have deeply lobed leaves. Stems are rigid with alternate, narrow leaves. Stem leaf bases extend down the stem, giving a winged appearance. Both stems and leaves are covered with dense hair, resulting in their characteristic gray-green color. Flower heads consist of numerous bright yellow florets that bloom in midsummer. The base of the flower head is covered with bracts ending in long (up to ¾ in or 2 cm), sharp spines. Two types of seeds are produced: tan-colored plumed seeds from the center, and dark brown unplumed seeds from the periphery.



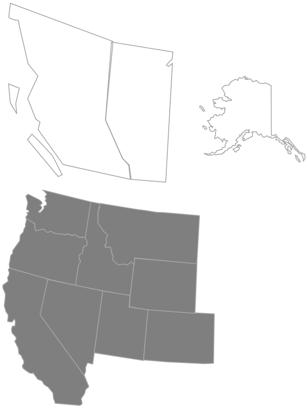
a) plant (Laura Parsons, University of Idaho), b) infestation (Rachel Winston, MIA Consulting)

c) rosette (Steve Dewey, Utah State University), d) winged stems (Rachel Winston, MIA Consulting), e) flower head (Peggy Greb, USDA ARS) (c,e www.bugwood.org)

HABITAT: A serious weed of roadsides, rangeland, abandoned cropland, and disturbed places. It occurs in a variety of soils and conditions but is most common below 4000 ft (1200 m) on south-facing slopes in areas with more than 6 in (15 cm) of rain annually.

ECOLOGY: Spreads only by seed. In Mediterranean climates, germination occurs in fall following autumn rains. Spring germination occurs elsewhere in North America. Rosettes develop from fall through spring; stems bolt in spring and throughout the summer. Seeds are readily transported by water, wildlife and human activity and may remain viable in the soil for up to 10 years.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Bangasternus orientalis, Chaetorellia australis, Eustenopus villosus, Larinus curtus, Puccinia jaceae* var. *solstitialis,* and *Urophora sirunaseva.*



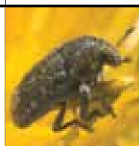
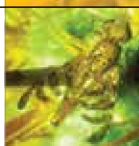
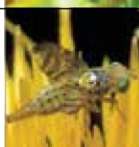
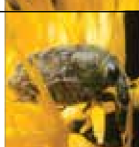
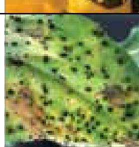
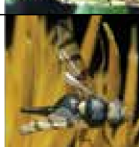
NOTES: Horses feeding on yellow starthistle can develop a fatal nervous disorder called chewing disease. The PLANTS database and other data distribution sources indicate the species is established in AB (CAN). While populations have been found in the past, none have persisted.

Yellow Starthistle Biological Control

HISTORY IN THE NORTHWEST: The USA biocontrol program for yellow starthistle began with the introduction of a fly believed to *Urophora sirunaseva* in 1969. After introductions failed, it was determined the species was indeed *U. jaculata*, one that is specific to yellow starthistle biotypes growing only in Italy. The true *U. sirunaseva* was released in 1984. Four additional species were released subsequently (one fly and three weevils). A contaminant fly species was accidentally introduced to the USA along with the approved fly in 1991 shipments. A rust fungus was introduced in 2003 to supplement the action of the established seed-feeding insects.

CURRENT STATUS: All intentionally introduced insect species successfully established in the USA, though the abundance of each species has changed dramatically over time and with the introduction of additional species. *Bangasternus orientalis, Larinus curtus*, and *Urophora sirunaseva* were all more abundant in the few years following their release. These are since being replaced by higher populations of *Eustenopus villosus* and the unapproved fly, *Chaetorellia succinea* to the point of being considered insignificant agents. The approved *C. australis* often relies on the presence of the exotic weed bachelor's button early in the spring, so is restricted in distribution and also has low attack rates on yellow starthistle. In combination, *E. villosus* and *C. succinea* reduce overall seed production by >70%. However, only at low initial plant densities can this impact yellow starthistle population growth; at many study sites plants compensate for decreased seedling density by growing larger and producing more seeds. The rust *Puccinia jacea* var. *solstitialis* has proven difficult to establish, being ill-suited to the dry climate found throughout much of yellow starthistle's invaded range. Populations remain very small and with low impact in CA.

RECOMMENDATIONS: USA: The low impact and continuously decreasing population size of *B. orientalis, C. australis, L. curtus*, and *U. sirunaseva* make these agents a low priority for redistribution. *C. australis* is also considered a low priority due to its resemblance and often co-ccurrence with the unapproved *C. succinea*. *P. jacea* var. *solstitialis* is also a low priority due to its low impact and limitations for establishment. It should only be redistributed to moist areas and where the other agents are limited. **It is illegal to redistribute *C. succinea*, though this agent is already widespread.** *E. villosus* is also already widely distributed and likely abundant at most infestations, demonstrating that seed-feeding agents are often insufficient to control yellow starthistle alone, and releases of additional agents attacking non-reproductive tissue are warranted. Such agents are currently under study. In the meantime, *E. villosus* would be the highest priority for redistribution. Adults can be collected in midsummer with a sweep net and aspirator. CAN: Canada does not have an official yellow starthistle biocontrol program. **None of the agents described herein are approved for release in Canada; yellow starthistle currently does not occur in Canada.**

Agent	Adult	Impact	Recommendation
Bangasternus orientalis		Seed-feeding reduces up to 60% seeds in attacked capitula. Attack rates low and continue to decrease from competition, parasitism.	Low efficacy and decreasing abundance makes low priority for redistribution. Not released in CAN.
Chaetorellia australis		Seed-feeding reduces up to 90% seeds in attacked capitula. Attack rates low. Often requires bachelor's button for spring generation.	Low efficacy, need for bachelor's button, difficulty differentiating from *C. succinea* make low priority for redistribution. Not released in CAN.
Chaetorellia succinea		Seed-feeding reduces overall seed production >70% with *E. villosus*.	Accidental introduction not approved for redistribution in USA. Not released in CAN.
Eustenopus villosus		Seed-feeding and adult-caused capitula abortion reduce overall seed production >70% with *C. succinea*.	Most effective of approved agents. Recommended for redistribution wherever not established. Not released in CAN.
Larinus curtus		Seed-feeding reduces up to 100% seeds in attacked capitula. Attack rates decreasing from parasitism, perhaps competition.	Low attack rates/efficacy and decreasing abundance makes low priority for redistribution. Not released in CAN.
Puccinia jacea var. *solstitialis*		Rust infection stunts plants, reduces seed production.	Abundance, distribution very low. Ill suited to climatic conditions at most infestations. Recommended only for moist areas. Not released in CAN.
Urophora sirunaseva		Galls reduce seed production in attacked capitula. Many seeds still produced, and attack rates decreasing, possibly from competition.	Low efficacy and decreasing abundance makes low priority for redistribution. Not released in CAN.

Bangasternus, C. succinea, Eustenopus, Larinus, Urophora: Laura Parsons & Mark Schwarzländer, University of Idaho, *C. australis*: Charles Turner, USDA ARS, www.bugwood.org, *Puccinia*: Stephen Ausmus, USDA ARS, www.bugwood.org

Bangasternus orientalis (Capiomont)

Yellow starthistle bud weevil

DESCRIPTION: Larvae are up to 6 mm long with white, C-shaped bodies and brown head capsules. Adults are 4-6 mm long with short snouts and brown bodies with yellow-white hairs that give them a mottled appearance.

Bangasternus orientalis: a) egg (University of Idaho Archive), b) adult (Laura Parsons & Mark Schwarzländer, University of Idaho) (both www.bugwood.org)

LIFE CYCLE: Adults overwinter in soil litter and resume activity in spring when yellow starthistle is bolting. Females lay eggs singly just below flower heads. They may lay up to 470 eggs in a lifetime. Eggs are covered with a dark, protective substance. Hatching larvae tunnel through the stem to reach the flower head where they feed on bracts, receptacle tissue, and developing seeds through three instars. Pupation occurs in chambers made of damaged seed and receptacle tissue. Adults emerge in late summer. There is one generation per year.

DAMAGE: Larvae feed on flower head tissue and developing seeds. Seed consumption does not kill existing plants, but does help reduce the rate of spread of starthistle populations.

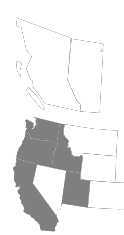
PREFERRED HABITAT: Specific habitat requirements are unknown, but can be found throughout most yellow starthistle infestations in the western USA.

HISTORY: Introduced from Greece and released on yellow starthistle in the USA from 1985 (CA, ID, OR, WA). A redistribution was attempted from to the related Iberian starthistle in CA in 1994, but this failed to establish.

CURRENT STATUS: In the USA, larval feeding typically destroys 60% of seeds within attacked seed heads. It was initially the most widespread of established agents. However, densities of the weevil have been declining since their peak a few years after their original release. The current attack rate is only 1% of available capitula. Predation, parasitism, and displacement by other established agents limit populations in many areas.

REDISTRIBUTION: Though populations are increasingly low in the USA, some populations are reportedly large enough for redistribution. Adults can be collected with a sweep net (with or without an aspirator) in early summer as yellow starthistle is in the early bud stage. Releases of 200 individuals should be made on patches of at least 2,000 m² (1/2 acre). Establishment can be monitored the following summer by checking for adults and/or feeding larvae within capitula. Note that feeding larvae can be very difficult to distinguish from other starthistle weevil species.

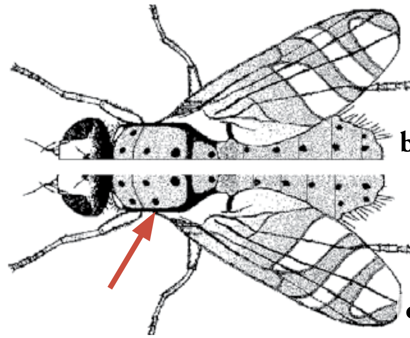
NOTES: This species has a shorter snout than both *Eustenopus villosus* and *Larinus curtus* and is becoming the least abundant (consequently also becoming the least effective). **This agent is not approved for release in Canada.**



Chaetorellia australis (Treitschke) & *C. succinea* (Costa)

Yellow starthistle peacock fly & False yellow starthistle peacock fly

DESCRIPTION: Larvae are up to 5 mm long, barrel-shaped, and whitish with no head capsules. Adults are tan with black spots (8 on the thorax of *C. australis* while *C. succinea* has 10). Eyes are multi-colored and metallic. Wings are clear with thick brown bands. Males are 3-4 mm long; females are 4-6 mm, including ovipositors.



Chaetorellia: a) larva in seed head (Gary Piper, Washington State University, www.bugwood.org), b,c) adult thorax comparison: b) *C. australis,* c) *C. succinea* with extra dot (J. Johnson, University of Idaho)

LIFE CYCLE: Adults of both species emerge in early spring as yellow starthistle bolts. Females lay eggs singly beneath bracts of closed buds. Hatching larvae tunnel into capitula, feeding on receptacle tissue and developing seeds through three instars. Pupation occurs in flower heads inside chambers made of pappus and chewed seeds. Adults emerge in early summer, mate, and lay eggs on more starthistle buds. Larvae of this generation overwinter within flower heads. There are two, sometimes three, generations per year. First generation *C. australis* adults emerge earlier than *C. succinea*, often too early to utilize starthistle. Consequently they frequently use buds of the earlier-flowering invasive weed bachelor's button (*Centaurea cyanus*). The second generation utilizes yellow starthistle.

DAMAGE: Larvae feed on developing seeds. Seed consumption does not kill existing plants, but does help reduce the rate of spread of starthistle populations.

PREFERRED HABITAT: *C. australis* does best where bachelor's button co-occurs with yellow starthistle. Both fly species do better in warm, low-elevation sites.

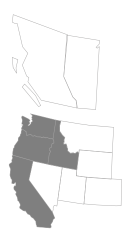
HISTORY: *C. australis* was introduced from Greece and released on yellow starthistle in the USA from 1988 (CA, ID, OR, WA), but quickly established on bachelor's button as well. A release made in OR in 1991 believed to be just *C. australis* was contaminated with *C. succinea*. The contaminant was unknowingly redistributed with *C. australis* throughout CA, OR, WA from 1994.

Adults of d) *Chaetorellia australis*, (Charles Turner, USDA ARS), e) *C. succinea* (note extra dot on thorax, Laura Parsons & Mark Schwarzländer, University of Idaho) (both www.bugwood.org)

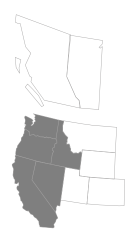
CURRENT STATUS: *C. australis* is established on both bachelor's button and yellow starthistle. Its abundance varies, often in relation to bachelor's button presence. Attack rates are often higher on bachelor's button, on which it can reduce seed production by up to 70% in WA. It can destroy up to 90% of seeds in attacked yellow starthistle capitula. However, attack rates have typically not exceeded 10% of available capitula, likely due to poor synchrony in spring. *C. succinea* is considered the more effective control agent for yellow starthistle. Larval feeding destroys up to 80% of seeds within attacked yellow starthistle seed heads and decreases pollinator visitation. In conjunction with *Eustenopus villosus,* it can reduce seed production by >70% overall. Only at low initial plant densities can this impact the population growth; at many study sites plants compensate for decreased seedling density by growing larger and producing more seeds.

REDISTRIBUTION: **_C. succinea_ is not approved for redistribution in the USA.** However it is already widespread and abundant. *C. australis* is approved, though its low overall impact on starthistle and its occasional reliance on bachelor's button make it a low priority for redistribution. In addition, it is difficult to ensure only the approved *C. australis* is the one released. Establishment of either species can be confirmed by observing larvae in capitula throughout the growing season. Adults are needed in order to determine which species is present.

NOTES: *Eustenopus villosus* oviposition deters *Chaetorellia succinea* oviposition. *C. succinea* consumes a higher proportion of seeds when plants are not infected with *Puccinia jacea* var. *solstitialis*. **Neither agent is approved for release in Canada.**



C. australis

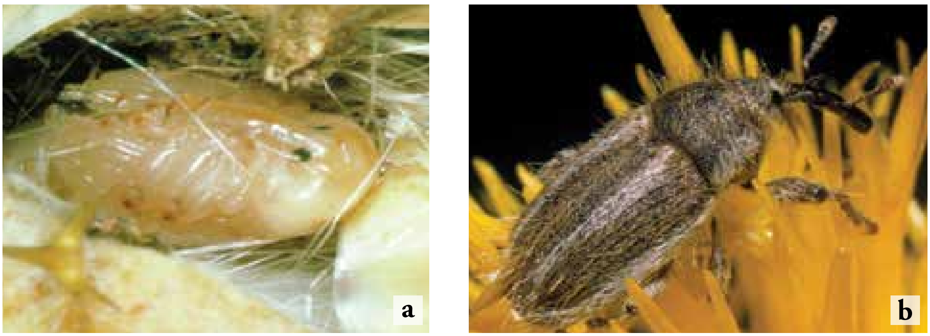


C. succinea

Eustenopus villosus (Boheman)

Yellow starthistle hairy weevil

DESCRIPTION: Larvae are up to 6 mm long with white, C-shaped bodies and brown head capsules. Adults are 4-6 mm long and have brown bodies with white stripes. Their snouts are very long and slender, and they have long hairs on their back.



Eustenopus villosus: a) pupa (University of Idaho, www.bugwood.org), b) adult (Laura Parsons & Mark Schwarzländer, University of Idaho)

LIFE CYCLE: Adults overwinter in soil litter and emerge in spring when yellow starthistle is bolting. They feed heavily on immature starthistle buds. Females chew holes in the sides of mature, closed buds in early to midsummer, lay eggs inside, and cap holes with a dark substance. Hatching larvae feed on developing seeds through three instars. Pupation occurs in chambers made of damaged seed and receptacle tissue. Adults emerge in late summer. There is one generation per year.

DAMAGE: Larvae feed on receptacle tissue and developing seeds. Adult feeding leads to a high percentage of seed head abortion. Both forms of feeding do not kill existing plants, but help reduce the rate of spread of starthistle populations.

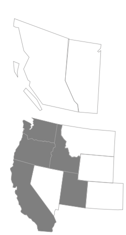
PREFERRED HABITAT: Does well throughout the majority of conditions yellow starthistle has invaded in the USA.

HISTORY: Introduced from Greece and released on yellow starthistle in the USA from 1990 (CA, ID, NV, OR, WA).

CURRENT STATUS: Abundant and widespread in the USA where larval feeding destroys up to 100% of seeds within attacked seed heads. Adult feeding also causes abortion of attacked seed heads, having the largest total effect on the weed's fecundity. However, bud herbivory reduces the plant's attractiveness to ovipositing seed predators, reducing direct negative effects of bud herbivory. In conjunction with *Chaetorellia succinea*, this species can reduce seed production by >70% overall. Only at low initial plant densities can this impact population growth; at many study sites plants compensate for decreased seedling density by growing larger and producing more seeds. Parasitism and predation negate impact at some sites.

REDISTRIBUTION: Already widespread throughout the range of yellow starthistle. Wherever not currently established, adults can be collected with a sweep net (with or without an aspirator) in midsummer when yellow starthistle is in the late bud stage. Releases of 200 individuals should be made on patches of at least 2,000 m^2 (1/2 acre). Establishment can be monitored the following summer by checking for adults and/or feeding larvae within capitula. Note that feeding larvae can be very difficult to distinguish from other starthistle weevil species.

NOTES: This species has a longer snout than both *Bangasternus orientalis* and *Larinus curtus*. *E. villosus* consumes a higher proportion of seeds when plants are not infected with *Puccinia jacea* var. *solstitialis*. **This agent is not approved for release in Canada.**



Larinus curtus Hochhut

Yellow starthistle flower weevil

DESCRIPTION: Larvae are up to 6 mm long with white, C-shaped bodies and brown head capsules. Adults are 5-6 mm long and have medium-length snouts. Bodies are brown with white hairs that give them a mottled appearance. Hairs are often yellowish from pollen.

Larinus curtus: a) larva in seed head (Charles Turner, USDA ARS, www.bugwood.org), b) adult (Laura Parsons & Mark Schwarzländer, University of Idaho)

LIFE CYCLE: Adults overwinter in soil litter and emerge in summer when yellow starthistle is in bud and flowering. They feed on florets and pollen through four larval instars. Females lay eggs singly at the base of florets. Hatching larvae feed on developing seeds. Pupation occurs in chambers made of damaged seed and receptacle tissue. Adults emerge in late summer. There is one generation per year.

DAMAGE: Larvae feed on flower head tissue and developing seeds. Seed consumption does not kill existing plants, but does help reduce the rate of spread of starthistle populations.

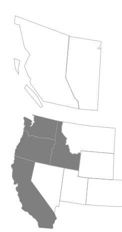
PREFERRED HABITAT: Specific habitat requirements are unknown, but can be found throughout most yellow starthistle infestations in the western USA.

HISTORY: Introduced from Greece and released on yellow starthistle in the USA from 1992 (CA, ID, OR, WA).

CURRENT STATUS: In the USA, larval feeding destroys up to 100% of seeds within attacked seed heads; however, attack rates are typically low. Abundance plateaued within a few years of introduction and it varies from high in portions of OR, to moderate in WA, and becoming more limited in ID and CA. It is less abundant than the other seed-feeding agents which have been unable to impact yellow starthistle population trajectories. Some weevil populations are limited by *Nosema* sp. parasites.

REDISTRIBUTION: **Only *Nosema*-free populations (lab-reared) are permitted for release in the USA.** Releases of 200 individuals should be made on patches of at least 2,000 m^2 (1/2 acre). Establishment can be monitored the following summer by checking for adults and/or feeding larvae within capitula. Note that feeding larvae can be very difficult to distinguish from other starthistle weevil species.

NOTES: This species has a longer snout than *Bangasternus orientalis* but shorter than *Eustenopus villosus*. **This agent is not approved for release in Canada.**



Puccinia jacea var. *solstitialis* Savile

Yellow starthistle rust

DESCRIPTION and LIFE CYCLE: This fungus has several stages in its life cycle. Teliospores can withstand freezing temperatures and are the overwintering stage. These germinate in spring and produce basidiospores which initiate the sexual process of rust development. Aeciospores are then produced, followed by urediospores. Urediospores are the most distinctive spore. They are flat, round, tiny (25 µ in diameter) and covered with short spines. Masses of urediospores occur in a pustule on an infected leaf. They appear reddish brown and powdery and are easily blown to uninfected plants. With suitable levels of moisture and temperature, spores germinate and repeat the cycle, producing more urediospores. This process can take two weeks to complete. When host starthistle plants die back in late summer, the fungus produces teliospores in preparation for winter.

Puccinia jacea var. *solstitialis*: a) dew on yellow starthistle leaf, b) infected leaf (a,b Stephen Ausmus, USDA ARS, www.bugwood.org)

DAMAGE: Infected plants can experience stunted growth, reduced seed production, and a higher susceptibility to interspecific competition and attack from additional biocontrol agents.

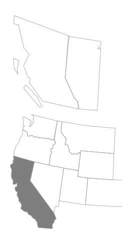
PREFERRED HABITAT: Requires climates with dew periods that result in moisture forming or collecting on starthistle foliage.

HISTORY: Introduced from Turkey and released in the USA from 2003 (CA 2003, OR 2008).

CURRENT STATUS: Established only in CA (USA). Under optimal conditions (moist, mild temperatures) the rust can reduce biomass and number of capitula, especially in conjunction with high plant competition. At drier sites, impact is decreased and likely to be of only minor biological significance. Across much of yellow starthistle's range, suboptimal conditions prevent the rust's persistence and/or significant impact.

REDISTRIBUTION: Should be collected by vacuuming urediospores from infected leaves throughout the growing season, suspending the spores in water, and spraying them on new foliage prior to a dew period. Alternatively, transfer infected stems to new sites in the evening during summer, and spray uninfested plants with water. Take care not to spread yellow starthistle seeds to new sites as this may introduce new genetic material. Establishment can be monitored by observing pustules on new yellow starthistle foliage throughout the following growing season.

NOTES: Infection by this rust is sometimes additive with the effects of seed predators; under other conditions it indirectly causes a reduction of seed predation which can cancel out entirely the direct negative impact of the rust. **This agent is not approved for release in Canada.**



Urophora sirunaseva (Héring)

Yellow starthistle gall fly

DESCRIPTION: Larvae are up to 5 mm long and barrel-shaped. They are whitish and have no head capsules. Adults are black with a yellow spot on the bottom part of the thorax. Eyes are multi-colored and metallic. Wings are clear with dark crossbands. Males are 3-4 mm long while females are 4-6 mm, including ovipositors.

Urophora sirunaseva: a) larva in gall, b) adult (Laura Parsons & Mark Schwarzländer, University of Idaho), c) multiple galls in capitulum (a,c Charles Turner, USDA ARS, www.bugwood.org)

LIFE CYCLE: Adults emerge in spring as yellow starthistle bolts. Females lay eggs (up to 270 in a lifetime) on top of immature, closed buds. Hatching larvae feed on florets. When they reach the receptacle, a woody gall is formed around each larva; multiple galls may occur in one flower head. There are three larval instars, prior to pupation within galls. Adults emerge in summer, mate, and lay eggs on more starthistle buds. Larvae of this generation overwinter within galls. There are two generations per year.

DAMAGE: Floret feeding and gall formation reduce seed production. Galls act as nutrient sinks, diverting plant resources from regular plant function.

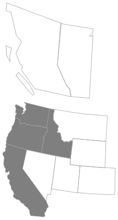
PREFERRED HABITAT: Specific habitat requirements are unknown, but does not seem to do well at overly windy locations.

HISTORY: The first introductions occurred on yellow starthistle in CA, USA from 1969 utilizing flies collected in Italy. After these failed to establish, it was determined the species introduced was in fact *Urophora jaculata,* which is specific to yellow starthistle biotypes growing only in Italy. Two additional populations were subsequently introduced and released from 1984 (from Greece into CA, ID, OR, WA; from Turkey into ID). The Turkish introduction presumably did not survive.

CURRENT STATUS: In the USA, gall formation decreases seed production, though multiple galls are required per seed head before seed reduction is significant. High gall density per capitulum is not common. Though this species is widely distributed, abundance is low. Attack rates have decreased from peaks around 50% within the few years following successful establishment to usually around 10%. Overall impact is now limited. Populations at some sites are hindered by competition with other seed head agents.

REDISTRIBUTION: Sweeping adult flies is possible, though may be damaging. Instead, infested capitula can be collected in fall and stored at 39-46°F (4-8°C). Two to three weeks prior to their normal emergence time, bring them to room temperature in rearing cages or breathable, clear containers. Once they emerge, flies can be transferred to new yellow starthistle infestations in groups of 50-100. **Prior to release, ensure that insect populations do not contain *Chaetorellia succinea,* which is not approved for redistribution, though it is already widespread in the USA.** Establishment can be monitored by observing adults on starthistle foliage the following summer or by dissecting capitula for galls/larvae from summer throughout the following spring. Note that feeding larvae can be difficult to distinguish from other starthistle seed head insects. *Urophora* can be distinguished by their presence within galls.

NOTES: **This agent is not approved for release in Canada.**



ST. JOHNSWORT

Common St. Johnswort

Hypericum perforatum L.

SYNONYMS: St. Johnswort, klamath weed, goatweed

ORIGIN: Native to Asia, Europe, northern Africa. Introduced to the United States on multiple occasions by European settlers interested in the plant's medicinal properties. First escaped cultivation in 1793.

DESCRIPTION: Perennial, upright forb typically growing 1-3 ft tall (⅓-1 m) with numerous stems somewhat woody at their base. Stems turn rust-colored later in the growing season. Roots produce short runners. Leaves are opposite, without stems or lobes, and are up to 1 in long (2½ cm). Leaves have numerous transparent dots as well as tiny black glands along their margins. Flowers are numerous, bright yellow, ¾ in (1½ cm) in diameter, have many stamens, and have petals with additional black glands along margins. Seed pods are sticky, 3-celled, ¼ in (⅔ cm) long, and filled with numerous seeds.

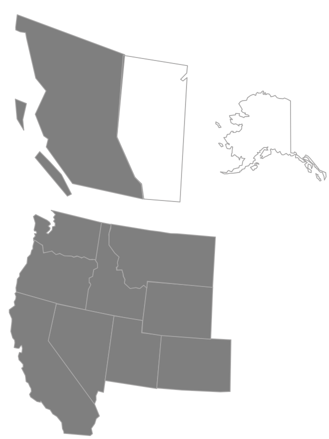
a) plant (Richard Old, XID Services, Inc, www.xidservices.com, www.bugwood.org), b) infestation (Marianna Szucs, Colorado State University)

c) leaves (Steve Dewey, Utah State University), d) mature plant (Norman Rees, USDA ARS) e) flowers (Marianna Szucs, Colorado State University) (c,d www.bugwood.org)

HABITAT: Found in diverse areas, often with open sunlight and disturbance, such as clear cuts, roadsides, and overgrazed land. Frequents sandy or gravelly soil.

ECOLOGY: Spreads by seed and root runners. Sticky seed capsules can be dispersed short distances by wind and longer distances by water and adhering to humans and other animals. First year plants do not produce flowers or seeds, and it may take two to several years to reach maturity. Flowering occurs from late spring through autumn. Seeds germinate throughout spring and summer or following autumn rains. Seeds may remain viable in the soil for several years, especially if buried more than 1 in deep (2½ cm). Vegetative reproduction is responsible for much of the growth in a common St. Johnswort population.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Agrilus hyperici, Aplocera plagiata, Chrysolina hyperici, C. quadrigemina, C. varians,* and *Zeuxidiplosis giardi;* CAN: *A. hyperici, Aphis chloris, A. plagiata, C. hyperici, C. quadrigemina, C. varians* and *Z. giardi.*



NOTES: This plant is toxic to white-haired animals, though usually not resulting in death.

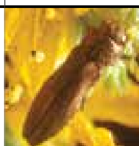
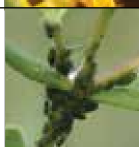
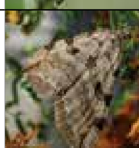
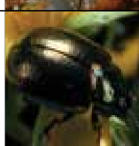
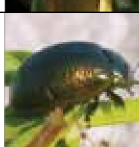
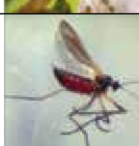
St. Johnswort Biological Control

HISTORY IN THE NORTHWEST: The first approved biological control agents released against common St. Johnswort in North America were the klamathweed beetles *Chrysolina hyperici* and *C. quadrigemina* released in the USA in 1945 and 1946, respectively. The introductions of these insects led to a marked decrease of common St. Johnswort throughout much of its invaded range, though some infestations continued to expand even with *Chrysolina* present. Consequently, the root borer *Agrilus hyperici* and the gall midge *Zeuxidiplosis giardi* were released in 1950; the defoliating inchworm *Aplocera plagiata* was released in 1989. *C. hyperici* and *C. quadrigemina* were subsequently redistributed from the USA to Canada in 1951 and 1952, respectively, while *A. hyperici* and *Z. giardi* were redistributed from the USA to Canada in 1955 and 1995, respectively. *A. plagiata* was introduced directly from Europe prior to its release in Canada from 1967. The aphid *Aphis chloris* was introduced from Europe and released only in Canada. A third *Chrysolina* species, *Chrysolina varians*, was introduced from Europe and released on common St. Johnswort in the USA in 1950 and in Canada from 1957, but failed to establish in either country.

CURRENT STATUS: *A. hyperici* is established in both the USA and CAN and its root-boring initially demonstrated high control ability for common St. Johnswort. It has since been displaced by *C. quadrigemina*, and populations are limited in both countries. Defoliation by *A. plagiata* can be damaging locally, but populations are limited in both the USA and CAN. *Z. giardi* failed to establish in Canada. Heavy parasitism has limited populations to only select locations in CA, USA. *A. chloris* is established only in CAN where it can provide control locally, but populations fluctuate with the weather and due to interspecific competition with *Chrysolina* spp. The *Chrysolina* spp. have been the most effective common St. Johnswort agents to date. Within 10 years of the first release, most common St. Johnswort populations in open, sunny areas were reduced more than 97%. *Chrysolina* spp. frequently occur in mixed populations and often in boom/bust cycles. The plant still cyclically rebounds, especially where land management practices have not improved, but infestation levels are much lower than they were historically. *C. hyperici* is still considered widespread and abundant in some places, though *C. quadrigemina* has since become the main factor controlling the weed throughout much of the western USA and CAN.

RECOMMENDATIONS: USA and CAN: The limited impact and decreased abundance of *A. hyperici* and *A. plagiata* make them a low priority for redistribution. *Z. giardi* is so heavily parasitized, it should not be redistributed in the USA or back to CAN where it failed to establish. *A. chloris* should be redistributed to cold sites in CAN where *Chrysolina* spp. are limited or absent.

***Aphis chloris* is not approved for release in the USA.** *Chrysolina* spp. are typically widespread, but populations fluctuate. Where populations are in the bust stage, redistributions of adults should be made. In cold, moist climates, *C. hyperici* should be considered. Elsewhere, *C. quadrigemina* is the most recommended species. Mixed populations may increase the probability of a successful redistribution. In shady habitats, other agents and/or control methods should be utilized.

AGENT	ADULT	IMPACT	RECOMMENDATION
Agrilus hyperici		Root-boring initially displayed ability to control the weed, but populations have since been largely displaced by *C. quadrigemina*. Now limited.	Decreased and limited abundance coupled with current low overall impact make this low priority for redistribution in USA and CAN.
Aphis chloris		Sap-sucking provides control at some sites. Populations fluctuate due to weather and abundance/impact of *Chrysolina* spp.	Not released in USA. Recommended for redistribution in CAN where *Chrysolina* spp. are limited or not established.
Aplocera plagiata		Defoliation can be damaging locally, but populations are typically low throughout range in USA and CAN.	Limited abundance coupled with current low overall impact make this low priority for redistribution in USA and CAN.
Chrysolina hyperici		Defoliation first considered high impact. Now less important than *C. quadrigemina* in most habitats; better suited to others.	Lower priority than *C. quadrigemina,* but recommended for colder, more moist habitats where *C. quadrigemina* is less suited.
Chrysolina quadrigemina		Defoliation has extremely high impact. Most important agent. Doesn't thrive in all habitats. Populations follow boom/bust cycle with weed.	Already widespread throughout much of North America. Recommended for redistribution where populations currently limited.
Zeuxidiplosis giardi		Galls reduce growth of heavily infested plants. However populations highly parasitized so are very limited in abundance. Not established in CAN.	High parasitism rates and extremely low abundance make this a low priority for redistribution in the USA.

Agrilus, Chrysolina hyperici: Laura Parsons & Mark Schwarzländer, University of Idaho, *Aphis:* *Aplocera, C. quadrigemina:* Eric Coombs, Oregon Department of Agriculture, *Zeuxidiplosis:* Norman Rees, USDA ARS, www.bugwood.org

Agrilus hyperici (Creutzer)

St. Johnswort root borer

DESCRIPTION: Larvae are white with brown mouthparts and reach 11 mm in length. Adults are a metallic brown color; females are all one color while males' heads are slighter greener than the rest of their bodies. Adults are flattened and tapered toward the rear and reach 5 mm in length.

Agrilus hyperici: a) larva in root (Eric Coombs, Oregon Department of Agriculture), b) pupa in root (Norman Rees, USDA ARS), c) adult (Laura Parsons & Mark Schwarzländer, University of Idaho)

LIFE CYCLE: Larvae overwinter within roots, feeding again within the roots the following spring as plants bolt. After the fourth instar, pupation occurs in the roots. Adults emerge through early summer as the weed flowers. Adults are most active in the heat of the day. Oviposition occurs near the base of common St. Johnswort plants in late summer. Newly emerging larvae burrow into the roots to feed and then overwinter. There is one generation per year.

DAMAGE: When larvae feed within roots of common St. Johnswort, root tissue can be completely consumed. Stems arising from attacked roots and root crowns are stunted and produce fewer flowers, with the attacked plant dying outright in some instances.

PREFERRED HABITAT: Found mostly in mountainous regions in North America and drier, more southern portions of Europe. Damp sites are less suitable as larvae are often susceptible to fungal attack. This beetle prefers large plants with multiple stems. It will attack plants in shade, unlike some other common St. Johnswort biological control agents.

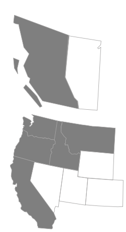
HISTORY: Introduced from France and released on common St. Johnswort in the USA from 1950 (CA, ID, MT, NV, OR, WA). Populations established in CA were redistributed to BC, Canada in 1955, 1964, and 1977, but all shipments failed to establish. A population from Idaho was successfully redistributed to

BC in 1987.

CURRENT STATUS: Abundance and impact in the USA vary. It disperses widely, but populations are typically low until occasional explosions. This beetle initially displayed the ability to destroy common St. Johnswort in CA but was displaced by *Chrysolina quadrigemina* and persisted only in some areas. Infestation levels reached up to 87% in WA. It contributed significantly to common St. Johnswort suppression in ID where it is still abundant. Established Canada though it is typically uncommon. At only one site have populations been large enough to redistribute. Overall impact has been negligible.

REDISTRIBUTION: Adults can be collected with a sweep net (with or without an aspirator) during summer when plants are in flower and can be transferred to new infestations in groups of 50-100. Preference should be placed on new sites with no to minimal *Chrysolina* populations. Establishment can be monitored by observing adults on St. Johnswort foliage the following spring and summer during the heat of the day or by dissecting roots for evidence of larval mining from autumn through the following spring.

NOTES: Has been observed attacking *Hypericum concinnum*, a forb/small shrub endemic to California.



Aphis chloris Koch

St. Johnswort aphid

DESCRIPTION: Eggs are yellowish at first, turning black with time. Nymphs and adults are lime green, tending to dark green in cooler climates. They are typically 1-2 mm long. Winged females have transparent wings.

Aphis chloris: a) eggs (Peter Harris, Agriculture and Agri-Food Canada), b) adults and nymphs (© Province of British Columbia. All rights reserved. Reproduced with permission of the Province of British Columbia)

LIFE CYCLE: Eggs overwinter. Self-fertile females hatch in late spring and produce live young. 6-11 days are required for these immatures to reach the reproductive stage. Live young births continue until temperatures cool in the fall, though in warm areas, self-fertile females continue to be produced. Under crowded conditions from summer through fall, winged females disperse to start new colonies. Adults and nymphs congregate on stems, root collars, leaf axils, flowers and leaves. The onset of cool, short days in northern regions initiates the production of males and egg-producing females. Each female produces four eggs on average, depositing them onto basal winter foliage.

DAMAGE: Nymphs and adults attack stems and leaves, feeding on plant fluids. Under high aphid densities this feeding can cause individual common St. Johnswort plants to wither and die. In field studies, healthy potted plants were killed in one month when attacked by this species.

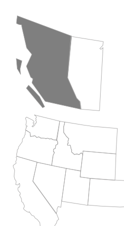
PREFERRED HABITAT: Does best where summers are humid and temperatures are cool. Sufficient cold winter temperatures are required for egg development. Does not do well in hot, dry locations where plants wither and burn from heat.

HISTORY: Introduced from Austria, Germany, and Hungary and released in BC, Canada from 1979.

CURRENT STATUS: Provides significant control at some sites in Canada, though populations fluctuate due to weather and abundance/impact of *Chrysolina* spp. Low numbers of the beetles provide more suitable habitat for the aphid.

REDISTRIBUTION: Plant material infested with adults and nymphs can be transferred to new infestations throughout the growing season. Alternatively, foliage with eggs attached can be collected from fall through spring and transferred to new sites prior to egg hatch. In either case, infested plant material should be placed in direct contact with uninfested stems at new sites (taking care not to spread common St. Johnswort seeds to new sites as this may introduce new genotypes). Establishment can be monitored throughout the same or following by observing adults or nymphs on foliage of common St. Johnswort.

NOTES: **This agent is not approved for release in the USA.**



Aplocera plagiata (L.)

St. Johnswort inchworm

DESCRIPTION: Eggs are small, pearly-white ovals. Larvae resemble twigs and are reddish brown with weak gray stripes. They are up to 2½ cm long. Pupae are greenish-golden and slender. Adults are triangular in shape and have gray wings with dark gray bands. Wingspans reach 3¾ cm (1½ inches).

Aplocera plagiata: a) eggs (Norman Rees, USDA ARS, www.bugwood.org), b) larva (Eric Coombs, Oregon Department of Agriculture)

LIFE CYCLE: Overwintering larvae emerge in early spring and feed on common St. Johnswort foliage (typically at night) when the plant is bolting. They develop through four instars. Pupation occurs in the soil. Adults emerge in late spring and early summer and lay eggs on foliage. Larvae of the first new generation emerge in midsummer as common St. Johnswort flowers, repeating the life cycle. Second generation larvae hatch in late summer, coinciding with the late flowering stage of common St. Johnswort, and feed on foliage and flowers. This generation overwinters in the larval stage within the soil. There are up to two generations per year, depending on winter temperatures.

DAMAGE: Larval defoliation only weakens common St. Johnswort plants. Attack by large populations of this biological control agent can lead to a reduction of flower and seed formation.

PREFERRED HABITAT: This species prefers dry areas to those with high rainfall. It does well on rocky ground, open sandy places, and in limestone regions.

HISTORY: Introduced from France, Germany, Switzerland and released in the USA (CA, MT, OR) from 1989. Introduced from Germany, Switzerland, and France and released in BC, Canada in 1967, 1977, and 1980, respectively. All

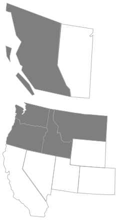
Aplocera plagiata: c) adult (Eric Coombs, Oregon Department of Agriculture), d) defoliation (Norman Rees, USDA ARS, www.bugwood.org)

three populations established and subsequently intermixed.

CURRENT STATUS: In the USA where it is locally abundant, defoliation hinders and may kill plants outright. However, overall abundance is typically limited. It is most effective in warm, dry areas where the insect can complete two generations. In Canada, it disperses readily throughout southern interior BC. However, populations remain low and do minimal damage.

REDISTRIBUTION: Adults may be collected and transferred, however this stage is fragile and sweep netting often results in injury to the moths. The species is best collected in the larval stage using sweep nets. First generation larvae are available in midsummer as common St. Johnswort flowers. Second generation larvae hatch in late summer or early fall, coinciding with the late flowering stage of common St. Johnswort. Groups of 50-100 can be transferred to new infestations immediately after collection. Establishment can be monitored by observing adults on St. Johnswort foliage the following spring/summer or larvae feeding on foliage (typically at night) in midsummer or early fall. Attacked plants appear stripped and wilty.

NOTES: Adults are usually fewer in number the first generation compared to the second generation. Warm, dry, and long summers are needed to complete both generations. When cold temperatures arrive too soon, second generation larvae do not survive winter.



Chrysolina hyperici (Forster) & *C. quadrigemina* (Suffrian)

Klamathweed beetles

DESCRIPTION: Two species of klamathweed beetles are established in North America, both morphologically very similar. *C. quadrigemina* is slightly larger than *C. hyperici*. Eggs are orange and cylindrical. Larvae are initially orange and later gray and up to 6 mm in length. Adults are oval-shaped, robust, and are up to 6 mm long. They are shiny metallic with green, bronze, or blue undertones.

Chrysolina spp. a) eggs (Norman Rees, USDA ARS, www.bugwood.org), b) larva, c) *C. hyperici* adult (Laura Parsons & Mark Schwarzländer, University of Idaho), d) *C. quadrigemina* adult (b,d Eric Coombs, Oregon Department of Agriculture, www.bugwood.org)

LIFE CYCLE: Larvae emerge in early spring and feed on young foliage when the plant is bolting. Ingesting common St. Johnswort makes larvae photosensitive, so most feeding occurs before sunrise. They develop through four instars, and pupation occurs in the soil in late spring. Adults emerge in early summer as common St. Johnswort begins flowering. They feed and then often rest in the soil over summer. If fall rains are sufficient, adults return to plants and resume feeding on foliage in the fall and laying eggs on leaves as common St. Johnswort is senescing. Both species primarily overwinter as eggs. When fall rains are not significant, adults overwinter and lay eggs in spring. In mild climates, fall-hatched larvae can survive the winter. There is one generation per year.

DAMAGE: Larval feeding can decimate populations of common St. Johnswort. Summer defoliation by adults is also striking, but not as effective as larval feeding.

PREFERRED HABITAT: Both do poorly in shaded, barren, or rocky areas. They prefer warm, sunny regions with wet winters. *C. quadrigemina* prefers more maritime conditions than *C. hyperici*, which is more cold and moisture tolerant.

HISTORY: *C. hyperici* and *C. quadrigemina* were introduced from England and France (respectively) via Australia. They were released on common St. Johnswort in the USA from 1945 and 1946, respectively, in CA, ID, MT, NV, OR, UT,

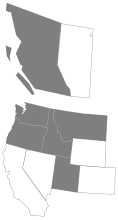
e, f) *Chrysolina spp.* adults and damage: (both Jennifer Andreas, Washington State University Extension)

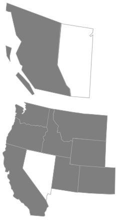
WA. Populations of *C. hyperici* and *C. quadrigemina* established in the USA were redistributed to BC (CAN) from 1951 and 1952, respectively.

CURRENT STATUS: Within 10 years of the first *Chrysolina* release, the weed population was reduced more than 97% at most open, sunny sites. The beetles are ineffective in shady habitats. Populations of both the weed and the beetles often follow a boom/bust cycle; when St. Johnswort control is high, beetle populations often crash, leading to St. Johnswort increase but at lower than historical levels. Without improvement of land use, St. Johnswort will continue being a cyclical problem. *C. hyperici* and *C. quadrigemina* are often mixed in both the USA and Canada, though *C. quadrigemina* is now typically considered to be more abundat and effective throughout the western USA and Canada.

REDISTRIBUTION: Adults can be collected with a sweep net during summer when plants are in flower and transferred to new infestations in groups of 200. Keep in mind that *Chrysolina* adults often rest in the soil during late summer (July and August). Establishment can be monitored by observing larvae on St. Johnswort foliage the following spring (larvae feed at night). Alternatively, adults can be observed throughout the following summer during the heat of the day. Attacked plants will appear stripped and wilty.

NOTES: In the USA, *C. quadrigemina* attacks the native *Hypericum concinnum* and the exotic *H. calycinum*. A third *Chrysolina* species, *C. varians* (Schaller), was introduced from Europe and released on common St. Johnswort in the USA (CA, ID) from 1950. It was also introduced from Sweden and released in CAN (BC) from 1957, but failed to establish in either country.


C. hyperici


C. quadrigemina

Zeuxidiplosis giardi (Kieffer)

St. Johnswort gall midge

DESCRIPTION: Eggs are elongated and pale red in color. Larvae are orange and can reach up to 2 mm. Pupae are a yellowish-red, becoming darker red as they mature. Adults are very small (3 mm long) and have dark red bodies with gray heads, wings, and legs.

Zeuxidiplosis giardi: a) adult, b) gall damage (both Norman Rees, USDA ARS, www.bugwood.org)

LIFE CYCLE: Larvae emerge in early spring and feed on leaf buds, causing leaves to grow into a spherical gall that is green with reddish markings. Larvae feed inside at the base of the gall through three instars; several larvae are often found within one gall. Pupation also occurs inside. Adults are sexually mature upon emergence and live for up to five days. There may be up to seven generations per year, though there are usually fewer than five. Larvae and pupae overwinter inside galls.

DAMAGE: In suitable habitats, this insect can cause a loss of vigor and reduction of both root and foliage development. Heavily attacked plants are unable to obtain moisture and frequently die during drier seasons.

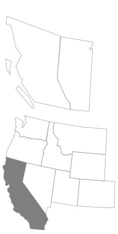
PREFERRED HABITAT: Does best with moderate to high humidity, thriving in damp locations and at high elevations. It does poorly in areas with dry summers and constant wind. Nor does it do well with heavy livestock grazing.

HISTORY: Introduced from France and released in the USA from 1950 (CA, ID, MT, OR, WA). A second release attempt was made in 1992 utilizing a population from Hawaii reportedly doing much better than individuals in the USA. This second introduction failed to establish. Populations in CA (USA) were redistributed to BC (CAN) from 1995.

CURRENT STATUS: Established only in CA (USA) where it can reduce growth in heavily infested plants. However the species is heavily parasitized so populations are very limited. Not established in Canada. Populations thrived the first summer of release but were subsequently annihilated due to sudden sub-zero temperatures in mid-November.

REDISTRIBUTION: Sweeping adult flies is possible, though may be damaging. Instead, place plants infested with galls into uninfested patches throughout the growing season. Alternatively, galls infested with larvae may be hand-picked and transferred to uninfested patches of common St. Johnswort. When transferring galls, it is important to keep the galls moist to prevent dessication. Transferring infested galls may also transfer unwanted parasitoids, other seed head insects, or common St. Johnswort seed from different genotypes. To avoid this, galls can be collected and adults reared out indoors Refer to Additional Considerations in the Introduction for instructions on how to do so. Once they emerge in spring, flies can be transferred to new common St. Johnswort infestations in groups of 50-100. Establishment can be monitored throughout the following season by observing galls on new foliage.

NOTES: Capable of forming galls on *Hypericum concinnum*, a forb/small shrub endemic to California. However, damage to this plant is insignificant.



Dalmatian toadflax

Linaria dalmatica ssp. *dalmatica* (L.) Mill.

SYNONYMS: broad-leaved toadflax; *Linaria genistifolia* (L.) Mill. ssp. *dalmatica* (L.) Maire & Petitm., *Linaria dalmatica* (L.) Mill., *Linaria genistifolia* (L.) Mill.

ORIGIN: Likely introduced from Eurasia by 1900 in horticultural trials.

DESCRIPTION: Upright, herbaceous perennial typically growing numerous stems 1-4 ft tall (⅓-1.2 m) from a deep taproot with lateral roots. Leaves are alternate, thick, blue-green, and often waxy. Leaves are heart-shaped at the base, clasp the stem, and are typically 1-2 in long (2-5 cm) and nearly as wide. Flowers are bright yellow and snapdragon-like with two lips. Each has a bearded, yellowish-orange throat and a long spur. Flowers occur in spiked clusters emerging from leaf axils. Each flower produces a round capsule holding 60-300 small, somewhat triangular seeds.

HABITAT: A weed of wastelands, roadsides, abandoned pastures, slash piles, and rangeland. It does well in cool, semiarid climates and on coarse-textured soils.

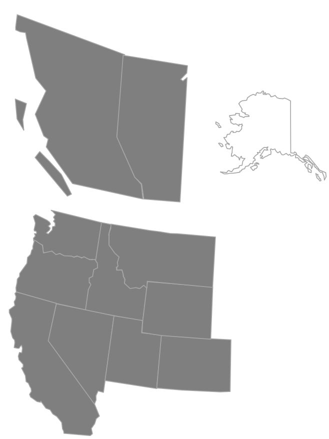
a) plant (K. George Beck & James Sebastian, Colorado State University, www.bugwood.org), b) infestation (Jennifer Andreas, Washington State University Extension)

c) leaves, d) flower (c,d Bonnie Million, National Park Service), e) seeds (Steve Hurst, USDA NRCS PLANTS database) (all www.bugwood.org)

ECOLOGY: Reproduces both by seed and by its spreading root system. Seedlings germinate in fall or spring; bolting occurs in spring. Flowering occurs throughout the summer. Seeds may remain viable in the soil for up to 10 years.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Brachypterolus pulicarius, Calophasia lunula*, *Eteobalea intermediella, E. serratella, Mecinus janthinus, M. janthiniformis, Rhinusa antirrhini,* and *R. linariae*; CAN: *C. lunula*, *E. intermediella, M. janthinus, M. janthiniformis, R. antirrhini,* and *R. linariae.*

NOTES: May be toxic to grazing livestock. Dalmatian and yellow toadflax can both be highly variable in North America, which is compounded by their ability to hybridize. The taxonomic status of this group of species and their hybrids remains uncertain. The authors of this manual follow the interpretation that *Linaria genistifolia* (L.) Mill. is distinct from *L. dalmatica* (L.) Mill. and that *L. dalmatica* consists of two subspecies, of which only one (*L. dalmatica* ssp. *dalmatica*) is invasive and weedy in North America. Two widely recognized forms of *L. dalmatica* subsp. *dalmatica* (narrow-leaved and broad-leaved) could be hybrids or unique species. It is the broad-leaved form that has proven most problematic in North America.



Yellow toadflax

Linaria vulgaris Mill.

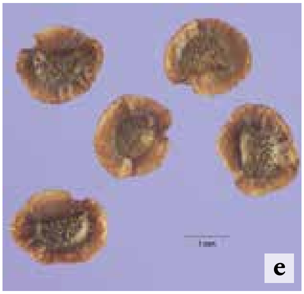
SYNONYMS: common toadflax, butter-and-eggs

ORIGIN: Possibly introduced from Eurasia as early as 1600s as an ornamental and medicinal plant, and as a source of textile dye.

DESCRIPTION: Upright, herbaceous perennial typically growing numerous stems 1-3 ft tall (⅓-1 m) from a taproot with spreading rhizomatous roots. Leaves are alternate, pale green, pointed at both ends, and have small stalks. They are narrow and typically 2 in long (5 cm) with a large central vein on the underside. Flowers are bright yellow and snapdragon-like with two lips. Each has a bearded, bright orange throat and a long spur. Flowers occur in spiked clusters emerging from leaf axils Each flower produces a round capsule holding up to 250 round, winged seeds.

HABITAT: A weed of wastelands, roadsides, clear cuts, and field edges. It does

a) plant (Tiffany Wax, Washington State University Extension), b) infestation (Michael Shephard, Forest Service, www.bugwood.org)



c, d) leaves, d) flowers (both Michael Shephard, Forest Service), e) seeds (Steve Hurst, USDA NRCS PLANTS database) (all www.bugwood.org)

well on coarse-textured soils in cool climates that are typically more moist than those preferred by Dalmatian toadflax.

ECOLOGY: Reproduces both by seed and by its spreading root system. Seedlings typically germinate and bolt in spring. Flowering occurs throughout the summer. Seeds generally have low viability, but some may remain viable in the soil for several years.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Brachypterolus pulicarius*, *Calophasia lunula*, *Eteobalea intermediella*, *E. serratella*, *Mecinus janthinus*, *M. janthiniformis*, and *R. linariae*; CAN: *C. lunula*, *E. serratella*, *M. janthinus*, *M. janthiniformis*, and *R. linariae.*

NOTES: This species is reportedly not sought after by grazing livestock. Yellow and Dalmatian toadflax can both be highly variable in North America, which is compounded by their ability to hybridize. The taxonomic status of this group of species and their hybrids remains uncertain.

Toadflax Biological Control

HISTORY IN THE NORTHWEST: The first biological control agents for control of toadflax in North America were accidentally introduced. A strain of *R. antirrhini* preferring yellow toadflax arrived by 1909 and was found on (or intentionally redistributed to Dalmatian) in the USA and CAN by 1957. A second strain of *R. antirrhini* was intentionally introduced on Dalmatian toadflax in the USA and CAN in 1996 and 1993, respectively. *Brachypterolus pulicarius* arrived to the USA by 1919 and CAN by 1953. One population was subsequently redistributed to both species in the USA from 1992. *R. neta* arrived accidentally in the USA by 1937 and CAN by 1957. This agent has not been intentionally redistributed. A third *Rhinusa* species (*R. linariae*) was only intentionally introduced, and was released on both species in both the USA and CAN in 1996. *Calophasia lunula* was intentionally introduced in 1962 onto both toadflaxes in CAN, and redistributed to both species in the USA by 1968. What was believed to be *Mecinus janthinus* was released on both toadflaxes in CAN from 1991 and in the USA from 1996. It has since been revealed the cryptic *M. janthiniformis* was part of releases made in CAN in 1992. *M. janthiniformis* has since been redistributed and spread naturally to the USA. The two *Eteobalea* moths (*E. intermediella* and *E. serratella*) were intentionally released on both toadflaxes in both countries in 1992.

CURRENT STATUS: Both *Eteobalea* moths failed to establish in both the USA and CAN. *R. linariae* failed to establish in the USA, and is only established on yellow toadflax in BC where its populations and root-galling impact are both limited. *B. pulicarius* and *R. antirrhini* are both widespread on yellow toadflax in the USA and CAN. Impact and abundance are greater on this species than Dalmatian. However, even at high densities, the flower- and seed-feeding by both species has little overall impact. *C. lunula* occurs on both species in both countries, but populations are typically limited. Even at high densities, plants can typically recover from heavy defoliation. *Mecinus janthiniformis* has proven highly effective against Dalmatian toadflax in the USA and CAN. It has controlled the weed at numerous sites in both countries. *M. janthinus* is more limited by cold climates and by the confusion from the cryptic species identification, though populations are increasing now that the situation has been clarified. Additional time is needed to determine if populations will build on yellow toadflax, similar to *M. janthiniformis* on Dalmatian, though early results are encouraging.

RECOMMENDATIONS: USA and CAN: Due to their already widespread distribution and limited impact, redistributions of *B. pulicarius* and *R. antirrhini* are not recommended. The limited populations of *R. linariae* make this species difficult to collect; its limited impact also makes it a low priority for redistribution. *C. lunula* is more available and its limited populations may warrant supplementation. However, this species is less damaging to toadflax over time as heavily attacked plants often recover. Consequently it is a low priority for redistribution. **Concern for nontarget attack should dissuade intentional redistribution of *C. lunula*.** *M. janthiniformis* is very effective on Dalmatian toadflax but is already quite widespread. Where this species is absent, adults should be redistributed in spring using nets and aspirators. The true *M. janthinus* should also have a high priority for redistribution to yellow toadflax sites, when populations are sufficiently large for collection. Nets and aspirators can again be used to collect adults in spring. Emphasis should be placed on redistributions to sites with warmer climates and low elevations.

Agent	Adult	Impact	Recommendation
Brachypterolus pulicarius		Prefers yellow on which delays flowering, reduces seed production. Though abundant, overall impact minimal.	Already widespread in USA and CAN with little overall impact to yellow so is a low priority for redistribution. Not intentional in CAN.
Calophasia lunula		Limited abundance on both yellow and Dalmatian in USA and CAN. High densities cause heavy defoliation, but plants usually recover.	Limited impact makes low priority for redistribution. Reports of nontarget attack; redistribute with caution.
Mecinus janthiniformis *Mecinus janthinus*		Mining and adult feeding decrease Dalmatian significantly in USA and CAN. Populations still limited on yellow.	*M. janthiniformis* most effective agent on Dalmatian. Should be redistributed where not already present. *M. janthinus* should be redistributed to yellow.
Rhinusa antirrhini		Most abundant strain in USA and CAN prefers yellow. Floral feeding reduces seed production. Despite high abundance, impact limited.	Limited impact despite high abundance on yellow makes this a low priority for redistribution on either species.
Rhinusa linariae		Prefers yellow. Adult feeding, larval root-galling reduce plant nutrient reserves. In BC only; populations too low for significant impact.	Widely failed releases and low impact of established populations make this a low priority for redistribution.

Brachypterolus: Daniel K. MacKinnon, Colorado State University, *Calophasia, Rhinusa antirrhini*: Laura Parsons, University of Idaho, *Mecinus, Rhinusa linariae*: Bob Richard, USDA APHIS PPQ (all www.bugwood.org)

Brachypterolus pulicarius (L.)

Toadflax flower-feeding beetle

DESCRIPTION: Larvae are yellow with brown head capsules and are up to 7 mm long. Adults are shiny, dark brown to black, or sometimes black with brown mottling. They are 2-3 mm long and somewhat oval.

Brachypterolus pulicarius: a) larva, b) adult (a,b Daniel K. MacKinnon, Colorado State University), c) adults (Susan Turner, British Columbia Ministry of Forests) (all www.bugwood.org)

LIFE CYCLE: Adults emerge in late spring and feed on young toadflax shoot tips. Females lay eggs singly into unopened toadflax buds, just beneath the folded petals. Hatching larvae feed on flower pollen, anthers, ovaries, and immature seeds. They develop through three instars and drop to the soil in fall to overwinter as pupae in soil litter. There is one generation per year.

DAMAGE: Adult feeding can delay flowering and reduce the number of healthy flowers (and thus seeds) produced. Larval feeding is generally more significant, reducing seed output by more than 75% in attacked flowers. Decreasing seed output does not kill existing plants but can help reduce the rate of spread for toadflax population spread.

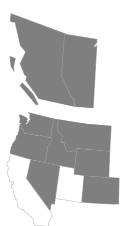
PREFERRED HABITAT: Well adapted to a variety of environmental conditions and can be found throughout the majority of toadflax infestations in North America.

HISTORY: Initially found as an unintentional introduction on yellow toadflax in NY (USA) in 1919 from where it spread throughout the USA on both yellow and Dalmatian toadflax. First recorded on Dalmatian and yellow toadflax as an accidental introduction in BC (CAN) in 1953. One population found feeding exclusively on Dalmatian in Canada was subsequently redistributed to Dalmatian in MT, ID, NV, and WY in 1992 and yellow toadflax in MT in 1997. The different groups of *B. pulicarius* in the USA now overlap. Because they are not genetically different and are likely moving between the two weed species on their own, they can no longer be differentiated.

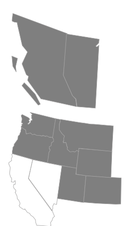
CURRENT STATUS: It was initially believed different biotypes of *B. pulicarius* had evolved sufficiently to be suited differently to yellow and Dalmatian toadflax. Recent genetic studies have since found no evidence to support this. *B. pulicarius* prefers and performs better on yellow toadflax; the use of Dalmatian is incidental in both the USA and Canada. On Dalmatian toadflax in the USA, high densities (such as in ID, OR, WA) can stunt weed height and causes increased branching, though overall impact to flowering and seed production is minimal at most sites. It is abundant on yellow toadflax in the USA on which it can delay flowering and reduce seed production by 80-90% at some locations. However, overall impact is minimal. On yellow toadflax in Canada, it is abundant but overall impact is limited. (It delays flowering and seed production but has not truly changed the scope or prevalence of problems associated with yellow toadflax). Found sporadically on Dalmatian toadflax in Canada but appears to be too rare to have any major impact on seed production.

REDISTRIBUTION: Adults can be collected with a sweep net and aspirator during spring when plants are in bud or flowering and transferred to new infestations in groups of 200. Establishment can be monitored by observing adults on toadflax stem tips the following spring. Alternatively, flowers can be dissected to reveal larvae feeding within during late spring and early summer.

NOTES: **This agent was not an intentional introduction in Canada.** Though *B. pulicarius* was first an accidental introduction in the USA, it was subsequently intentionally redistributed and also later introduced intentionally from Canada. Competition between *Rhinusa antirrhini* and *Brachypterolus pulicarius* prevents additive impact in many locations.



Dalmatian



yellow

Calophasia lunula (Hufnagel)

Toadflax moth

DESCRIPTION: Eggs are pale yellow and strongly ribbed. Larvae are gray initially but have black and yellow stripes with white spots at the final instar. They can be up 40 cm long. Pupae are golden brown within green cocoons. Adults are a mottled gray-brown with light and dark markings on the wings. They are 1-1½ cm long with a wingspan of 2½-3 cm.

Calophasia lunula: a) larva, b) cocoon (Gary Piper, Washington State University, www.bugwood.org), c) adult (a,c Laura Parsons & Mark Schwarzländer, University of Idaho)

LIFE CYCLE: Adults emerge in late spring and feed on nectar. Females lay 30-80 eggs on toadflax foliage. Hatching larvae feed on young leaves, but will consume lower stem leaves as plants become increasingly defoliated. Upon maturation after the fifth instar, larvae move to the base of toadflax and spin cocoons of silk, chewed leaves, and soil. Adults emerge in mid-summer and repeat the process. There are 1-3 generations per year, the final one overwintering as pupae within cocoons.

DAMAGE: Larval defoliation can kill young toadflax plants.

PREFERRED HABITAT: Prefers dry with coarse-textured soils. Establishment can be limited in cold climates.

HISTORY: Introduced onto both Dalmatian and yellow toadflax in AB and BC (CAN) from populations sourced in Switzerland (1962) and former Yugoslavia (1989). The Switzerland population was redistributed from Canada to the USA from 1968 on both species of toadflax (CO, ID, MT, NV, OR, WA, WY).

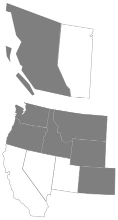
CURRENT STATUS: Populations are limited on both Dalmatian and yellow toadflax throughout much of the USA, though some localized population explosions occur. At high densities it can lead to patch defoliation. Overall, larval feeding typically decreases leaf area but does not disrupt the photosynthetic

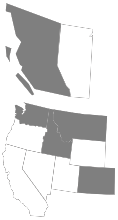
Calophasia lunula: d) larvae and damage (Laura Parsons & Mark Schwarzländer, University of Idaho), e) larval damage (Susan Turner, British Columbia Ministry of Forests) (both www.bugwood.org)

capacity sufficiently to have significant impact on attacked plants. The population from former Yugoslavia established on both yellow and Dalmatian toadflax in Canada where the impact is limited for the same reasons as in the USA. Parasitism may also limit populations in some parts of Canada.

REDISTRIBUTION: Adults are delicate and are easily damaged by sweep netting. They are also difficult to find. Consequently, this biocontrol agent is best transferred in the larval stage. Larvae can be gently picked from toadflax foliage using forceps in summer through fall. Later instar larvae may regurgitate a dark liquid when handled; this is not harmful to the insect or collector. Establishment can be monitored by observing larvae on toadflax foliage throughout the following growing season.

NOTES: **There are reportedly some concerns regarding this agent's host specificity. Caution should be taken during its redistribution, especially in areas with desirable snapdragon species present.**





Mecinus janthiniformis Toševski & Caldara & *M. janthinus* Germar

Toadflax stem weevils

DESCRIPTION: Both species are morphologically very similar. Larvae are white with brown head capsules and are up to 5 mm long. Adults are bluish-black, elongate with long snouts, and are up to 5 mm long.

Mecinus spp. a) larva (Rosemarie De Clerck-Floate, Agriculture and Agri-Food Canada), b) pupa, c) adult (b,c Bob Richard, USDA APHIS PPQ) (all www.bugwood.org)

LIFE CYCLE: Overwintering adults emerge in early spring and feed on shoot tips, producing a shot hole pattern in upper leaves. *M. janthinus* emerges a few weeks earlier on yellow toadflax than *M. janthiniformis* does on Dalmatian. Females chew holes into toadflax stems and lay eggs singly (up to 45 in a lifetime), covering eggs with chewed plant tissue. Hatching larvae feed in short tunnels chewed into toadflax stems. *M. janthinus* tends to mine lower in toadflax stems than does *M. janthiniformis*. Pupation occurs in late summer within the chambers inside feeding tunnels. Adults overwinter inside pupal chambers. There is one generation per year.

DAMAGE: Adult feeding stunts shoots and roots and suppresses flowering. Larval mining severs water/nutrient conducting tissues, causing desiccation and death.

PREFERRED HABITAT: *M. janthiniformis* is well adapted to a variety of environmental conditions and can be found throughout much of Dalmatian toadflax infestations in the Northwest. *M. janthinus* prefers more mild, low-elevation sites in its native range.

HISTORY: What was originally released in the USA and Canada as *Mecinus janthinus* was recently discovered to be a mixture of *M. janthinus* and the cryptic *M. janthiniformis*. The true *M. janthinus* was sourced from France and Germany and released in the USA on Dalmatian from 1996 (MT, WA, WY) and on yellow from 1997 (CO, ID, MT, OR, UT, WA, WY). The same France/Germany source was used for *M. janthinus* releases on both Dalmatian and yellow toadflax

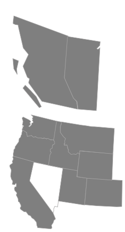
Mecinus spp. damage: (d,e,f) d) Jennifer Andreas, Washington State University Extension, e) (Gary Piper, Washington State University, www.bugwood.org), f) (Laura Parsons, University of Idaho)

in Canada from 1991 (AB, BC). *M. janthiniformis* was reportedly introduced from the Republic of Macedonia and released on Dalmatian toadflax in Canada from 1992 (AB, BC). It was redistributed from Dalmatian to yellow toadflax in AB, BC from 2000. Redistributions of *M. janthiniformis* were made from Canada to Dalmatian in the USA post 1996 (CA, CO, ID, MT, NV, OR, UT, WA, WY) and to yellow in MT post 1996 in mixes with the true *M. janthinus*.

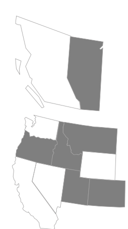
CURRENT STATUS: *M. janthiniformis* usually prefers Dalmatian toadflax; *M. janthinus* usually prefers yellow. *M. janthiniformis* is abundant on Dalmatian in the USA and Canada where it has reduced the weed dramatically throughout much of its range. *M. janthinus* is established on yellow in the USA and Canada where densities and impact can be high locally but are typically low overall. Parasitism, cold climates, and incorrect host/agent matching with the *janthinus/janthiniformis* complex are all contributors, though impact is now increasing at some sites.

REDISTRIBUTION: Adults can be swept from toadflax foliage from spring through mid-summer when plants are bolting to late flowering. Adults should be readily visible, mating and congregating on shoot tips and in leaf axils. They are most active during the warm time of day and in calm, sunny weather. Establishment can be monitored by observing adults on toadflax foliage the following spring or by dissecting stems for larvae from late spring through late summer.

NOTES: As the identification of the cryptic *M. janthiniformis* has only recently been made, sorting the release history and establishment status of both *Mecinus* species on both toadflax species is a work in progress in North America.



M. janthiniformis on Dalmatian



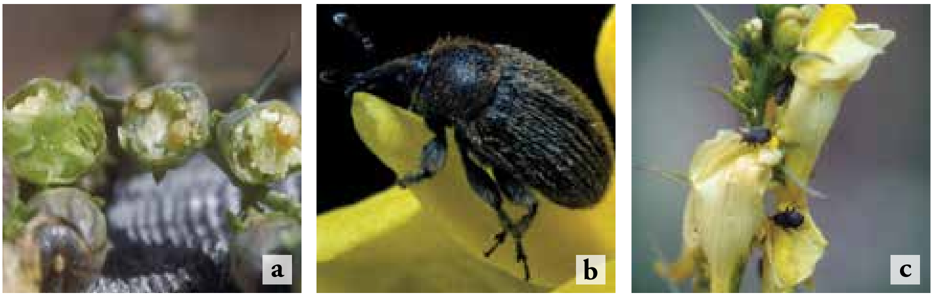
M. janthinus on yellow

Rhinusa antirrhini (Paykull)

Toadflax seed capsule weevil

SYNONYMS: *Gymnetron antirrhini* (Paykull)

DESCRIPTION: Larvae are creamy white with dark brown head capsules and are up to 4 mm long. Adults are gray to black and covered in dense, short hairs. They have a long, distinctly curved and pointed snout. Adults are typically 2½ mm long and have a wide body.



Rhinusa antirrhini: a) larvae in seeds, b) adult (Laura Parsons, University of Idaho), c) adults on flowers (a,c Eric Coombs, Oregon Department of Agriculture) (all www.bugwood.org)

LIFE CYCLE: Overwintering adults emerge in late spring and feed on shoot tips and young leaves. As toadflax flowers open, adults feed on pollen and flower tissue. Females lay 40-50 eggs singly inside flower ovaries, triggering the development of galls of enlarged seed tissue. Hatching larvae feed on seed tissue. Pupation occurs within seed capsules, with adults emerging in late summer or early fall to overwinter in soil litter. There is one generation per year.

DAMAGE: Galls and larval feeding reduce seed viability. Adult feeding is typically insignificant.

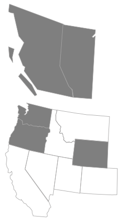
PREFERRED HABITAT: Overall habitat preferences are unknown but it is distributed throughout much of the toadflax habitats in North America.

HISTORY: An unintentional introduction referred to as the vulgaris biotype was found on yellow toadflax in the eastern USA in 1909 and on Dalmatian toadflax by 1957. This biotype was also intentionally redistributed from yellow to Dalmatian toadflax in WY in 1986. An additional strain (dalmatica biotype) was intentionally introduced from former Yugoslavia and released against Dalmatian toadflax from 1996 (MT, WY). An accidentally introduced population was first recorded in BC (CAN) in 1917. An additional strain was intentionally introduced from former Yugoslavia and released on Dalmatian toadflax in AB and BC from 1993.

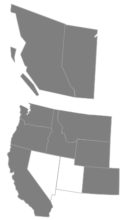
CURRENT STATUS: The vulgaris biotype is established on the narrow-leaved form of Dalmatian toadflax in the USA. Though attack rates on this form can be high locally, it is the least common and problematic form of Dalmatian toadflax so overall impact is minimal. It is unknown if the dalmatica biotype established on Dalmatian toadflax in the USA. Larval feeding of the vulgaris biotype on yellow toadflax destroys some seeds in attacked capsules. Seed reduction between 85 and 90% have been reported in WA, though it is typically much lower in other areas. Attack rates from 30-40% in OR had minimal impact on plant density, so it is believed that overall impact is limited. The unintentionally introduced strain of *R. antirrhini* is established on both Dalmatian and yellow toadflax in Canada. Populations of the new strain are confirmed established and increasing on Dalmatian. Though the impact of this intentional strain has yet to be studied in Canada, the yellow toadflax strain is widespread but still has yet to achieve satisfactory control.

REDISTRIBUTION: Already widespread on yellow toadflax in North America. Where redistributions may be required, adults can be collected with a sweep net and aspirator during late spring when plants are in bud or early flowering and can be transferred to new infestations in groups of 200. Establishment can be monitored by observing adults on toadflax flowers the following spring. Alternatively, seeds can be dissected to reveal larvae feeding within throughout the summer.

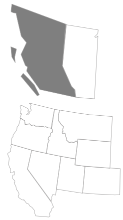
NOTES: Competition between *R. antirrhini* and *Brachypterolus pulicarius* prevents additive impact in many locations. *R. antirrhini* has a more pointed and curved snout than *R. neta* and is grayish-black while *R. neta* is gray to brown. *R. antirrhini* differs from *R. linariae* in its location of attack (adults attack flowers and larvae attack seeds while *R. linariae* adults attack stems and larvae attack roots).



vulgaris biotype
Dalmatian



vulgaris biotype
yellow



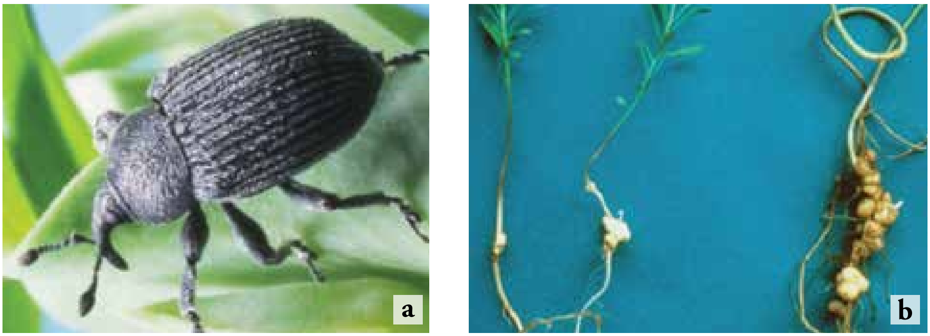
dalmatica biotype
Dalmatian

Rhinusa linariae (Panzer)

Toadflax root-galling weevil

SYNONYMS: *Gymnetron linariae* Panzer

DESCRIPTION: Larvae are creamy white with brown head capsules and are up to 4 mm long. Adults are small and black with pronounced, curved snouts. They are covered in dense, short hairs and up to 2½ mm long.



Rhinusa linariae: a) adult (Bob Richard, USDA APHIS PPQ), b) damage (Rosemarie De Clerck-Floate, Agriculture and Agri-Food Canada) (both www.bugwood.org)

LIFE CYCLE: Overwintering adults emerge in spring and feed on toadflax stems. As flowers open, adults feed on pollen and flower tissue. Females lay eggs singly into pockets chewed into toadflax root crowns, triggering gall formation. Hatching larvae feed on galled root tissue. Pupation occurs in galls with adults emerging in mid- to late summer. Adults may feed briefly on toadflax stems, then overwinter in soil litter. There is one generation per year.

DAMAGE: Galls are a metabolic sink and disrupt nutrient transport. Adult and larval feeding reduces nutrient reserves which may stunt plants and reduce reproductive output.

PREFERRED HABITAT: Habitat preferences are unknown are populations are restricted to limited areas in only BC. In European literature, *R. linariae* does well in grassland habitats.

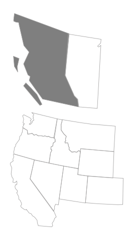
HISTORY: Introduced from Germany and released on Dalmatian toadflax in ID, MT, OR (USA) from 1996 as well as on yellow toadflax in MT from 1996. Introduced from central and southern Europe and southern Russia and released on both Dalmatian and yellow toadflax in AB and BC (CAN) from 1996. After USA introductions failed to establish, a population from BC was redistributed to CO (USA) in 2008.

CURRENT STATUS: Established only on yellow toadflax and only in Canada where populations are very limited. Because populations are slow to build, redistributions are made every 2-4 years when possible. Adult foliage feeding and larval galling reduce plant nutrient reserves. However, populations are too low for significant impact.

REDISTRIBUTION: Populations are restricted to BC (CAN) where they are generally too small to redistribute. Where appropriate, adults could be collected from toadflax stems and flowers in spring using a sweep net and aspirator. They can be transferred in groups of 100-200 to new infestations. Establishment can be monitored by observing adults on toadflax foliage the following spring or by digging up roots in summer to observe galls on root tissue.

NOTES: *R. linariae* has a more pointed and curved snout than *R. neta* and is black while *R. neta* is gray to brown. *R. linariae* differs from *R. antirrhini* in its location of attack (adults on stems and larvae on roots compared to *R. antirrhini* adults attacking flowers and larvae attacking seeds.)

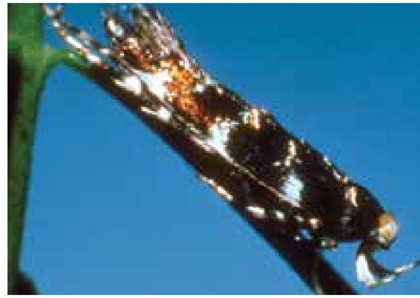
Dalmatian



yellow

Toadflaxes, Non-Established Agents

Eteobalea intermediella Riedl & *E. serratella* Treitschke (Lepidoptera: Cosmopterigidae)



Eteobalea intermediella: Bob Nowierski, Montana State University (www.bugwood.org)

DESCRIPTION AND LIFE CYCLE: Both species are very similar, differing mainly in their egg-laying behavior and number of generations per year. Adults are slender, 8-10 mm long, and are black with white and yellow spots. They have a wingspan up to 18 mm. Adults emerge in late spring, and females lay up to 180 eggs in small strings at the base of toadflax stems. Hatching larvae bore into the root crown where they feed on tissue inside tunnels they carve and line with silk. Larvae are off-white with brown heads. They develop through five instars and are up to 12 mm long. *E. serratella* has one generation per year while *E. intermediella* has two; second generation adults emerge in mid-summer. Mature larvae of both species overwinter in roots then pupate in spring inside cocoons within the root crown.

HISTORY: *E. intermediella* from former Yugoslavia and *E. serratella* from Italy were introduced against both Dalmatian and yellow toadflax in MT (USA) from 1996. *E. intermediella* from Serbia was released on Dalmatian toadflax in AB and BC (CAN) in 1992. *E. serratella* from Italy was released on yellow toadflax in AB and BC in 1992. All introductions failed to permanently establish in both the USA and Canada.

Rhinusa neta (Germar)
(Coleoptera: Curculionidae)

Gyorgy Csoka, Hungary Forest Research Institute (www.bugwood.org)

DESCRIPTION AND LIFE CYCLE: Overwintering adults emerge in late spring and feed on toadflax shoot tips and young leaves. Adults are gray or brown with a snout that is somewhat blunt and only slightly curved. They are covered in dense, short hairs and are typically 3 mm long. As flowers open, adults feed on pollen and flower tissue. Females lay 40-50 eggs singly inside flower ovaries. Hatching larvae feed on seed tissue through three instars. Larvae are creamy white with light brown head capsules and are up to 4 mm long. Pupation occurs within seed capsules, with adults emerging in late summer or early fall to overwinter in soil litter. There is one generation per year.

HISTORY AND CURRENT STATUS: Accidental introduction discovered on both Dalmatian (narrow-leaved form) and yellow toadflax in eastern states of the USA in 1937 and in Canada by 1957. It is presently established on both species in at least WA and possibly other states in the Northwest, but occurs only in scattered populations. Established on both species in BC (CAN), but only on yellow toadflax in AB. It prefers yellow toadflax over Dalmatian in both countries. Larval feeding destroys a high proportion of seeds in attacked capsules, though overall attack rates to yellow toadflax are typically limited in the USA. Even in Canada, where yellow toadflax attack rates are higher, satisfactory control has yet to be achieved. **Not approved for redistribution in the USA.**

Leafy spurge

Euphorbia esula L.

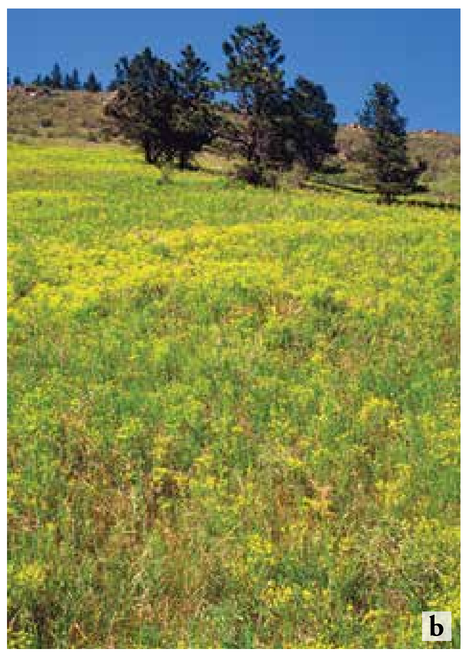
SYNONYMS: N/A

ORIGIN: Native to Eurasia. Likely introduced to North America in contaminated ship's ballast; recorded as early as 1827.

DESCRIPTION: Herbaceous perennial with thickly clustered stems up to 3 ft tall (90 cm) and roots 9-21 ft deep (3-7 m). The rhizomatous roots are brown and have pinkish buds. Leaves are alternate, narrow, and 1-3 in long (2½-7½ cm). They have smooth margins and a deep midvein. Flowers are tiny, lime green, and enclosed by showy, yellow-green bracts. The are arranged in clusters at stem tips. Seed pods contain three smooth, elongated, gray-brown seeds.

HABITAT: Occupies many different habitats and soil types and can be found from grasslands to forests to riparian areas. It is dominant in pastures, rangelands, waste areas, and along roadsides.

ECOLOGY: Reproduces both by seed and by its spreading root system. Root



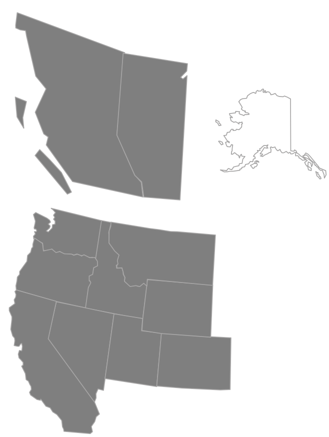
a) plant (John M. Randall, The Nature Conservancy), b) infestation (William M. Ciesla, Forest Health Management International) (both www.bugwood.org)

c) milky latex, d) leaves and stem (K. George Beck & James Sebastian, Colorado State University), e) flowers (c,e Norman E. Rees, USDA ARS) (all www.bugwood.org)

pieces as small as ½ in (1 cm) can develop into new plants. Peak germination is from April through May with new seedlings usually not flowering the first year. Flowers appear from June to July. A second flowering often occurs in late summer or early fall. Seed pods shatter upon maturation, scattering seeds great distances. Seeds are also readily transported by water, humans, and other animals. Seeds may remain viable in the soil for up to eight years.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Aphthona abdominalis, A. cyparissiae, A. czwalinai, A. flava, A. lacertosa, A. nigriscutis, Chamaesphecia crassicornis, C. hungarica, C. tenthrediniformis, Hyles euphorbiae, Oberea erythrocephala, Spurgia capitigena* and *S. esulae*; CAN: *Aphthona cyparissiae, A. czwalinai, A. flava, A. lacertosa, A. nigriscutis, Chamaesphecia astatiformis, C. crassicornis, C. hungarica, C. tenthrediniformis, H. euphorbiae, Lobesia euphorbiana, Minoa murinata, O. erythrocephala, Pegomya curticornis, P. euphorbiae, S. capitigena* and *S. esulae.*

NOTES: Leafy spurge is a controversial and morphologically variable species considered to represent a complex of forms, species and hybrids. A toxic, milky latex oozes from damaged stems and leaves. Caution should be taken while handling this plant.



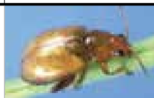
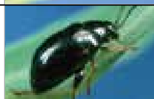
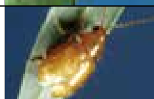
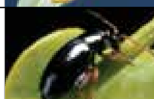
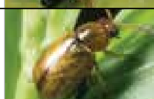
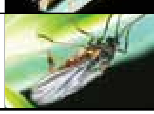
Leafy Spurge Biological Control

HISTORY IN THE NORTHWEST: Biological control of leafy spurge began in 1966 in North America with the release of *Hyles euphorbiae* in both the USA and Canada. *Oberea erythrocephala* was next released in Canada in 1979 and in the USA from 1980. Five *Aphthona* flea beetles were released in both countries throughout the 1980s, with an additional species (*A. abdominalis*) released in 1993 only in the USA. *Lobesia euphorbiana* and *Minoa murinata* were released only in Canada in 1983 and 1988, respectively. Four *Chamaesphecia* species were released in North America from the 70s to the 90s. *Pegomya* and *Spurgia* agents were released as single species in the late 80s, though both have since been split into two species each. *Pegomya* spp. were approved in both the USA and Canada but released only in the USA.

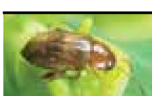
CURRENT STATUS: All *Chamaesphecia* and *Pegomya* species failed to establish in North America, as did *A. abdominalis* and *M. murinata*. *Spurgia capitigena* is established only in more eastern states and provinces not covered in this field guide. *S. esulae* is established on leafy spurge in a few states in western USA where its density remains low and stem-galling impact is negligible. *H. euphorbiana* populations are hindered by disease and predation. Even at high densities, defoliation caused by *H. euphorbiana* does not kill plants. *L. euphorbiana* is established in BC, Canada where leaf tying causes moderate impact to leafy spurge. *O. erythrocephala* is widely distributed but typically at densities too low to cause significant impact. This species may be too host-specific to some leafy spurge biotypes. The five established *Aphthona* flea beetles have variable abundance and impact in North America. *A. cyparissiae* and *A. czwalinai* are believed to be of only limited abundance in western states and provinces, though this is currently under study. *A. flava* is of moderate abundance where its root-feeding impact is likely limited alone, but may be significant in combination with other agents. *A. lacertosa* and *A. nigriscutis* are highly effective at reducing leafy spurge density in both the USA and Canada. *A. lacertosa* is suited to a variety of habitats while *A. nigriscutis* is typically only effective at dry, open sites.

RECOMMENDATIONS: USA: *A. flava* and *H. euphorbiana* have medium priority for redistribution. Though they likely do not provide control alone, they can be useful in combination with other agents at mesic, open sites. *A. lacertosa* and *A. nigriscutis* have the highest priority for redistribution; *A. lacertosa* can be used under a variety of conditions while *A. nigriscutis* should be redistributed only to dry, open sites. Remaining species have the lowest priority for redistribution. ***L. euphorbiana* is not approved for release in the USA.** CAN: Similar to the USA, however *L. euphorbiana* is also of medium priority for redistribution to warm sites to complement other agents.

Established Agents

AGENT	ADULT	IMPACT	RECOMMENDATION
Aphthona cyparissiae		Limited abundance so root-feeding ineffective alone. Best in combination with others.	Low priority but could be redistributed to dry, mesic sites to complement other agents.
Aphthona czwalinai		Root-feeding reduces plant density. Currently believed to be limited in abundance.	Tentative low priority in CAN and western USA due to decreasing abundance.
Aphthona flava		Limited-moderate abundance so root-feeding ineffective alone. Best in combination.	Medium priority but could be redistributed to dry, mesic sites to complement other agents.
Aphthona lacertosa		Abundant so root-feeding highly effective at most sites in USA and CAN.	Already widespread, but high priority for redistribution to sites with variable conditions.
Aphthona nigriscutis		Abundant so root-feeding highly effective at dry sites in USA and CAN.	Already widespread but high priority for redistribution to dry open sites.
Hyles euphorbiae		Defoliation at high densities does not kill plants. Hindered by disease and predation.	Low priority alone but could be redistributed where it complements other agents.
Lobesia euphorbiana		Moderate abundance and impact in BC CAN. Leaf tying reduces reproduction.	Not released in USA. Medium priority for redistribution to warm sites as complement.
Oberea erythrocephala		Stem-mining kills large plants but abundance typically too low for high impact.	Low priority as populations remain limited. May be too host-specific for some spurge.
Spurgia capitigena & *S. esulae*		Abundance low. Even at high densities, stem tip galling occurs too late for impact.	Low impact and continued limited abundance make low priority for redistribution.

Approved, Non-Established Agents

Aphthona abdominalis	*Chamaesphecia* spp.	*Minoa murinata*	*Pegomya* spp.
			

Credits for photos above: See individual agent pages

Aphthona cyparissiae (Koch)

Brown dot leafy spurge flea beetle

DESCRIPTION: Larvae are 1-5 mm long, have short legs, a white body and yellow head with thick head capsule. Adults are usually just over 3 mm long. They are a light reddish-brown color and oval in shape.

Aphthona cyparissiae: a) pupa (Neal Spencer, USDA ARS, www.bugwood.org), b) adult (R. Richard, USDA APHIS)

LIFE CYCLE: Overwintering larvae resume feeding on young roots in early spring as leafy spurge is resuming growth. Pupation occurs in the soil. Adults are active from early summer to late summer as leafy spurge bolts, flowers, and matures. Females lay numerous eggs in the soil throughout the growing season. Hatching larvae burrow into the soil to feed on roots, developing through three instars. There is one generation per year.

DAMAGE: Larvae feed on root hairs and young roots, inhibiting root function and stunting leafy spurge stem growth. Adults feed on leaves and flowers, decreasing photosynthesis and plants' sugar-making ability for root reserves.

PREFERRED HABITAT: Does best in moderately-dense infestations of leafy spurge found on more dry, mesic sites. Does poorly in soils with too much sand or clay.

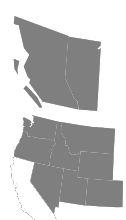
HISTORY: Introduced from Austria, Hungary, Italy, and Switzerland and released on leafy spurge in the USA from 1986 (CO, ID, MT, NV, OR, UT, WA, WY). Introduced from Austria, Hungary, and Switzerland and released on leafy spurge in Canada from 1982 (AB, BC).

CURRENT STATUS: Widespread on leafy spurge in the USA where it is well established at a few release sites but is overall much less abundant than other

Aphthona spp. Populations are highest at dry, mesic sites with sandy loam soils. Under these conditions, plant density may decrease quickly, but unattacked roots recover. Numerous years under the right conditions are required for this agent to decrease leafy spurge populations permanently. Damage is typically greatest in combination with other *Aphthona* spp. High populations in Canada effectively control the weed at dry, open sites, but insect densities are too low and ineffective elsewhere.

REDISTRIBUTION: Best collected in the adult stage using a net and aspirator in mid-summer when plants are flowering. They can be transferred to new sites in groups of 200-300. Establishment can be monitored by observing adults on leafy spurge foliage the following summer during the heat of the day. Keep in mind flea beetles quickly jump away when disturbed. Alternatively, roots can be dissected for evidence of larval feeding from autumn through the following spring. Note that feeding larvae can be extremely difficult to distinguish from other leafy spurge *Aphthona* species.

NOTES: *A. nigriscutis* typically has a black spot on the back while *A. flava* is generally more orange in color than *A. cyparissiae*. However, coloration differences among brown beetles are often unreliable. *A. czwalinai* and *A. lacertosa* are black beetles.



Aphthona czwalinai (Weise)

Black leafy spurge flea beetle

DESCRIPTION: Larvae are up to 5 mm long, slender, whitish and with a brown head capsule. Adults are shiny black. Middle and front legs are reddish-brown while the entire surfaces of the hind femurs are dark. Males are just under 3 mm, while females are usually just over 3 mm.

Aphthona czwalinai: a) pupa (Neal Spencer, USDA ARS, www.bugwood.org), b) adult (R. Richard, USDA APHIS)

LIFE CYCLE: Overwintering larvae resume feeding on young roots in early spring as leafy spurge is resuming growth. Pupation occurs in the soil. Adults are active from early summer to late summer as leafy spurge bolts, flowers, and matures. Females lay numerous eggs in the soil throughout the growing season. Hatching larvae burrow into the soil to feed on roots, developing through three instars. There is one generation per year.

DAMAGE: Larvae feed on root hairs and young roots, inhibiting root function and stunting leafy spurge stem growth. Adults feed on leaves and flowers, decreasing photosynthesis and plants' sugar-making ability for root reserves.

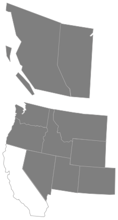
PREFERRED HABITAT: Does best in moderately-dense infestations of leafy spurge found on more mesic sites. Does poorly in soils with too much sand or clay.

HISTORY: Introduced from Austria and Hungary and released on leafy spurge in the USA from 1987 (CO, ID, MT, NV, OR, UT, WA, WY). A second population from Russia was released in MT in 1993. Introduced from Austria and released on leafy spurge in Canada from 1985 (AB). Populations initially from Austria and Hungary were redistributed from the USA and released in Canada from 1995 (AB, BC).

CURRENT STATUS: The population from Austria and Hungary is established on leafy spurge in the USA. For many years it was believed that control of leafy spurge on the local level was achieved primarily by *Aphthona nigriscutis, A. czwalinai* and *A. lacertosa*. *A. czwalinai* was thought to have been a major component in the early years of the leafy spurge biocontrol program until it was discovered that most of what was being called *A. czwalinai* was in fact *A. lacertosa*. It was subsequently considered insignificant, until large populations were recently found in ND. It is unknown if the Russian population established in MT. *A. czwalinai* is established on leafy spurge in Canada though its distribution is limited. Release sites now appear to be dominated by *A. lacertosa.* Resampling efforts are currently underway at initially pure *A. czwalinai* release sites and pure *A. lacertosa* sites throughout Canada for molecular analysis.

REDISTRIBUTION: Best collected in the adult stage using a net and aspirator in mid-summer when plants are flowering. They can be transferred to new sites in groups of 200-300. Establishment can be monitored by observing adults on leafy spurge foliage the following summer during the heat of the day. Keep in mind flea beetles quickly jump away when disturbed. Alternatively, roots can be dissected for evidence of larval feeding from autumn through the following spring. Note that feeding larvae can be extremely difficult to distinguish from other leafy spurge *Aphthona* species.

NOTES: *A. czwalinai* has solid dark hind femurs compared to the other black beetle, *A. lacertosa*. *A. cyparissiae, A. flava,* and *A. nigriscutis* are all brown beetles. Occasionally referred to as *A. czwalinae*.



Aphthona flava Guillebeau

Copper leafy spurge flea beetle

DESCRIPTION: Larvae are 1-6 mm long, slender, whitish (more translucent when young) and with a brown head capsule. Adults are orangish-copper in color and 3½ mm long. Females are slightly larger than males.

Aphthona flava: a) larva (Neal Spencer, USDA ARS), b) adult (USDA APHIS PPQ), c) adults and damage (Norman E. Rees, USDA ARS) (all www.bugwood.org)

LIFE CYCLE: Overwintering larvae resume feeding on root hairs in early spring as leafy spurge is resuming growth. Pupation occurs in the soil. Adults are active from early summer to early fall as leafy spurge bolts, flowers, and matures. Females lay numerous eggs in groups on leafy spurge stems at or just below the soil surface. Hatching larvae burrow into the soil to feed on roots, developing through three instars. There is one generation per year.

DAMAGE: Larvae feed on root hairs and young roots, inhibiting root function and stunting leafy spurge stem growth. Adults feed on leaves and flowers, decreasing photosynthesis and plants' sugar-making ability for root reserves.

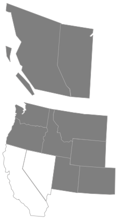
PREFERRED HABITAT: Does best in moderately-dense infestations of leafy spurge found on more mesic, dry sites in alluvial soils above flood lines and light shade (USA) and at mesic, dry sites with warm temperatures (CAN). Does poorly in soils with too much sand or clay. It is probably less likely to survive low temperatures than other *Aphthona* spp.

HISTORY: Introduced from Hungary and Italy and released on leafy spurge in the USA from 1985 (CO, ID, MT, NV, OR, UT, WA, WY). Introduced from Hungary and Italy and released on leafy spurge in Canada from 1982 (AB, BC).

CURRENT STATUS: Widespread in the USA. In one area in MT its effect has been spectacular, but overall it is much less abundant than other *Aphthona* spp. It persists at fairly low levels with little noticeable impact on infestations. Moderately abundant in Canada. Leafy spurge density has declined where populations of *A. flava* are high, however it's not possible to attribute the reduction to *A. flava* alone as the site has been grazed by sheep, and *A. nigriscutis* is also present.

REDISTRIBUTION: Best collected in the adult stage using a net and aspirator in late summer when plants are flowering and beginning to mature. They can be transferred to new sites in groups of 200-300. Establishment can be monitored by observing adults on leafy spurge foliage the following summer during the heat of the day. Keep in mind flea beetles quickly jump away when disturbed. Alternatively, roots can be dissected for evidence of larval feeding from autumn through the following spring. Note that feeding larvae can be extremely difficult to distinguish from other leafy spurge *Aphthona* species.

NOTES: *A. flava* is typically more orange than the other two brown beetles, *A. cyparissiae* and *A. nigriscutis*. *A. flava* also does not have the black spot on the back that *A. nigriscutis* has. However, coloration differences among brown beetles are often unreliable. *A. czwalinai* and *A. lacertosa* are black beetles.



Aphthona lacertosa Rosenhauer

Brown-legged leafy spurge flea beetle

DESCRIPTION: Larvae are up to 5 mm long, slender, whitish and with a brown head capsule. Adults are shiny black and 3 mm long. Legs are largely reddish-brown in color. The top of the hind femurs sometimes have dark patches.

Aphthona lacertosa: a) adult (Laura Parsons & Mark Schwarzländer, University of Idaho), b) adults and damage (Todd Pfeiffer, Klamath County Weed Control) (both www.bugwood.org)

LIFE CYCLE: Overwintering larvae resume feeding on young roots in early spring as leafy spurge is resuming growth. Pupation occurs in the soil. Adults are active from early to late summer as leafy spurge bolts, flowers, and matures. Each female lays 200-300 eggs in the soil throughout the growing season. Hatching larvae burrow into the soil to feed on roots, developing through three instars. There is one generation per year.

DAMAGE: Larvae feed on root hairs and young roots, inhibiting root function and stunting leafy spurge stem growth. Adults feed on leaves and flowers, decreasing photosynthesis and plants' sugar-making ability for root reserves.

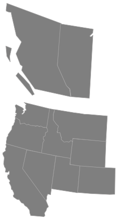
PREFERRED HABITAT: Does best in moderately-dense infestations of leafy spurge found growing in loamy soils. It can adapt locally to both dry and wet habitats in the USA but does better at mesic to moist sites in Canada. Does poorly in soils with too much sand or clay.

HISTORY: Introduced from Austria, Hungary, and former Yugoslavia and released on leafy spurge in the USA from 1993 (CA, CO, ID, MT, NV, OR, UT, WA, WY). Introduced from Hungary and former Yugoslavia in Canada from 1987 (AB, BC from 1990). Populations from Hungary established in the USA were also redistributed to AB and BC from 1995.

CURRENT STATUS: Widespread and abundant in the USA. Along with *A. nigriscutis,* it is significantly reducing leafy spurge density at the local level in most regions. Not effective at all sites. Abundant in Canada where it is reducing leafy spurge plant density at most sites. *A. lacertosa* appears to be displacing *A. czwalinai* at many locations. Resampling efforts are currently underway at initially pure *A. czwalinai* release sites and pure *A. lacertosa* sites throughout Canada for molecular analysis.

REDISTRIBUTION: Best collected in the adult stage using a net and aspirator in early summer when plants are bolting. They can be transferred to new sites in groups of 200-300. Establishment can be monitored by observing adults on leafy spurge foliage the following summer during the heat of the day. Keep in mind flea beetles quickly jump away when disturbed. Alternatively, roots can be dissected for evidence of larval feeding from autumn through the following spring. Note that feeding larvae can be extremely difficult to distinguish from other leafy spurge *Aphthona* species.

NOTES: *A. lacertosa* has lighter colored hind femurs than the other black beetle, *A. czwalinai. A. cyparissiae, A. flava,* and *A. nigriscutis* are all brown beetles.



Aphthona nigriscutis Foudras

Black dot leafy spurge flea beetle

DESCRIPTION: Larvae are 1-6 mm long, slender, whitish (more translucent when young) and with a brown head capsule. Adults are usually just over 3 mm long. They are orangish-brown and typically have a black dot on the back near the leading edge of the wings.

Aphthona nigriscutis: a) larva (Neal Spencer, USDA ARS, www.bugwood.org), b) adult (R. Richard, USDA APHIS)

LIFE CYCLE: Overwintering larvae resume feeding on root hairs in early spring as leafy spurge is resuming growth. Pupation occurs in the soil. Adults are active from early to late summer as leafy spurge bolts, flowers, and matures. Females lay numerous eggs in groups on leafy spurge stems at or just below the soil surface. Hatching larvae burrow into the soil to feed on roots, developing through three instars. There is one generation per year.

DAMAGE: Larvae feed on root hairs and young roots, inhibiting root function and stunting leafy spurge stem growth. Adults feed on leaves and flowers, decreasing photosynthesis and plants' sugar-making ability for root reserves.

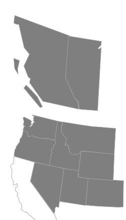
PREFERRED HABITAT: Prefers relatively sparse leafy spurge patches at dry sites with sandier soil. Does poorly in soils with too much clay.

HISTORY: Introduced from Hungary and released on leafy spurge in AB and BC (CAN) from 1983. Canadian populations were redistributed to leafy spurge in the USA from 1989 (CA, CO, ID, MT, NV, OR, UT, WA, WY).

CURRENT STATUS: Widespread and abundant on leafy spurge in the USA. Along with *A. lacertosa*, it is significantly reducing plant density at the local level in most regions. Not effective at all sites. Impact may be hindered by a bacterium which causes high mortality in males, resulting in female-biased populations. Abundance and impact are variable in Canada. It is extremely effective at reducing or removing leafy spurge in open, warm, very dry habitats with lighter soils. Populations are low or absent at moist, sheltered sites on heavy soil.

REDISTRIBUTION: Best collected in the adult stage using a net and aspirator in mid-summer when plants flower. They can be transferred to new sites in groups of 200-300. Establishment can be monitored by observing adults on leafy spurge foliage the following summer during the heat of the day. Keep in mind flea beetles quickly jump away when disturbed. Alternatively, roots can be dissected for evidence of larval feeding from autumn through the following spring. Note that feeding larvae can be very difficult to distinguish from other leafy spurge *Aphthona* species.

NOTES: The other brown beetles *A. cyparissiae* and *A. flava* typically do not have the black spot on the back. *A. flava* is also usually more orange in color than *A. nigriscutis*, though coloration differences among brown beetles are often unreliable. *A. czwalinai* and *A. lacertosa* are black beetles. Spillover feeding by *A. nigriscutis* has been observed on the native *Euphorbia robusta*; as leafy spurge density declined, so did feeding on *E. robusta*, and *E. robusta* populations increased.



Hyles euphorbiae (L.)

Leafy spurge hawk moth

DESCRIPTION: Larvae are up to 10 cm long. They change color upon maturation going from dark green, to brown and yellow longitudinally striped, to green with white spots, to red, black, yellow, and white with a horn at the back end. Larvae contain leafy spurge toxin and are poisonous. Adults have wingspans up to 5 cm and are white, pink, and brown.

Hyles euphorbiae: a) larva, b) pupa (Whitney Cranshaw, Colorado State University, www.bugwood.org), c) adult (a,c R. Richard, USDA ARS)

LIFE CYCLE: There are two generations per year. Adults emerge in early to mid-summer when leafy spurge is bolting/flowering. Females lay 70-150 eggs in clumps on leaves and bracts. Hatching larvae feed on these parts as leafy spurge is flowering. Larvae feed through five instars, and then pupation occurs in the soil. Next generation adults emerge in late summer and repeat the cycle. New hatching larvae move to the soil to overwinter as pupae.

DAMAGE: Larval feeding defoliates leafy spurge plants, though this often does not kill the weed.

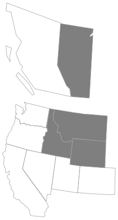
PREFERRED HABITAT: Does best in thick leafy spurge infestations growing in open areas near trees. Pupae are heavily preyed upon so sites with decreased amounts of rodents, ants, etc., are preferred.

HISTORY: Introduced from France, Germany and Switzerland and released on leafy spurge in Canada from 1966 (AB, BC). This material was redistributed to the USA from 1966 (CO, ID, MT, NV, OR, WA, WY). A second population was introduced from Hungary and released in CO, ID, MT, OR, WA, WY from 1980.

CURRENT STATUS: Both source populations established in the USA where they have since intermixed and can no longer be differentiated. Though moth densities may be locally high in some years, disease and predation typically prevent densities from developing to levels substantial enough to impact leafy spurge populations in some areas. Even where high densities have resulted in total plant defoliation, impact has been insignificant as this does not kill plants. In Canada, abundance is typically only moderate due to predation. Even when populations are high, plants recover from defoliation. It has limited biocontrol value alone, but may stress the weed in combination with other agents.

REDISTRIBUTION: Though this species can be collected in various stages, larval is the preferred stage to transport. Both generations are suitable for collection, either in spring/early summer as leafy spurge is beginning to flower, or late summer/fall as leafy spurge matures. Any instar can be collected, though the larger, mature larvae are most conspicuous and easy to find. Gently remove larvae by hand or with forceps, and place them directly in a waiting container. Larvae may regurgitate liquid as a defense measure; this is not harmful to the insect or the collector. They can be transferred in groups of 50-100 to new infestations. Establishment can be monitored by observing adults or larvae on leafy spurge foliage throughout the following growing season.

NOTES: This agent resembles native hawk moth species but is more active during daytime.



Lobesia euphorbiana (Freyer)

Spurge leaf tying moth

DESCRIPTION: Eggs are translucent yellow and round. Larvae have brown head capsules and segmented bodies up to 12 mm long. Young larvae are pale yellowish-green, turning nearly black with maturity. Pupae are pale green initially, turning brown with time. Adults are mottled with yellow, brown, and rust tones and light colored legs and antennae. Adults can be 9-11 mm long with wingspans up to 14 mm.

Lobesia euphorbiana: a) larva, b) cocoon, c) pupa (all Laura Parsons, University of Idaho, www.bugwood.org)

LIFE CYCLE: Adults emerge in spring as leafy spurge is bolting and flowering. Females lay eggs immediately (an average of 55 eggs each) and singly on the undersides of leaves. Hatching larvae move towards terminal leaf tips and tightly tie leaves with silky webbing. They feed on buds within ties, developing through four instars typically but occasionally five when food is scarce. Prior to pupation, larvae move to leaf tips where they spin thick webs. Second generation adults emerge from mid- to late summer and repeat the process. Second generation pupae overwinter in the soil litter within folded leaves. There are two generations per year, with three possible in suitable climates.

DAMAGE: Larval feeding of buds prevents flowering while repeated heavy attack may eventually kill plants. When larvae vacate leaf ties, the sites often receive secondary attack from thrips and aphids.

PREFERRED HABITAT: Does best at mesic sites where plants have high nutrient quality. Complete development requires high temperatures so sites that are warm to hot over summer are preferred. Often inhabits riparian areas as well as fringe forested areas, so shade is tolerated.

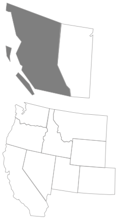
HISTORY: Introduced from Italy and released on leafy spurge in Canada from 1983 (AB, BC from 1987).

Lobesia euphorbiana: d) adult (CABI, previously IIBC), e) damage (Laura Parsons, University of Idaho, www.bugwood.org)

CURRENT STATUS: Established on leafy spurge in Canada where populations are dispersing well from release sites. Impact is moderate and fluctuates with leafy spurge density and vigor.

REDISTRIBUTION: The best stage for redistribution is larvae in leaf ties. In early to mid-summer, clip below infested leaves. Transfer material to new sites as soon as possible; make sure infested leaves touch the foliage of plants at the new sites. Establishment can be monitored the following season by observing leaf ties on new spurge foliage throughout the growing season.

NOTES: Gall terminals made by *Spurgia esulae* will occasionally be used by *L. euphorbiana*. **This agent is not approved for release in the USA.**



Oberea erythrocephala (Schrank)

Red-headed leafy spurge stem borer

DESCRIPTION: Mature larvae are up to 20 mm long, slender, and white. Bodies are obviously segmented and the head is yellowish with a head capsule. Adults are slender and 10-12 mm long with long, dark antennae, red heads, and black eyes. Adult bodies are dark grey above and lighter grey with reddish markings below. The legs are yellowish-brown.

Oberea erythrocephala: a) larva in root (R. Richard, USDA ARS), b) adult (Mark Schwarzländer, University of Idaho), c) damage (Eric Coombs, Oregon Department of Agriculture) (all www.bugwood.org)

LIFE CYCLE: Adults emerge in early to mid-summer and feed on leafy spurge leaves and flowers. Females girdle a leafy spurge stem, chew a hole, and deposit a single egg (up to 40 in a lifetime). Hatching larvae mine down the stem until reaching the root crown and nearby lateral roots. Larvae overwinter and pupate within the root crown in spring. Adults chew through remaining plant tissue and emerge from the soil. There is one generation per year in Europe, though two years may be required for full development in colder parts of North America.

DAMAGE: Adult feeding is insignificant. Larval mining kills shoots and reduces root reserves.

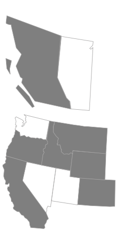
PREFERRED HABITAT: Prefers mesic sites with tree cover. It is believed to do well in riparian areas and has been shown to survive winter temperatures below freezing.

HISTORY: Introduced from Italy and released on leafy spurge in OR and WY (USA) from 1980. After these failed to establish, a different population was sourced from Austria, Hungary and Italy and released from 1982 in CA, CO, ID, MT, NV, OR, UT, WA, WY. Introduced from Switzerland and released in Canada from 1979 (AB 1980).

CURRENT STATUS: Established on leafy spurge in CA, CO, ID, MT, OR, WY (USA). It was initially believed to have the potential to greatly depress leafy spurge populations, but beetle densities have remained too low to impart significant impact in the field. At some infestations, it may cause declines in larger plants. Established on leafy spurge in AB (CAN) but is considered rare. At high densities, small plants can be killed, however field populations are too low to have a significant impact.

REDISTRIBUTION: Adults should be collected in early summer as leafy spurge flowers. They often fly or drop when disturbed, so sweep netting is less efficient than for other species. Alternatively, the beetles can be collected by hand or with soft forceps and placed directly in containers. Collect during the heat of the day. They can be transferred to new sites in groups of 50-100. Establishment can be monitored by observing adults on leafy spurge foliage the following summer during the heat of the day or by dissecting stems/root crowns for mining larvae from summer through the following spring.

NOTES: This species may attack only specific biotypes of leafy spurge, thus limiting its efficacy in many areas.



Spurgia capitigena (Bremi) & *S. esulae* Gagné

Leafy spurge tip gall midges

SYNONYMS: *Bayeria capitigena* Bremi

DESCRIPTION: Both "species" are virtually indistinguishable (see Notes). Eggs are orange and cylindrical. Larvae are orange and 1-2 mm long. Adults are dark gray with reddish abdomens and tiny, dark heads. Adults are just under 2 mm long, Males are slightly smaller than females. Males have forceps on the end of the abdomen while females have an exposed ovipositor.

Spurgia esulae: a) eggs (L.L. Berry), b) larvae and pupae in galls (Norman Rees, USDA ARS), c) adult (USDA APHIS PPQ Archive) (all www.bugwood.org)

LIFE CYCLE: Adults emerge in spring when leafy spurge is resuming growth. They live only a number of hours. Eggs are laid in groups of 20+ among the leaves of spurge growing tips. Hatching larvae feed on tips (through three instars), causing galls to form. Pupation occurs in silken cocoons within galls; adults emerge and repeat the cycle. There are two generations/year in cold climates, and 3-5 in warmer areas if new shoots are available. Last generation larvae overwinter and pupate in the soil.

DAMAGE: Larvae attacking leafy spurge growing tips destroy the shoots' ability to flower and produce seeds. The shoots eventually die and are replaced by new stems that are attacked by the next generation of midges.

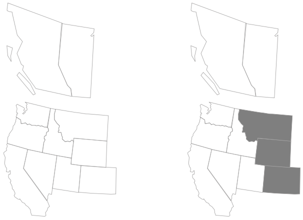
PREFERRED HABITAT: Prefers dense leafy spurge infestations growing on south-facing slopes in cooler climates. It can reportedly tolerate some shading.

HISTORY: The two species were previously lumped together under the name *Bayeria capitigena.* It wasn't until after their introduction that *B. capitigena* was transferred to *Spurgia* and split into the two species. Consequently, the release history is convoluted. What is now *S. esulae* was introduced from Italy and released on leafy spurge in the USA from 1985 (CO, ID, MT, NV, OR, UT, WA, WY). *S. capitigena* is believed to have been a contaminant of one population of *S. esulae* released in ND in 1986. Both species were redistributed to leafy spurge in Canada from 1987, though it is believed only *S. esulae* was released in western provinces (AB, BC) and only from 1989. A new population of *S. capitigena* was intentionally released in ND from 2001-2002 utilizing two different shipments from France.

CURRENT STATUS: *S. esulae* is established portions of the western USA. Densities are generally low, but even where it is most abundant, galls form following flowering so overall impact is insignificant. *S. capitigena* (from both sources) is established only in ND where impact is largely unknown but assumed to be negligible. Both species are only established on leafy spurge in more eastern provinces of Canada where their impact appears negligible.

REDISTRIBUTION: Midges are most safely collected by gathering galls infested with both larvae and pupae. The first generation is often best synchronized with leafy spurge, so collect from mid-May to mid-June (depending on location) prior to leafy spurge flowering. Clip at least 6 in (15 cm) below galls, bunch clipped stems, and wrap the bottoms in damp paper towels. Transfer to new sites as soon as possible, and place upright to help avoid predation. Establishment can be monitored by observing galls on new leafy spurge shoot tips throughout the following growing season.

NOTES: More recent studies with these midges revealed no evidence for two species. However, a revision of this group has not been published, so the two separate names are retained as valid at the time of publication of this field guide.



S. capitigena *S. esulae*

Leafy Spurge, Non-Established Agents

Aphthona abdominalis Duftschmidt (Coleoptera: Chrysomelidae)

R. Richard, USDA APHIS (www.bugwood.org)

DESCRIPTION AND LIFE CYCLE: In Europe, overwintering adults emerge from plant litter in late spring and feed on leafy spurge foliage during bolting or flowering. Adults are 2 mm long and grayish-brown with a reddish-yellow head and transparent outer wings. Females lay eggs at or just below the soil surface. Hatching larvae burrow into the soil and feed on roots and root hairs through three instars. Larvae are white with a yellow head and prominent head capsule and are 1-3 mm long. Pupation occurs in the soil near roots. There are up to 4 generations per year.

HISTORY: Introduced from Italy and released on leafy spurge in the USA from 1993 (CO, MT, OR) but failed to establish. **Not released in Canada.**

Chamaesphecia spp. (Lepidoptera: Sesiidae)

Chamaesphecia crassicornis: R. Richard, USDA APHIS (www.bugwood.org)

DESCRIPTION AND LIFE CYCLE: The four species all have white larvae up to 15 mm long. In Europe, overwintering larvae resume feeding in root tunnels in early spring. They mine upwards in the plant stem, pupating within. Adults emerge from late spring and lay eggs on spurge plants. Adults are dark brown with yellow-white bands. Bodies are typically 10-14 mm long; wingspans are 16-22 mm. Each wing is brown with yellow markings and a few transparent windows with dark margins. Body and wing tips are fringed. Hatching larvae burrow into the stem, mine down, and feed on roots. There is one generation per year.

HISTORY: *C. crassicornis, C. hungarica* and *C. tenthrediniformis* were introduced from Europe and released in the USA from 1975 (ID, MT, OR). *C. astatiformis, C. crassicorn*is and *C. hungarica* from Europe were released in AB (CAN) from 1991. All introductions failed. ***C. astatiformis* was not released in the USA.**

Minoa murinata (Scopoli) (Lepidoptera: Geometridae)

Siga

DESCRIPTION AND LIFE CYCLE: Pupa overwinter just beneath the soil. Adults emerge in late spring and lay eggs on leaves. Adults are gray to tan with a metallic sheen. Wings are fringed and span 18-23 mm. Hatching larvae feed on the undersides of leaves. Larvae are grayish-pink with variable black markings, brown heads, pink warts and an orange or yellow stripe along each side. They can be up to 13 mm long and develop through four instars before dropping to the soil in fall. There can be two generations per year in suitable climates. Adults of the second generation emerge in late summer.

HISTORY: Introduced from Germany and Austria and released in Canada from 1988 (AB, BC from 1991), but eventually died out. **Not released in the USA.**

Pegomya curticornis (Stein) & *P. euphorbiae* (Kieffer) (Diptera: Anthomyiidae)

Pegomya euphorbiae: André Gassmann, CABI-Switzerland

LIFE CYCLE: Both species are virtually indistinguishable. Adults emerge in early spring and lay eggs in the leaf buds of new shoots. Adults are dark colored with maroon eyes and scattered black hairs on the head and thorax. Wings are dark and translucent and span up to 6 mm. Hatching larvae tunnel down young shoots, which have less toxic milky latex. Larvae are a light gray and grub-like. Larvae eventually tunnel into the roots where their vascular tissue feeding induces the formation of galls. They overwinter as pupae within the roots. There is one generation per year.

HISTORY: Both species were previously lumped under *Pegomya argyrocephala.* Both were introduced from Hungary and released in AB (CAN) from 1988, though both eventually failed to establish. Due to taxonomic uncertainty, it is possible all material released was *P. euphorbiae.* **Not released in the USA.**

Field bindweed

Convolvulus arvensis L.

SYNONYMS: morning glory

ORIGIN: Native to Eurasia. Likely introduced via contaminated crop seed; identified in North America as early as 1739.

DESCRIPTION: Twining and trailing perennial with prostrate stems typically growing 1-4 ft long (⅓-1.2 m). The fleshy roots can extend up to 20 ft in length (6 m). The plant also produces rhizomes which may root and send up additional above ground shoots. Leaves are alternate and shaped like arrowheads with lobes at their base. Flowers are bell-shaped, white to pinkish, and 1 in (2½ cm) in diameter. Two small bracts are located ½ to 1 in (1-2½ cm) below the flower. Fruit is small and circular, usually containing four wedge-shaped seeds.

HABITAT: Well-adapted to many different habitats, but is dominant on dry soils

a) plant (Rachel Winston, MIA Consulting), b) infestation (Barry Rice, sarracenia.co, www.bugwood.org)

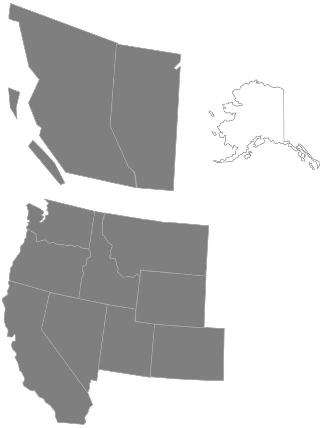
c) leaf (Ohio State Weed Lab Archive, The Ohio State University, www.bugwood.org), d) flower, e) bracts (d,e Rachel Winston, MIA Consulting)

in open and disturbed areas including abandoned fields, roadsides, orchards, and gardens.

ECOLOGY: Reproduces both by seed and by its spreading root system. Small root pieces can develop into new plants. Stems sprout from vegetative roots throughout the growing season. Peak germination is from April through May. Flowers typically appear from June through late fall. Seeds are readily transported by water, birds, and other animals, and may stay viable up to 50 years.

APPROVED BIOLOGICAL CONTROL AGENTS: USA and CAN: *Aceria malherbae* and *Tyta luctuosa*.

NOTES: Mildly toxic to grazing animals.

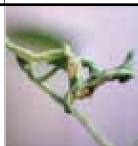
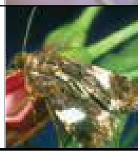


Bindweed Biological Control

HISTORY IN THE NORTHWEST: The North American field bindweed biological program began in the 1960s and 70s in Canada with the redistribution of a number of native insects. These attempts largely failed. A classical biological control program was subsequently initiated, leading to the introduction of *Tyta luctuosa* in 1987 and *Aceria malherbae* in 1989 (releases in Pacific Northwest states and provinces occurred shortly thereafter).

CURRENT STATUS: Both species established in the USA, though to date, populations of *T. luctuosa* are too limited to have any impact. Results with *A. malherbae* vary. The agent has proven effective at some sites, while having no impact at others. Reasons for this variability are not understood, but populations are known to be impacted by climate and possibly host plant resistance. Only *A. malherbae* established in Canada, and in such limited amounts that overall impact is considered minor.

RECOMMENDATIONS: USA and CAN: Additional research is needed to understand why both species have established poorly in North America and what is causing the variability of *A. malherbae* impact. Additional releases of both species are warranted with the intent of finding some sites and conditions where each species can thrive. *A. malherbae* galls can be transferred throughout the growing season. *T. luctuosa* field populations are likely too limited to be used for redistribution; lab colonies may be the best source for new populations. As noticeable impact by either species may take several years, additional control methods are also warranted.

Agent	Adult	Impact	Recommendation
Aceria malherbae		Galls stunt stem, reduce flowering. Helps control weed at some USA sites; ineffective at others for unknown reasons. Limited in CAN.	Continue redistributing galls throughout range of weed in attempt to find sites/conditions where agent thrives and has high impact.
Tyta luctuosa		Larval feeding defoliates plant. Populations too limited in USA to date to have impact. Not established in CAN.	Continue releasing species (with lab colonies) throughout range of weed in attempt to find sites/conditions where agent thrives and has high impact.

Aceria: Bob Nowierski, Montana State University, *Tyta*: USDA ARS, both www.bugwood.org

Aceria malherbae Nuzzaci

Bindweed gall mite

DESCRIPTION: Nymph and adult stages are similar except for the presence of external genitalia on adults. Both stages are worm-like with two pairs of legs on the joined head and thorax, and both have yellowish, translucent bodies. Mites are tiny and can be seen only through a microscope. Consequently, it is their damage that is more useful for identifying their presence.

Aceria malherbae: a) adult (USDA-ARS), b) damage (Bob Nowierski, Montana State University), c) damage (Jennifer Andreas, Washington State University Extension) (a,b www.bugwood.org)

LIFE CYCLE: Adults emerge in early spring and feed on new bindweed growth. They lay eggs within galls and produce multiple generations per year. There are two nymphal stages prior to the adult stage; their development can be completed in 10 days, depending on temperature. Overwintering occurs in both the nymphal and adult stage on root buds.

DAMAGE: Both nymphal and adult stages form galls on actively growing leaves, leaf stems, and stem tips of bindweed. Galls are characterized by the discolored folding and twisting of leaves along the midrib where mites feed. Attacked stem tips fail to elongate and form clusters of stunted leaves. Attacked plants also experience a reduction in flowering.

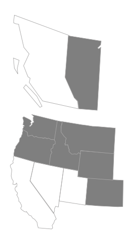
PREFERRED HABITAT: Largely unknown, but appears to do better under hot, dry conditions.

HISTORY: Introduced from Greece and released on field bindweed in the USA and Canada from 1989 (CO, ID, MT, NV, OR, WA, WY from 1992; BC 1992, AB 1993).

CURRENT STATUS: Established on field bindweed in the USA, though abundance, attack levels and impact vary dramatically across and within established states. There has been no impact at some sites, and >90% decrease in aboveground plant biomass at others. Reasons for this variability have not been studied explicitly, but populations are known to be impacted by climate and possibly host plant resistance. In Canada, its distribution and abundance are limited. Galling damage has been found up to 1.4 km from one site. Some plants are heavily galled and stunted, though impact has not been evaluated quantitatively. Field bindweed continues to be a problematic weed in many parts of Canada.

REDISTRIBUTION: Can be redistributed by collecting galls from attacked plants and placing these on uninfested bindweed plants in new locations. This can be done throughout the year when bindweed is actively growing. Establishment can be monitored the following season by observing galls on new bindweed growth. Once established, mite populations can be encouraged to multiply by mowing the bindweed infestation.

NOTES: Also released on the similar hedge bindweed (*Calystegia sepium*) in MD, USA, where establishment is unknown and in WA (from 2010) where establishment has thus far failed.



Tyta luctuosa (Denis & Schiffermüller)

Bindweed moth

DESCRIPTION: Larvae are a drab brown color with three dark-edged strips along their back and a dark brown line along the side with two wavy lines above it. Larvae also have four lines of black dots on their heads and can be up to 34 mm long at maturity. Adults are dark brown with four large white spots, one on each wing. The white spots on the hind wings form a wide band that sometimes becomes narrowed. Adults are typically 11 mm long with wingspans up to 29 mm.

Tyta luctuosa: a) larva (Eric Coombs, Oregon Department of Agriculture), b) pupa, c) adult (b,c USDA ARS) (all www.bugwood.org)

LIFE CYCLE: Adults emerge in late spring and lay eggs on elongating stems. Larvae feed on foliage, developing through five larval instars prior to pupation, which occurs in the soil or in plant litter. Second generation adults emerge in late summer on bindweed that is both elongating and flowering. There are usually two generations per year. Overwintering occurs in both the larval and adult stage.

DAMAGE: Larvae feed on flowers and leaves, sometimes defoliating whole plants.

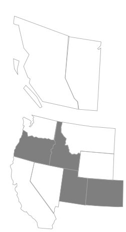
PREFERRED HABITAT: Still being determined in North America. The moth is reportedly not restricted to any certain habitat in its native range.

HISTORY: Introduced from Italy and released on field bindweed in the USA in 1987 (ID, MT, OR, WA from 1996) and Canada in 1989 (AB 1990).

CURRENT STATUS: Established on field bindweed in the USA but at such small levels that impact of larval feeding on flowers and foliage is likely minor at best. Adults were found one year after release in AB (CAN). They possibly still remain, but permanent establishment has not been confirmed.

REDISTRIBUTION: Populations are still very limited in the USA, so redistribution is likely not yet possible. In its native range, this moth is best redistributed by hand-collecting larvae from infested plants, or by using a tap & funnel. If larvae are abundant on the plant, infested plant material can be clipped and placed in gauze bags. Larvae can be found from spring to early fall on elongating bindweeds. Adult moths can be collected at night with the aid of light traps with black light bulbs. The adults can be found when bindweeds are actively growing from spring to early fall. Both adults and larvae can be transferred to new infestations in groups of 50-100. Establishment can be monitored the following year by observing adults or larvae on foliage throughout the growing season. Larvae can be cryptic and are often found feeding at night.

NOTES: Also released on the similar hedge bindweed (*Calystegia sepium*) in eastern regions of North America, but is believed to have failed establishment.



Scentless chamomile

Tripleurospermum inodorum (L.) Sch. Bip.

SYNONYMS: scentless false mayweed, *Matricaria perforata* Mérat, *Tripleurospermum maritimum* (L.) W. D. J. Koch subsp. *inodorum* (L.) Appleq., *Tripleurospermum perforatum* (Mérat) M. Laínz

ORIGIN: Native to Eurasia. Introduced to North America by the 1920s.

DESCRIPTION: An erect, branching annual or short-lived perennial growing ½-3.2 ft tall (15-100 cm) from a fibrous root system. Leaves are alternate and very finely divided, giving the plant an overall fern-like appearance. Flower heads are daisy-like with white outer ray florets and yellow inner disc florets. Flower heads are typically 1¼-1⅝ in (30-40 mm) in diameter. Seeds are small (0.08 in or 2 mm long), elongate, brown, and ribbed, with no pappus.

HABITAT: Well-adapted to many different habitats, thriving in disturbance

a) plant (Robert Vidéki, Doronicum Kft., www.bugwood.org), b) infestation (Alec McClay, McClay Ecoscience)

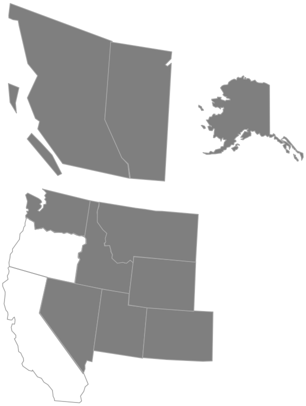
c) leaves (Caleb Slemmons, University of Wisconsin, Stevens Point, www.bugwood.org), d) flower heads (Alec McClay, McClay Ecoscience)

typical of annual and perennial crops, pastures, wasteland, roadsides, and ditches. It germinates readily at sites with periodic flooding.

ECOLOGY: Reproduces by seed only. Plants germinate throughout the growing season. Those germinating before mid-July often behave as annuals, bolting and flowering within the same growing season. Those germinating after mid-July behave as winter annuals, developing into an overwintering rosette which bolts and flowers the following summer. Most plants die after flowering and setting seed, though a small proportion overwinter and re-grow from the root crown to flower again in the following season. This species is a prolific seed producer; dense populations can yield up to 1.8 million seeds/m². Seeds are readily transported by water, birds, and other animals, and may stay viable up to 15 years.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: There are no approved biocontrol agents; CAN: *Microplontus edentulus, Omphalapion hookerorum* and *Rhopalomyia tripleurospermi*.

NOTES: Diploid and tetraploid forms occur in both Europe and North America.

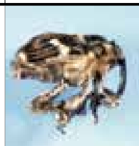


Chamomile Biological Control

HISTORY IN THE NORTHWEST: The North American scentless chamomile biological program began in the 1980s in Canada. To date, releases have occurred only in Canada. The first agent approved for use, *Omphalapion hookerorum*, was released in AB and BC from 1992. An adventive population of *O. hookerorum* was discovered established in NS in 1990, but field observations indicated it was host specific as well. Both populations (intentional and adventive) of *O. hookerorum* were subsequently intermixed in the field and are no longer differentiated. *Microplontus edentulus* and *Rhopalomyia tripleurospermi* were approved and released in 1997 and 1999, respectively.

CURRENT STATUS: All three species established in AB, while *O. hookerorum* and *R. tripleurospermi* established in BC as well. To date, only one population of *M. edentulus* is established in AB and is too limited to have any impact. Populations of the other two species are abundant and widespread, though impact is only medium overall. Seed-feeding by *O. hookerorum* and galling by *R. tripleurospermi* lead to reduced seed production and stunted growth.

RECOMMENDATIONS: USA: **No species have been approved for use or released in the USA for the control of scentless chamomile.** CAN: *Microplontus edentulus* is rare in the field with no documented impact, consequently it is not a recommended priority for redistribution efforts, though releases with laboratory colonies could be made if more suitable field conditions are determined. *Omphalapion hookerorum* and *R. tripleurospermi* are already widespread throughout much of AB and some of BC. Though they reduce seed production, scentless chamomile is a prolific seed producer and many seeds escape attack. Still, the additional stunting effect of *R. tripleurospermi* in combination with the seed reducing impact of both species make them useful in combination with other (complementary) control methods or at locations where some control methods are not feasible. *O. hookerorum* can be redistributed using adults collected from new growth of scentless chamomile in spring, or from mature seed heads in late summer. For *R. tripleurospermi,* gall-infested plants should be transplanted into field sites as the adults are too short-lived and delicate for field collection. To avoid transferring unwanted parasitoids, other insects, or scentless chamomile seeds, gall-infested plants can be collected and adults reared out indoors prior to release in spring and summer.

AGENT	ADULT	IMPACT	RECOMMENDATION
Microplontus edentulus		Stem-mining weakens stems, may reduce seed production. Only one population established thus far in CAN. No measurable impact.	Low establishment rates and impact make low priority for redistribution in CAN. Not approved for use in USA.
Omphalapion hookerorum		Seed-feeding reduces seed output and possible rate of population spread in CAN. Plant is prolific seed producer; many seeds escape attack.	Already widespread; should be redistributed to any uninfested sites to complement other control methods. Not approved for use in USA.
Rhopalomyia tripleurospermi		Galling stunts growth, delays flowering, decreases seed production in CAN. Plant is prolific seed producer; many seeds escape attack.	Already widespread; should be redistributed to any uninfested sites to complement other control methods. Not approved for use in USA.

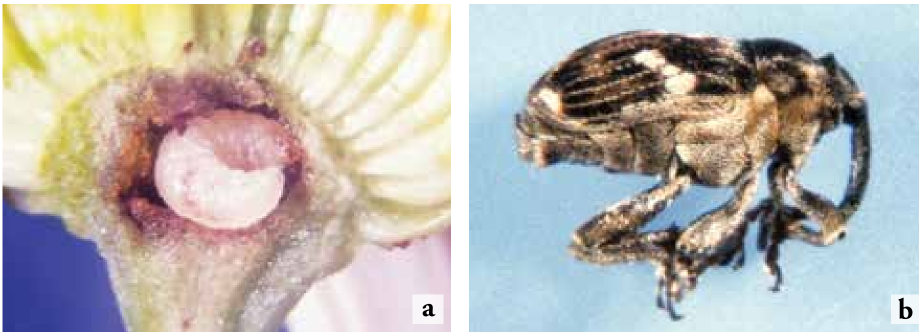
Microplontus, Omphalapion, Rhopalomyia: all Alec McClay, McClay Ecoscience

Microplontus edentulus (Schultze)

Scentless chamomile stem-mining weevil

SYNONYMS: *Ceutorhynchus edentulus* Schultze

DESCRIPTION: Larvae are white, C-shaped grubs with brown head capsules. They are approximately 3 mm long. Adults are about 3 mm long and 2 mm wide. Females are slightly larger than males. Adults are mottled gray with lighter patches at the base and sides of wing covers. They have long, curved snouts.



Microplontus edentulus: a) larva in flower head, b) adult (both Alec McClay, McClay Ecoscience)

LIFE CYCLE: Adults emerge in early spring and begin mating and ovipositing prior to chamomile flowering. Eggs are deposited singly into holes chewed by females in upper plant stems, near leaf bases. Hatching larvae mine stems and sometimes into flower bases, though they do not feed on or damage seeds. Larvae develop through three instars prior to dropping to the ground and burrowing into the soil to build cocoons out of soil particles. Pupation occurs within cocoons. Adults typically overwinter within cocoons, but some emerge in fall and overwinter in soil and litter. There is one generation per year.

DAMAGE: Larval stem-mining causes plants to produce thin stems, which reduces plant mass and seed production. Large, healthy plants appear less affected.

PREFERRED HABITAT: Specific habitat requirements are unknown.

HISTORY: Introduced from Austria and released on scentless chamomile in Canada from 1997 (AB, BC).

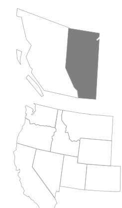
CURRENT STATUS: Established on scentless chamomile only at one site in AB Canada. To date there has been no evidence of impact in the field. Larval mining in stems occurs too late to impact plant fitness, and mining in receptacles does

Microplontus edentulus: c) larvae and mining damage in stem (Hariet Hinz, CABI-Switzerland), d) emergence hole in plant stem (Alec McClay, McClay Ecoscience)

not destroy seeds. Parasitism may play a role in the low population levels.

REDISTRIBUTION: Populations are currently too limited to field collect so releases should be made using laboratory colonies when available. In the future, should this agent be further established, field redistributions can be done utilizing a sweep net in early spring to collect adults from stems and foliage during the mating stage. These can be transferred to new, uninfested sites in groups of 100-200. Establishment can be monitored the following season by observing adults on plant foliage or dissecting stems to find larvae mining within.

NOTES: **This agent has not been released in the USA.**



Omphalapion hookerorum (Kirby)

Scentless chamomile seed weevil

SYNONYMS: *Apion hookeri* Kirby

DESCRIPTION: Eggs are small and round, changing from white to brown with age. Larvae are white, C-shaped grubs typically up to 2 mm long. Adult males are black and 1½-2 mm long. Females have a metallic sheen in shades of blue, turquoise or purple and are typically 2-2½ mm long. Both males and females have rounded bodies and curved snouts with bulging eyes.

Omphalapion hookerorum: a) larva in damaged flower head, b) adult, c) adults on a flower head (all Alec McClay, McClay Ecoscience)

LIFE CYCLE: Female adults emerge in spring and feed on scentless chamomile plants prior to laying eggs in young flower heads. Hatching larvae feed on florets and seeds, developing through three instars. Pupation occurs within the flower head. Adults emerge in late summer and mate, but females do not oviposit. They overwinter in soil or litter and will oviposit the following year. Males die before winter. There is one generation per year.

DAMAGE: Larval feeding destroys some seeds. Seed consumption does not kill existing plants, but does help reduce the rate of spread of scentless chamomile populations.

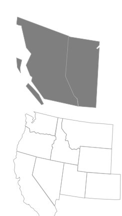
PREFERRED HABITAT: The weevil is reportedly not restricted to any particular habitat in its native range, though it seems to prefer cold, dry continental climates.

HISTORY: The population used for screening and the initial releases was introduced from Germany and released in Canada from 1992 (AB, BC). An adventive population was discovered in NS in 1990, possibly introduced by fishing or pleasure boats or via dry ballast from Europe. Both intentional and adventive populations eventually intermixed.

CURRENT STATUS: Established on scentless chamomile in AB and BC (CAN). Abundance is high and overall impact is medium. Up to 78% of scentless chamomile seed heads are attacked by *O. hookerorum* and up to 32% by *Rhopalomyia tripleurospermi.* Estimated seed production is reduced up to 19% by a combination of both species. Up to 17 *O. hookerorum* adults have been found in a single seed head (mean 3.9). It disperses up to 1.7 miles year (2.8 km/year).

REDISTRIBUTION: Already widespread throughout much of the range of scentless chamomile in Canada, though less widespread in BC than in other provinces. Wherever it is not currently established, adults can be transferred in groups of 200. Releases can be made in spring or late summer. Adult females can be collected in spring, using an aspirator, from the young buds and shoot tips of scentless chamomile. In late summer, adults can be collected as they emerge from the mature seed heads. Releases should be made on patches of at least 2,000 m^2 (1/2 acre). Establishment can be monitored the following spring by checking for adults on shoot tips and flower buds, or in summer by dissecting capitula for evidence of feeding larvae.

NOTES: **This agent has not been released in the USA.**



Rhopalomyia tripleurospermi Skuhravá & Hinz

Scentless chamomile gall midge

DESCRIPTION: Eggs are bright red and elongate. Larvae are bright red initially, changing to white at maturity. Male pupae are gray while female pupae are red to dark purple. Adult males and females also have distinct appearances. Males are approximately 2½ mm long with a brown head and thorax and gray abdomen. Male legs are long and slender. Adult females are typically 2½-3 mm long with a bright red abdomen and shorter, thicker legs. Females contain fully developed eggs; larger females contain more eggs.

Rhopalomyia tripleurospermi: a) eggs, b) male pupa, c) female adult (all Alec McClay, McClay Ecoscience)

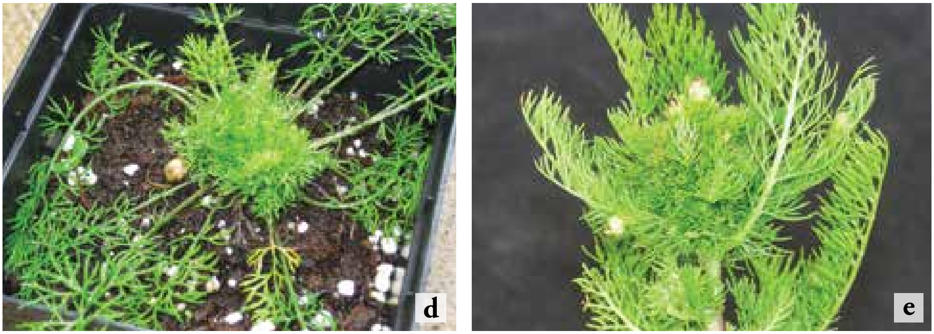
LIFE CYCLE: Pupation occurs in spring. Adults emerge in spring, and females lay eggs into scentless chamomile leaf axils or unopened buds. Hatching larvae enter and feed on bud tissue, developing through three larval instars. Larval feeding induces the formation of galls, which appear as masses of crowded, leaf-like growths with a mossy appearance. Galls may develop on growing points, leaves, stems, or flowers. In AB Canada there are three generations per year, but two are expected in colder climates. Larvae overwinter in galls and pupate within galls the following spring.

DAMAGE: Larval-induced galls interrupt and stunt the normal growth of the plant, reducing flowering. High attack rates can kill overwintering rosettes.

PREFERRED HABITAT: The midge appears to thrive in all habitats where scentless chamomile occurs.

HISTORY: Introduced from Austria and released in Canada from 1999 (AB, BC).

CURRENT STATUS: Established on scentless chamomile in AB and BC (CAN). Abundance is high and overall impact is medium. Up to 78% of seed heads are attacked by *Omphalapion hookerorum* and up to 32% by *R. tripleurospermi*.

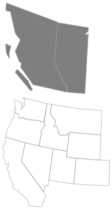


Rhopalomyia tripleurospermi: d) gall on rosette, e) gall on shoot tip (both Alec McClay, McClay Ecoscience)

Estimated seed production is reduced up to 19% by a combination of both species. Heavy galling stunts plants and decreases and/or delays flower production. Anecdotal reports suggest scentless chamomile populations are declining in areas with heavy attack. Dispersing up to 3.2 miles per year (5.2 km/yr).

REDISTRIBUTION: Adults are small, short-lived, and delicate so sweeping is not feasible. Instead, place infested plants into uninfested patches from spring through mid summer. To avoid transferring unwanted parasitoids, other insects, or scentless chamomile seeds, gall-infested stems can be collected and adults reared out indoors. Refer to Additional Considerations in the Introduction for instructions on how to do so. Once they emerge in spring, midges can be transferred to new chamomile infestations in groups of 50-100. Establishment can be monitored by observing scentless chamomile foliage for galls later in the same season or in subsequent years.

NOTES: Galls are susceptible to parasitoid attack, but parasitism levels in the field are not high enough to prevent rapid population growth. **This agent has not been released in the USA.**



Poison hemlock

Conium maculatum L.

SYNONYMS: N/A

ORIGIN: Native to Eurasia. Introduced to North America in the 1800s as a garden plant.

DESCRIPTION: An erect plant typically growing as a biennial but may behave as a winter annual or short-lived perennial. The plant often grows 3-6 ft tall (90-180 cm) from a deep taproot. Leaves are alternate and finely divided, giving the plant an overall fern-like appearance. Stems are hollow, smooth, and covered in purple spots or splotches. The inflorescence is a compound umbel with 12-16 umbellets. Individual flowers have five white petals. Seeds are brown, oval, flattened on one side, and have conspicuous wavy ribs.

HABITAT: Often occurs in dense stands at shady or moist sites. Is frequently

a) plant (Steve Dewey, Utah State University), b) infestation (Joe DiTomaso, University of California) (both www.bugwood.org)

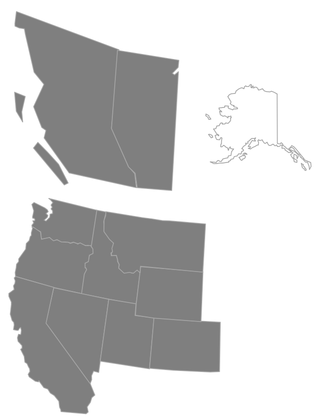
c) leaf, d) stem (Jan Samanek, State Phytosanitary Administration), e) inflorescence (c,e Pedro Tenorio-Lezama) (all www.bugwood.org)

found along roadsides, field margins, ditch banks and in low-lying waste areas. It also invades native plant communities in riparian woodlands and open flood plains of rivers and streams.

ECOLOGY: Reproduces by seed only. Plants germinate throughout the growing season. Most plants are biennials, remaining as rosettes the first year and bolting/flowering only during the second year. Flowering typically occurs in mid to late summer. Most plants die after flowering and setting seed, though a small proportion overwinter and re-grow from the root crown to flower again in the following season. Seeds are readily transported by farm machinery, vehicles, agricultural produce, mud and clothing as well as being carried by water and to a limited extent wind. Seeds may stay viable up to three years.

APPROVED BIOLOGICAL CONTROL AGENTS: USA: *Agonopterix alstroemeriana*

NOTES: All parts of the plant contain alkaloids that are highly toxic to livestock and humans.



Poison hemlock Biological Control

HISTORY IN THE NORTHWEST: There have been no intentional introductions of classical biocontrol agents to North America. *Agonopterix alstroemeriana* is an adventive agent first recorded in the USA (NY) in 1973, from where it spread rapidly throughout the northwestern states. It has since been granted redistribution permits by the USDA APHIS for use on poison hemlock and has been moved around extensively.

CURRENT STATUS: *Agonopterix alstroemeriana* is widespread and abundant in all western states. High populations cause severe defoliation at some sites. Though this can decrease seed production and cause plant mortality, many plants typically recover and resume growth after larvae pupate in mid-summer. Changes in poison hemlock stand density have not been documented, so the overall impact is believed to be limited.

RECOMMENDATIONS: USA: *Agonopterix alstroemeriana* is already widespread throughout the northwest. Its high abundance and typically low impact overall make it a low priority for redistribution. In areas where other control options are not available and/or where *A. alstroemeriana* is not already present, supplemental releases can be made. Larvae should be hand collected along with poison hemlock foliage in spring and transferred to new sites in groups of 50-100. Rubber gloves and protective clothing should be worn at all times during the cutting and handling of poison hemlock to help protect against the plant's high toxicity. CAN: **No species are approved for release in Canada for the control of poison hemlock.**

Agent	Adult	Impact	Recommendation
Agonopterix alstroemeriana		Larval feeding causes severe defoliation; reduces seed production, may kill plants outright; many plants recover; stand density not decreased	Already widespread; should be redistributed to any uninfested sites to complement other control methods. Not released in CAN.

Agonopterix alstroemeriana photo Eric Coombs, Oregon Department of Agriculture, www.bugwood.org

Agonopterix alstroemeriana (Clerck)

Defoliating hemlock moth

DESCRIPTION: Eggs are pale yellow and cylindrical. Early instar larvae are predominantly yellow with black head capsules. Later instar larvae are light green with three dark green longitudinal stripes. Mature larvae can be up to 12 mm long. Pupal cases are reddish-brown. Adults are about 10 mm long with 18 mm wingspans. Adults are speckled brownish-gray and have a distinctive dark brown spot on each wing.

Agonopterix alstroemeriana: a) eggs, b) larva, c) adult (all Eric Coombs, Oregon Department of Agriculture, all www.bugwood.org)

LIFE CYCLE: Adults emerge in early spring and begin mating and ovipositing. Eggs are deposited on the undersides of poison hemlock leaves. Hatching larvae feed on leaves, creating tubes of leaf particles. Leaf tubes are quickly abandoned when larvae are disturbed and drop to the ground. Larvae develop through five instars; late-instar larvae incorporate flower tissue into their tubes. They pupate in the soil with new adults emerging in mid-summer. Adults overwinter in soil and plant litter. There is one generation per year.

DAMAGE: Larval feeding defoliates plants which can lead to reduced reproduction and sometimes plant death. Many plants recover and produce more foliage after larvae have pupated.

PREFERRED HABITAT: Specific habitat requirements are unknown.

HISTORY: Accidental introduction first documented in the USA (NY) in 1973. It spread rapidly to many additional states including CA, OR and UT by 1983. Despite being introduced accidentally, the USDA APHIS has granted permits for its redistribution, and it is currently commercially available.

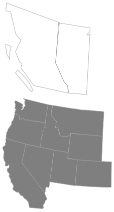
CURRENT STATUS: Established at high densities on poison hemlock

Agonopterix alstroemeriana: d) defoliated leaves, e) defoliated stand (both Eric Coombs, Oregon Department of Agriculture, www.bugwood.org)

throughout the western USA. It can reduce seed production and cause severe defoliation, however many plants recover after larvae terminate feeding in mid-summer. Changes in poison hemlock stand density have not been documented so the overall impact is believed to be limited.

REDISTRIBUTION: Populations are already widespread throughout the western USA. Where *Agonopterix alstroemeriana* appears to be missing, larvae can be hand-picked from other sites during late spring and transferred along with cut leaves of poison hemlock in groups of 50-100. As this weed is extremely toxic, gloves and protective clothing should be warn when cutting any foliage. Establishment can be monitored the following spring and summer by observing new larvae on poison hemlock foliage.

NOTES: Adults are nocturnal and hide away during the day. **This agent is not approved for release in Canada.**



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
adventive	Species that arrived in the geographical area from elsewhere by any means, but is not self-sustaining and whose numbers are only increased through non-reproductive means, unlike a naturalized species
aestivation	A period of dormancy to survive predictable, unfavorable environmental conditions, such as temperature extremes, drought or reduced food availability
alternate	Where leaves appear singly at stem nodes, on alternate sides of the stem
antenna (pl. antennae)	In arthropods, one of a pair of 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 a mouth aspirator, or mechanical as in a gasoline- or battery-powered vacuum aspirator
basal	Located at the base of a plant or plant part
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	A life cycle with four distinct stages (egg, larva, pupa, adult)
compound eyes	Paired eyes consisting of many facets, or ommatidia, in most adult Arthropoda
compound leaf	A leaf consisting of two or more leaflets borne on the same leaf stalk
coordinates	A set of numbers used to specify a location
crown	Location of where a plant's stems meets its roots
deciduous	Sheds its leaves annually
density	Number of individuals per unit area
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
erect	Grows upright and vertical as opposed to prostrate (spreading on the ground)
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
forb	Herbaceous plant (does not have solid woody stems)
genus (pl. genera)	A taxonomic category ranking below family and above species and consisting of a group of species exhibiting similar characteristics. The genus name is followed by a Latin adjective or epithet to form the name of a species
gradual metamorphosis	A life cycle with three distinct stages (egg, nymph, adult)
grub	A soft, thick-bodied, C-shaped beetle larva
head	Insect segment with the mouthparts, antennae, and eyes
head capsule	Hardened covering of the head of an immature insect
herbivory	Feeding on plants
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 nymphal or larval development between molts
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)
leaflet	A leaf-like part of a compound leaf. Though it resembles an entire leaf, a leaflet is not attached to the main plant stem or branch as a leaf is, but rather on a the leaf stalk
lobed	A leaf with shallow or deep, rounded segments, as in a thistle rosette leaf
membranous	Thin and transparent
molting	Process of insect development that involves shedding its exoskeleton and producing another for the next instar
NAD 83	North American Datum, the official datum used for the UTM geographic coordinate system in North America
node	Part of the stem of a plant from which a leaf, branch, or root grows
nontarget effect	When control efforts affect a species other than the species they were enacted to control (can be positive or negative)
nymph	Immature form of invertebrates that undergo gradual metamorphosis. Resembles adults
opposite	Where leaves appear in twos at stem nodes, on opposite sides of the stem
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 for more than two years
petiole	Leaf stalk that attaches it to a plant stem
proleg	A fleshy, unsegmented, abdominal walking appendage of some insect larvae, common among caterpillars
prostrate	Grows flat along the ground as opposed to growing erect (upright)
pupa (pl. pupae) (v. pupate)	Non-feeding, inactive insect stage between larva and adult
qualitative	Measurement of descriptive elements (e.g., age class, distribution)
quantitative	Measurement of quantity; the number or amount (e.g., seeds per capitula)
receptacle	Part of the stem to which the flower is attached
rhizome	A modified stem of a plant that grows horizontally underground, often sending out roots and shoots from its nodes
rosette	A compact, circular, and normally basal cluster of leaves
seed head	Synonym for capitulum of a plant in the sunflower family. Consists of a receptacle and florets
senescence	Final stage in a plant's life cycle
species	A fundamental category of taxonomic classification, ranking below a genus or subgenus and consisting of related organisms capable of interbreeding

stolon	Stem which grows at the soil surface or just below ground that forms adventitious roots at the nodes, and new plants from the buds (also called runner)
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
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
umbel	An inflorescence which consists of a number of short flower stalks which spread from a common point, somewhat like umbrella ribs. They can be simple or compound (the single flowers are replaced by many smaller umbels called umbellets).
UTM	Universal Transverse Mercator, a grid-based geographic coordinate system
WGS 84	The World Geodetic System, a datum for latitude/longitude geographic coordinate systems
whorled	Where multiple leaves radiate outward from a single stem node

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