Field Guide to the Biological Control of Weeds in British Columbia

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Field Guide to the Biological Control of Weeds in British Columbia

by

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1 INTRODUCTION

The biological control of weeds typically involves the local establishment of host-specific organisms from other parts of the world to give continuing control of weeds. Weeds reduce floral diversity and the capacity of land to support wildlife, livestock, trees, and recreational activities. The biological control of weeds has a long history as an economically sound and environmentally friendly method of controlling widespread introduced weeds on uncultivated land.

In Canada the biological control of weeds began in British Columbia in 1952 with the release of the defoliating beetles *Chrysolina quadrigemina* and *C. hyperici* to control St. John's wort. Although initial results of that trial were disappointing, within 13 years of the release the beetle populations had increased sufficiently to control the weed in most areas of the province, eliminating the need for chemical control of this species. From these early beginnings, biological control of weeds has expanded to most provinces of Canada, and the program now uses more than 50 insects and pathogens on more than 20 different introduced weed species.

This guide is designed to help resource managers in British Columbia identify weeds and select suitable biological control agents for those weeds. Biological control offers stable, long-term solutions to weed problems across the province.

2 HOW TO USE THIS FIELD GUIDE

This field guide is divided into two parts. The first is a guide to the problem weeds of British Columbia; the second is a guide to the biological control of those weeds.

The three steps outlined below will help the user identify weeds and select the appropriate biological control agents.

1. Weed Identification

Use the pictures and descriptions to identify the weed. Each weed is described here in detail and its habitat and approximate distribution in British Columbia are summarized. Weeds are listed in Sections 3.3–3.5, first by flower colour and then alphabetically (by scientific name) within flower colour groups. Where a plant has multiple or a range of colours, the most common colour has been used for its

classification. Refer to the flower colour code tab at the side of the page to narrow your choice of weeds. Note that only those weeds that have approved biological control agents available are included in the guide.

Weed identification can be confirmed by a local specialist with the B.C. Ministry of Forests, B.C. Ministry of Agriculture, Fisheries and Food, or other suitable government agency or educational institution. Bring along either fresh, dried, or pressed plant material, and try to include an entire plant. Flowers, fruits, and seeds are especially helpful.

2. Biological Control Agent Selection

Following the description of each weed is a listing of the organisms approved for its control in British Columbia. Because biological control agents can take a long time to establish, not all of the agents approved for control are available for general distribution. Refer to Appendix 1 for the status of the biological control agents and select an appropriate agent or agents from those listed as available for general release. Updates of this list will be issued periodically. Biological control agents are listed alphabetically (by scientific name) in Section 4.7. Read the release procedures and habitat requirements of the agents before requesting a release. Take special note of the time of year when an agent is available for redistribution.

3. Biological Control Agent Identification

To determine if an insect or pathogen found on a weed is a biological control agent, refer to Sections 3.3-3.5 on weed identification to narrow your choice of agents, and then refer to the listed agents in Section 4.7. Use the photos and descriptions in the guide to identify the biological control agent. Photos of different life stages are also provided where appropriate.

When collecting an agent, note the general habitat, the plant it is on, and its location on the plant. The stage of the agent's development, relative to the time of year, and damage patterns on the plant can also be helpful. Not all insects and plant diseases found on weeds are biological control agents, and they therefore do not appear in this guide.

Biological control agents have been cross-referenced by specific types (e.g., aphids, beetles, nematodes) in the index at the end of the manual.

3 GUIDE TO BRITISH COLUMBIA'S WEEDS

3.1 The Weed Problem in British Columbia

Weeds infest thousands of hectares in British Columbia, displacing other desirable vegetation. None of the weeds in this guide is native to North America. All have been introduced from elsewhere, and most are efficient competitors and prolific reproducers. Being generally free of natural predators, they have a distinct advantage over other vegetation. As a result, some weed populations have increased to densities that conflict with current management objectives. Their competitive ability has displaced native vegetation and lowered range productivity and habitat for wildlife and livestock. Some contain toxins or plant parts injurious or bothersome to animals. As well, weed infestations may reduce the aesthetic appeal of land, resulting in lower recreational value and decreasing the marketability or general enjoyment of an area.

3.2 Integrated Vegetation Management

Integrated vegetation management, using (as necessary) biological control, herbicides, and mechanical and cultural methods is the most effective approach to control weeds. In general, the best long-term solution to weed problems is through prevention and biological control. However, containing and preventing the spread of weeds through chemical, mechanical and cultural methods are necessary components of vegetation management in British Columbia.

3.2.1 Prevention

Preventing weed spread to uninfested areas is an important aspect of vegetation management. Recognizing new weed problems and detecting weeds early can also simplify their control. Management practices that maintain the vegetation in a vigorous, productive condition should be emphasized to deter the establishment and spread of weeds.

In general, prevention can be achieved through modifications of cultural practices and an integrated approach to land use. Preventative measures should include the following:

- establishing a program to increase public awareness of weeds and the consequences of the careless use of natural resources;

- restricting vehicle use to designated roads in weed-infested areas to prevent new disturbances that can encourage weed invasion;
- controlling roadside weeds to prevent vehicles from picking up and moving weeds;
- restricting recreational vehicles to designated areas, and minimizing recreational activities that result in excessive soil disturbance;
- encouraging people to keep their vehicles and equipment clean and free of weeds and weed seed, and to check vehicles frequently, especially after travelling through infestations of mature plants;
- applying good livestock management, including an appropriate level of grazing, and advocating practices that prevent excessive soil disturbance and promote healthy, competitive vegetation stands resistant to weed establishment;
- keeping sand, gravel, and rock quarries free of weeds to prevent their dissemination with the material;
- seeding newly disturbed areas, such as roadsides and construction sites, with adapted, desirable species to provide a quick cover in which weeds cannot establish;
- confining livestock for a period after grazing on a weed-infested site before moving them to a new area, and cleaning animals of burs and seeds before moving; and
- preventing weed movement in feed and seed, and keeping hay fields and pastures weed free.

3.2.2 Herbicides

Various herbicides are approved for spot treatment of weeds in British Columbia. The herbicide selected should depend on the target weed species and environmental factors. Application rate will be dictated by the size and accessibility of the infestation, its proximity to wells and other water, and the potential impacts of the application on non-target vegetation. Some herbicides have residual effects and persist in the soil in an active state for some time after application. Other herbicides become inactive once they contact soil. The residual activity of a herbicide varies with rate of application, soil properties, and climate, and its impact on non-target vegetation should be carefully

considered. Consult with a local specialist in the Ministry of Agriculture, Fisheries and Food for the most current information on herbicides registered for use, and approved application procedures.

3.2.3 Mechanical and cultural methods

Mechanical weed control employs various implements and techniques to physically disturb weeds or to interrupt their reproduction by depleting root reserves through repeated defoliation of the plant. Mechanical control includes the mowing, ploughing, chopping, and crushing of weeds.

Weed control can also be achieved through cultural methods, including selective grazing, irrigation and deliberate flooding, mulching, hand pulling, and burning. Strategies and timing should depend on the weed species and its location in the province. Consult with a local specialist in the Ministry of Agriculture, Fisheries and Food for the most current information on effective mechanical and cultural control methods.

3.2.4. Biological control

Biological control is the use of a weed's natural enemies (chiefly insects and pathogens) to reduce its population below a desired level. It can be divided into the following two approaches: inundative and classical. Inundative biological control uses mass application of an organism to attempt to eliminate a weed from an area. Like all such methods, it does not deal with the residual seedbank in the soil or prevent the weed from establishing from another source at a later date. Classical biological control uses the weed's natural enemies to establish a long-term balance between the biological control organism and the weed. The agents are thoroughly tested before release to ensure that they will not harm native and desirable introduced plants. When effective, classical biological controls provide self-perpetuating, self-dispersing, continual control of weeds. It is therefore a cost-effective, sustainable, and environmentally compatible means of controlling widespread introduced weeds. The classical approach is currently used in the biological control of British Columbia's weed infestations.

The agents of classical biological control may kill the weeds directly, but usually they reduce weed populations indirectly by decreasing plant vigour, reproduction, and competitive ability, which

in turn encourages the dominance of desired species. Biological control is not a substitute for good land management, however, and must be part of an overall land manangement plan. Weeds will persist and re-establish, or new weed species will invade, if soil and plant disturbances are excessive and the surrounding vegetation is not vigorous enough to take advantage of the weed's reduced competitive ability.

In some circumstances, weed populations can be controlled with a single biological control agent. In general, though, several agents are needed to achieve the desired population controls throughout the variety of ecological and climatic conditions present in British Columbia.

Biological control is a long-term solution and can take a long time to establish. Agents are usually scarce in their native regions because the plants (weeds) are often at a low population level there. Agents must be collected, propagated, and adapted to Canadian climates before their widespread distribution. Thus it can take several years to allow for the adequate population build-up and distribution of the agents necessary to control a given weed.

The agents currently available for biological control may not be successful in every situation. Precise habitat requirements of each biological control agent in British Columbia are not always known at the time of release. Research is ongoing, however, to determine the most effective use of biological control agents and to screen new biological control agents that will enhance the present program.

3.3 Pink/Purple-flowered Weeds

Russian Knapweed *Acroptilon repens* (L.)

FAMILY Asteraceae (Compositae)

DESCRIPTION AND LIFE CYCLE A perennial herb spreading by seeds and creeping horizontal roots. Roots are dark brown or black, scaly, and produce stem buds that develop into leafy shoots. Stems are highly branched, erect, 2–10 cm high, thin and stiff; young stems are covered with soft grey hairs. Stem leaves have smooth margins and alternate on the stem; rosette leaves are oblong to lance shaped, with irregular pinnate lobes (sometimes smooth), 5–10 cm long, and 1–2.5 cm wide. Solitary flower heads, 15–17 mm in diameter, are surrounded by bracts 12−14 mm long; flower heads are oval, greenish at the base with a papery, finely haired tip. Plants produce numerous tubular flowers, 10−13 mm long, pink or purple, becoming straw coloured at maturity. Flowering occurs from July to September. Seeds are 2–3 mm, grey or ivory in colour, surrounded by a white, deciduous fringe of hairs (pappus) 1 cm long.

GEOGRAPHICAL DISTRIBUTION Occurs mainly in warm valley bottoms of the southern interior. The northern limit in British Columbia is approximately 54°N latitude.

ECOLOGICAL DISTRIBUTION Found in both irrigated and non-irrigated areas, though more common in moist sites in valley bottoms. Pocket infestations occur up to the grassland-forest transition in the Bunchgrass, Ponderosa Pine, and Interior Douglas-fir biogeoclimatic zones. It grows in a variety of soil types; typically establishes under areas of recurring disturbance such as in cultivated fields and pastures, along roadsides and irrigation ditches, and in waste places. Once established in open areas, it tends to exclude other plants and forms essentially single-species stands.

BIOLOGICAL CONTROL AGENTS

1. *Subanguina picridis*: Nematode, stem, and leaf galls
2. *Puccinia acroptili*: Stem and leaf rust

REFERENCE

Watson, A.K. 1980. The biology of Canadian weeds. 43: *Acroptilon (Centaurea) repens*. Canadian Journal of Plant Science 60:993–1004.

Figure 1 Russian knapweed

Figure 2 Close-up of a Russian knapweed flower

Plumeless Thistle *Carduus acanthoides* L.

FAMILY Asteraceae (Compositae)

DESCRIPTION AND LIFE CYCLE An annual, winter annual, or biennial spread by seeds. Plants are 20–150 cm tall, generally smooth or with scattered hairs on stems and leaves. The upper stem is branched, with spiny wings extending to the flower heads. Mature plants have a well-developed basal rosette of narrow, oblong to elliptic leaves, deeply lobed; the lobes have one to three points, with each point ending in a spine. Solitary flower heads, 1.2–1.6 cm in diameter, form at the end of stems or in clusters on young branches. Flowers are usually purple, but some are white or cream coloured. Seeds are 2.5–3 mm long, and light brown at maturity.

GEOGRAPHICAL DISTRIBUTION Occurs in isolated pockets in the Cariboo, Kamloops, Kootenay, and Boundary areas.

ECOLOGICAL DISTRIBUTION Its geographic range across North America suggests plumeless thistle is adapted to a broad range of climatic conditions. It establishes into disturbance and occurs in pastures, along roadsides, in logged areas, in waste places, and frequently in the vicinity of gravel pits. It shows a preference for well-drained, coarse-textured soils. Increased interspecific competition from surrounding vegetation causes plumeless thistle populations to decline.

BIOLOGICAL CONTROL AGENTS

1. *Rhinocyllus conicus*: Beetle (weevil)
2. *Trichosirocalus horridus*: Beetle (weevil)
3. *Urophora solstitialis*: Fly

REFERENCE

Desroches, A.M., J.F. Bains, and S.J. Warwick. 1988. The biology of Canadian weeds. 89: *Carduus nutans* L. and *Carduus acanthoides* L. Canadian Journal of Plant Science 68:1053–1068.

Figure 3 Plumeless thistle

Figure 4 Close-up of a plumeless thistle flower

Nodding Thistle *Carduus nutans* L.

FAMILY Asteraceae (Compositae)

DESCRIPTION AND LIFE CYCLE A herbaceous biennial, or occasionally a winter annual, spreading primarily from wind-dispersed seed. It forms a large rosette in the first year, then produces flowering bolts, 0.2–2.4 m tall, with long, fleshy tap roots in the second-growth stage. One to seven erect, highly branched stems form; stems have spiny wings except immediately below the flower head. Leaves in the basal rosette are elliptic to lance shaped, 15–30 cm long, and pinnately lobed, with each lobe ending in a spine. Leaves range from hairless to densely pubescent. Leaves on the stems are similar but smaller, without lobes, and alternate on the stem. Solitary flower heads, 1.5–4.5 cm in diameter, occur at the ends of branches, usually drooping over (hence "nodding" thistle). Flowers are tubular, pink to purple (occasionally white) in colour. Flowering occurs from July to September.

GEOGRAPHICAL DISTRIBUTION Occurs in isolated pockets in the Chilcotin, Thompson, Nicola, Kootenay, Okanagan, Similkameen, and Boundary areas.

ECOLOGICAL DISTRIBUTION Its wide geographic range across North America suggests that nodding thistle does not have specific climatic requirements. It establishes into disturbance and occurs in pastures, along roadsides, in waste places, and frequently in the vicinity of gravel pits and other coarse soils. It shows a preference for well-drained soils, with a substratum of limestone. Nodding thistle can form thick stands where interspecific competition is low. Increased competition from surrounding vegetation causes nodding thistle populations to decline.

BIOLOGICAL CONTROL AGENTS

1. *Rhinocyllus conicus*: Beetle (weevil)
2. *Trichosirocalus horridus*: Beetle (weevil)
3. *Urophora solstitialis*: Fly

REFERENCE

Desroches, A.M., J.F. Bains, and S.J. Warwick. 1988. The biology of Canadian weeds. 89: *Carduus nutans* L. and *Carduus acanthoides* L. Canadian Journal of Plant Science 68:1053–1068.

Figure 5 Nodding thistle

Figure 6 Close-up of a nodding thistle flower

Spotted Knapweed *Centaurea maculosa* Lam.

FAMILY Asteraceae (Compositae)

DESCRIPTION AND LIFE CYCLE A short-lived perennial, spreading mainly by seed. Mature plants are 0.3–1.5 m tall, with long fibrous tap roots. Stems are somewhat hairy when young and highly branched. The basal and lower stem leaves are pinnately lobed; the upper leaves have smooth margins. Young leaves have a fine coating of hairs. Flowers are 1–1.5 cm long, pink to purple; bracts of the flower head are black tipped, giving the head a spotted appearance. Flowering occurs from July through to September. Seeds are black or brown, 3 mm long, and topped with bristles up to half the length of the seed. The plant contains volatile oils with a distinctive smell and an extremely bitter taste.

GEOGRAPHICAL DISTRIBUTION Found throughout British Columbia, but primarily at lower to mid-elevations of the southern interior from the Nelson area through the Kootenays, Okanagan, Thompson-Nicola, and Cariboo-Chilcotin. It occurs in isolated pockets elsewhere in the province.

ECOLOGICAL DISTRIBUTION Grows in a wide range of environmental conditions, though mostly in grasslands and open forests of the Bunchgrass, Ponderosa Pine, and Interior Douglas-fir biogeoclimatic zones. Local infestations occur in the Interior Cedar–Hemlock, Montane Spruce, and Englemann Spruce–Subalpine Fir zones. A rapid colonizer of disturbed soils, it can also displace native vegetation in undisturbed areas.

BIOLOGICAL CONTROL AGENTS

1. *Agapeta zoegana*: Moth
2. *Chaetorellia acrolophi*: Fly
3. *Cyphocleonus achates*: Beetle (weevil)
4. *Larinus minutus*: Beetle (weevil)
5. *Larinus obtusus*: Beetle (weevil)
6. *Metzneria paucipunctella*: Moth

7. *Pellochrista medullana*: Moth
8. *Puccinia jaceae*: Stem and leaf rust
9. *Sphenoptera jugoslavica*: Beetle
10. *Terellia virens*: Fly
11. *Urophora affinis*: Fly
12. *Urophora quadrifasciata*: Fly

REFERENCE

B.C. Ministry of Agriculture and Fisheries. 1988. Spotted knapweed (*Centaurea maculosa* Lam.). Agdex 640, Weed Control Series, Field Crop Facts. Field and Special Crops Branch, Victoria, B.C. 2 p.

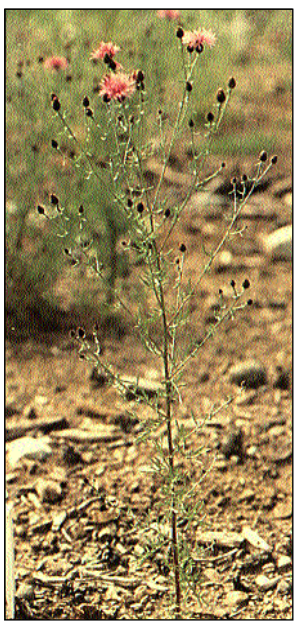

Figure 7 Spotted knapweed

Figure 8 Close-up of a spotted knapweed flower

Canada Thistle *Cirsium arvense* (L.) Scop.

FAMILY Asteraceae (Compositae)

DESCRIPTION AND LIFE CYCLE A perennial, spreading by seeds and a horizontal creeping root system. Stems are erect, up to 1.2 m tall, with alternate leaves, 4–21 cm long, divided into deep, irregular, spiny lobes. The leaves are dark green and shiny on the surface with white hairs underneath. Flowers form in clusters on small heads and are rose-purple, pink, or sometimes white. Flowering occurs throughout the summer.

GEOGRAPHICAL DISTRIBUTION Widespread and locally abundant in all areas of British Columbia.

ECOLOGICAL DISTRIBUTION Occurs in cultivated fields and pastures, along roadsides, and in waste places. It grows under a wide range of habitats and occurs in all biogeoclimatic zones.

BIOLOGICAL CONTROL AGENTS

1. *Ceutorhynchus litura*: Beetle (weevil)
2. *Larinus planus*: Beetle (weevil)
3. *Urophora cardui*: Fly

REFERENCE

B.C. Ministry of Agriculture and Food. 1985. Canada thistle (*Cirsium arvense* (L.) Scop.). Agdex 640, Weed Control Series, Field Crop Facts. Field and Special Crops Branch, Victoria, B.C. 4 p.

Figure 9 Canada thistle

Figure 11 Foliage of Canada thistle

Figure 10 Close-up of a Canada thistle flower

Bull Thistle *Cirsium vulgare* (Savi) Tenore

FAMILY Asteraceae (Compositae)

DESCRIPTION AND LIFE CYCLE A biennial, spreading by wind-borne seed. It forms a large, flat rosette with a long, fleshy tap root in the first year, and produces a 0.3–1.5 m bolt in the second year. The stems are spiny winged and slightly woolly. Leaves are alternate, deeply lobed, with each lobe ending in a long sharp spine up to 1 cm long. The upper leaf surface is deep green and has sharp prickles, while the lower surface is white with small white hairs. Purple flower heads, 3.8–7.8 cm in diameter, occur throughout the summer.

GEOGRAPHICAL DISTRIBUTION Widespread and locally abundant in all areas of British Columbia.

ECOLOGICAL DISTRIBUTION Occurs along roadsides, in cultivated fields, pastures, logged-over forest land, and waste places associated with soil disturbance. It grows under a wide range of habitats and occurs in all biogeoclimatic zones. Bull thistle can form thick stands where surrounding vegetation is sparse; increased interspecific competition causes bull thistle populations to decline.

BIOLOGICAL CONTROL AGENT

1. *Urophora stylata*: Fly

REFERENCE

B.C. Ministry of Agriculture. 1980. Bull thistle *(Cirsium vulgare)*. Weed Control Series Number 19, Field Crop Facts. Field and Special Crops Branch, Victoria, B.C. 2 p.

Figure 12 Bull thistle

Figure 14 Foliage of bull thistle

Figure 13 Close-up of a bull thistle flower

Hound's-tongue *Cynoglossum officinale* L.

FAMILY Boraginaceae

DESCRIPTION AND LIFE CYCLE A biennial or short-lived perennial, spreading mainly by seed. Germination of seeds is almost completely restricted to the spring after cold stratification in the winter. A basal rosette of leaves forms in the summer and autumn; the size of the rosette determines further development. Those larger than 30 cm in diameter bolt and flower from May to July of the following year. The inflorescence is a cyme with up to 23 red-purple flowers. An individual plant can produce up to 4000 large seeds (burs) covered with barbed spines. The spines aid in dispersal by animals, and are a source of annoyance for wildlife and livestock, which get the burs caught in their hair and fur. Seeds and plant material are toxic to livestock.

GEOGRAPHICAL DISTRIBUTION Occurs primarily in the southern interior of British Columbia; locally abundant in the Kootenays, Thompson-Nicola, Okanagan, Similkameen, Boundary, and southern tip of the Cariboo.

ECOLOGICAL DISTRIBUTION Associated with soil disturbance along roadsides and pastures and logged-over forest land. Found primarily in the Ponderosa Pine, Interior Douglas-fir, Montane Spruce, and Engelmann Spruce–Subalpine Fir biogeoclimatic zones. In the absence of soil disturbance, hound's-tongue declines with interspecific competition from surrounding vegetation.

BIOLOGICAL CONTROL AGENT

1. Agents are currently being screened.

REFERENCE

Freese, A. 1990. Weed projects for Canada: Houndstongue (*Cynoglossum officinale* L.). Work in Europe in 1990. European Station Report, C.A.B. International Institute of Biological Control, Delemont, Switzerland. 27 p.

Figure 15 Hound's-tongue

Figure 16 Close-up of a hound's-tongue flower

Figure 17 Hound's-tongue rosette

Purple Loosestrife *Lythrum salicaria* L.

FAMILY Lythraceae

DESCRIPTION AND LIFE CYCLE A perennial wetland plant, spreading by seed and root stock; floating seedlings are the main mode of dispersal. Seeds can remain viable in the soil for several years. Mature plants range between 0.5–2 m high, with a maximum of 30–50 shoots emerging from a common root stock. Three forms of purple flowers are produced prolifically throughout the summer, occurring in equal frequency. The profuse, showy flowers have given rise to the plant's use as a garden ornamental.

GEOGRAPHICAL DISTRIBUTION Occurs in wetlands and along irrigation canals, ditches, and lake and river shorelines in the Okanagan, Boundary, Vancouver Island, and the Fraser Valley areas.

ECOLOGICAL DISTRIBUTION Successful seed establishment occurs only on moist soil, in a wide variety of soil types. Moisture is the most important factor in growth and reproduction, but well-established plants can persist in dry sites for many years. Loosestrife is capable of establishing in the riparian areas of most mid- to low-elevation biogeoclimatic zones in the southern interior and southern coastal areas.

BIOLOGICAL CONTROL AGENTS

1. *Galerucella calmariensis*: Beetle
2. *Galerucella pusilla*: Beetle
3. *Hylobius transversovittatus*: Beetle (weevil)

REFERENCE

Blossey B. and D. Schroeder. 1991. Study and screening of potential biological control agents of purple loosestrife (*Lythrum salicaria* L.): Final report. European Station Report, International Institute of Biological Control, Delemont, Switzerland. 27 p.

Figure 18 Purple loosestrife

Figure 19
Close-up of a purple loosestrife flower

3.4 White-flowered Weeds

Diffuse Knapweed *Centaurea diffusa* Lam.

FAMILY Asteraceae (Compositae)

DESCRIPTION AND LIFE CYCLE A biennial to short-lived perennial, spreading primarily by seed dispersed with the movement of plant material. Stems are 60–90 cm in height with many branches. Leaves are 5–20 cm long, hairy, and highly divided. Leaves alternate from the stem, with basal leaves forming a rosette. Flower heads are numerous, urn shaped, and covered with small, narrow bracts ending in sharp, rigid spines. Flowers are white or occasionally pink or purple. Seeds are black to dark brown, 3 mm long, and lack a developed fringe of hairs (pappus). Diffuse knapweed contains volatile oils with a distinctive smell and extremely bitter taste.

GEOGRAPHICAL DISTRIBUTION Widely distributed throughout British Columbia, though primarily in the Kootenays, Thompson-Nicola, Okanagan, Kettle River, and Fraser Canyon areas of the southern interior. Occurs in pockets and at lower abundance in the Cariboo-Chilcotin.

ECOLOGICAL DISTRIBUTION Occurs over a wide range of ecological types, though it tends to dominate in dry valley bottoms in the Bunchgrass zone and transition areas of Ponderosa Pine, and Interior Douglas-fir biogeoclimatic zones. A rapid colonizer of disturbed soils, it can also invade and displace native vegetation in undisturbed areas.

BIOLOGICAL CONTROL AGENTS

1. *Agapeta zoegana*: Moth
2. *Chaetorellia acrolophi*: Fly
3. *Larinus minutus*: Beetle (weevil)
4. *Larinus obtusus*: Beetle (weevil)
5. *Pelochrista medullana*: Moth
6. *Pterolonche inspersa*: Moth
7. *Puccinia jaceae*: Stem and leaf rust
8. *Sphenoptera jugoslavica*: Beetle
9. *Urophora affinis*: Fly
10. *Urophora quadrifasciata*: Fly

REFERENCE

B.C. Ministry of Agriculture and Fisheries. 1988. Diffuse knapweed (*Centaurea diffusa* Lam.). Agdex 640, Weed Control Series, Field Crop Facts. Field and Special Crops Branch, Victoria, B.C. 2 p.

Figure 20
Diffuse knapweed

Figure 21
Close-up of a diffuse knapweed flower

3.5 Yellow-flowered Weeds

Rush Skeletonweed *Chondrilla juncea* L.

FAMILY Asteraceae (Compositae)

DESCRIPTION AND LIFE CYCLE A tap-rooted herbaceous perennial, spreading by rhizomatous lateral roots and prolific seed production. Plants range from 0.3 to 1.3 m in height at maturity. Rosettes develop from root buds in fall; rosette leaves are lance shaped, deeply lobed 1–3 cm wide and 5–12 cm long. Leaves develop a reddish tinge near the tips during the winter. Multi-branched, erect stems grow from the root crown in spring. Stems are pale green, slender, sparsely leaved, and smooth except for erect, downward-pointing hairs on the lower 5–10 cm. Flower heads develop along or at the end of stems, individually or in groups of two to five. Each flower head may contain 10–12 bright yellow flowers. Flowering occurs from mid-summer until the first frosts. Stems die back each year.

GEOGRAPHICAL DISTRIBUTION Occurs in pockets in the North Okanagan and the Kootenays.

ECOLOGICAL DISTRIBUTION Associated with roadsides, waste areas, and areas subject to repeated soil disturbance. Adapted to a wide variety of environmental conditions, though it prefers arid or semi-arid conditions and well-drained sand or gravel soils.

BIOLOGICAL CONTROL AGENTS

1. *Aceria chondrillae*: Gall mite
2. *Puccinia chondrillina*: Stem and leaf rust

REFERENCE

University of Idaho. 1991. Rush skeletonweed. Current Information Series No. 585. College of Agriculture Cooperative Extension Service, Agriculture Experiment Station, Moscow, Idaho.

Figure 22
Rush skeletonweed

Figure 23 Close-up of a rush skeletonweed flower

Leafy Spurge *Euphorbia esula* L.

FAMILY Euphorbiaceae

DESCRIPTION AND LIFE CYCLE A perennial, spreading by seeds and buds on persistent, creeping roots. Stems are erect, 1 m tall and hairless or with only a few hairs near the top. Plants grow in clumps forming dense and extensive stands. Stalkless leaves, 3–7 cm long and less than 5 mm wide, alternate one per node. A whorl of leaves marks the start of the flowering portion of the stem. Flower bracts, about 1 cm wide and 1.2 cm long with a sharp point, occur in pairs on flowering stems. Flowers lack petals and sepals, and are clustered with a pair of surrounding bracts such that the group resembles a single flower. Seeds are about 2 mm long, smooth, grey to yellow or brown and usually have a yellow bump near the base. Three seeds are produced per cluster. All parts of the plant contain a milky-coloured latex juice that can poison livestock and cause skin irritation on humans.

GEOGRAPHICAL DISTRIBUTION Occurs in isolated pockets in the Thompson, Cariboo, Boundary, East Kootenay, Nechako, and North Okanagan areas.

ECOLOGICAL DISTRIBUTION Spurge has a wide variety of ecological tolerances; it is associated primarily with grassland and open forests of the Bunchgrass, Ponderosa Pine, and Interior Douglas-fir biogeoclimatic zones.

BIOLOGICAL CONTROL AGENTS

1. *Aphthona cyparissiae*: Beetle (flea-beetle)
2. *Aphthona czwalinae*: Beetle (flea-beetle)
3. *Aphthona flava*: Beetle (flea-beetle)
4. *Aphthona lacertosa*: Beetle (flea-beetle)
5. *Aphthona nigriscutis*: Beetle (flea-beetle)
6. *Hyles euphorbiae*: Moth
7. *Lobesia euphorbiana*: Moth

REFERENCE

B.C. Ministry of Agriculture and Food. 1985. Leafy spurge (*Euphorbia esula* L.). Agdex 640, Weed Control Series, Field Crop Facts. Field and Special Crops Branch, Victoria, B.C. 5 p.

Figure 24 Leafy spurge

Figure 25 Close-up of a leafy spurge flower

Figure 26 Foliage of leafy spurge. Note latex dripping from the stem.

St. John's Wort *Hypericum perforatum* L.

FAMILY Hypericaceae

DESCRIPTION AND LIFE CYCLE A perennial spreading by seeds or short runners. Stems, growing to 1 m high, are numerous, erect, and rust coloured at the base. Leaves are opposite, oval, and attached directly to the stem; they appear to be perforated with many tiny translucent dots, visible when held up to a light source. Flowering begins in early summer; flowers are yellow with five separate petals and numerous stamens arranged in three groups. Rust-brown seed pods, containing numerous seeds, mature in late summer to early autumn. Germination occurs in the spring. St. John's wort contains a toxin which, in light-coloured livestock that feed on it, induces photosensitization (skin is irritated and blisters when exposed to sunlight).

GEOGRAPHICAL DISTRIBUTION Occurs in scattered pockets in the Kootenays, Okanagan, Boundary, North Thompson, Cariboo, Skeena, Fraser Valley, and Vancouver Island areas.

ECOLOGICAL DISTRIBUTION Associated primarily with the moist grasslands and open forest areas of the Bunchgrass, Ponderosa Pine, Interior Douglas-fir, Coastal Douglas-Fir, and Coastal Western Hemlock biogeoclimatic zones.

BIOLOGICAL CONTROL AGENTS

1. *Agrilus hyperici*: Beetle
2. *Aplocera plagiata*: Moth
3. *Aphis chloris*: Aphid
4. *Chrysolina hyperici*: Beetle
5. *Chrysolina quadrigemina*: Beetle

REFERENCE

Whitson, T.D. 1987. Weeds and poisonous plants of Wyoming and Utah. Co-published by University of Wyoming, College of Agriculture, Cooperative Extension Service, and Utah State University Extension Service and Agriculture Experiment Station, Laramie, Wyoming, pp. 90–91.

Figure 27
St. John's wort

Figure 28
Close-up of a
St. John's wort flower

Dalmatian Toadflax *Linaria dalmatica* (L.) Miller

FAMILY Scrophulariaceae

DESCRIPTION AND LIFE CYCLE A perennial, spreading by seeds and creeping root stock. Numerous light-green, smooth stems, 60–120 cm tall, are produced on each plant. Leaves are light green, heart shaped, and clasp the stem. Roots are large, rough surfaced, and somewhat branching, and may extend 180 cm or more into the soil. Long, slender lateral roots branch from the main roots and may extend 3 m or more. Buds appear from the lateral roots, producing new top growth at varying intervals. Flowers, yellow tinged with orange, are ``snapdragon'' shaped, and up to 4 cm long.

GEOGRAPHICAL DISTRIBUTION Distributed through the Okanagan, Similkameen, Thompson, East Kootenay, Cariboo, Skeena, and Boundary areas.

ECOLOGICAL DISTRIBUTION Occurs along roadsides and in waste areas, gardens, cultivated fields, open grassland, and transitional forest-grassland. Primarily associated with the Bunchgrass, Ponderosa Pine, and Interior Douglas-fir biogeoclimatic zones.

BIOLOGICAL CONTROL AGENTS

1. *Brachypterolus pulicarius*: Beetle
2. *Calophasia lunula*: Moth
3. *Eteobalea intermediella*: Moth
4. *Gymnaetron antirrhini*: Beetle (weevil)
5. *Mecinus janthinus*: Beetle (weevil)

REFERENCE

B.C. Ministry of Agriculture. n.d. Dalmatian toadflax *(Linaria dalmatica)*. Weed Control Series Number 16, Field Crop Facts. Field and Special Crops Branch, Victoria, B.C. 2 p.

Figure 29 Dalmatian toadflax

Figure 30 Close-up of a Dalmatian toadflax flower

Yellow Toadflax *Linaria vulgaris* L.

FAMILY Scrophulariaceae

DESCRIPTION AND LIFE CYCLE A perennial, spreading by creeping roots and seeds. Stems, growing up to 80 cm high, are hairless and usually unbranched. Leaves are numerous, one per node, essentially stalkless, and 2–10 cm long by 1–5 mm wide. The leaves are also hairless and usually narrowed towards the base. Bright yellow ``snapdragon''-shaped flowers are 2–3.5 cm long on stalks about 5 mm long.

GEOGRAPHICAL DISTRIBUTION Locally abundant in the Okanagan, Similkameen, Thompson, Boundary, East Kootenay, and Cariboo areas.

ECOLOGICAL DISTRIBUTION Occurs along roadsides and in waste areas, gardens, cultivated fields, open grassland, and transitional forest-grassland. Associated primarily with the Bunchgrass, Ponderosa Pine, and Interior Douglas-fir biogeoclimatic zones.

BIOLOGICAL CONTROL AGENTS

1. *Brachypterolus pulicarius*: Beetle
2. *Calophasia lunula*: Moth
3. *Eteobalea serratella*: Moth
4. *Gymnaetron antirrhini*: Beetle (weevil)
5. *Mecinus janthinus*: Beetle (weevil)

REFERENCE

B.C. Ministry of Agriculture and Food. 1985. Toadflax (*Linaria vulgaris* Mill.). Agdex 640, Weed Control Series, Field Crop Facts. Field and Special Crops Branch, Victoria, B.C. 4 p.

Figure 31
Yellow toadflax

Figure 32
Close-up of a yellow toadflax flower

Figure 33
Foliage of yellow toadflax

Tansy Ragwort *Senecio jacobeae* L.

FAMILY Asteraceae (Compositae)

DESCRIPTION AND LIFE CYCLE A biennial to short-lived perennial, spreading by prolific seed production (in excess of 150 000 seeds per plant). A low-growing rosette of leaves is produced in the first year. Erect stems, 0.3–1.2 m high, are produced in the second and subsequent years. The dark green, stalkless leaves are deeply lobed into irregular segments, giving the plant a ``ragged'' appearance. The daisy-like, bright yellow flowers are in bloom from July through September. Tansy ragwort is poisonous to livestock; cattle and horses are most seriously affected, sheep seldom.

GEOGRAPHICAL DISTRIBUTION Infestations occur in the lower Fraser Valley and southern Vancouver Island; a major infestation is also present in the southern Okanagan near Naramata.

ECOLOGICAL DISTRIBUTION Associated primarily with soil disturbance, tansy ragwort can be found in pastures, waste areas, and open, moist to wet woodlands. Infestations occur in the Coastal Douglas-fir, Coastal Western Hemlock, and Interior Douglas-fir biogeoclimatic zones.

BIOLOGICAL CONTROL AGENTS

1. *Cochylis atricapitana*: Moth
2. *Hylemya seneciella*: Fly
3. *Longitarsus flavicornis*: Beetle
4. *Longitarsus jacobaeae*: Beetle
5. *Tyria jacobaeae*: Moth

REFERENCE

B.C. Ministry Agriculture and Fisheries. n.d. Tansy ragwort in British Columbia. Co-published with Central Fraser Valley Regional District. Victoria, B.C. 4 p.

Figure 34
Tansy ragwort

Figure 35 Close-up of a tansy ragwort flower

4 GUIDE TO THE BIOLOGICAL CONTROL OF WEEDS

4.1 Screening Biological Control Agents

Organisms considered for use as biological control agents are carefully studied and screened before they are introduced into North America. Initial screening is conducted in Europe, which is within the native range of all the introduced weeds in British Columbia. Potential agents are collected in areas that have similar habitats to the potential release sites in British Columbia. During the screening process, they are tested on a wide variety of North American vegetation to ensure host specificity (that is, to ensure that agents will feed on – and damage – only weeds). By international agreement, an organism will be released in North America only if the screening process confirms that there will be no detrimental impact on non-target organisms. The second step in introducing a new biological control agent is a quarantine period in North America to ensure that no unwanted organisms are introduced with the agent. In a few situations, further host specificity tests may be conducted at quarantine sites in North America. Once the screening has been completed and reviewed, the suitable biological control agents are approved for release at field sites for propagation and distribution.

4.2 Propagating Biological Control Agents

To monitor new importations and ensure their successful establishment, agents are often confined to propagation units for their initial release. Tented plots containing the target weed provide a protected environment for the biological control agents to increase in population in preparation for operational releases (Figure 36). Propagation units also allow research staff to gather more information on the life cycles, habitat preferences, and collection, shipping, handling, and release procedures.

4.3 Collecting Biological Control Agents

Successful biological control depends on the effective distribution of the control agents. Not only can agents take many years to distribute themselves naturally, but weed populations are also often geographically isolated by the mountainous terrain in British

Figure 36 Biological control propagation plots

Columbia. Collection and redistribution, therefore, are key elements to a successful biological control program.

Biological control agents can be collected by a variety of techniques including hand picking, the collection of plant material containing the agents, aspirating, sweep netting, and the use of collection trays and funnels. Traditional collection techniques that damage or kill insects, such as sticky traps or pit traps, are obviously inappropriate.

For most agents, collection can be completed once the population has been located. The description of the specific biological control agent should be checked to determine if the agent is more active during certain times of the day than others. Some nocturnal moths can be attracted to a site with blacklight traps during the night to increase the likelihood of collection or detection.

4.3.1 Hand picking

Hand picking can be used for larger adult weevils and beetles and free-living moth larvae (caterpillars) that position themselves in visible locations on the plants and will not be damaged by handling.

- Pick these agents gently with your forefingers and store in aerated containers. If collecting for extended periods of time or during

hot days, store the collected material in shipping containers with cool packs (see Section 4.4, ``Shipping and Handling Biological Control Agents'').

- Do not forcefully dislodge insects that are holding onto plant material. It may damage them. As well, never handle adult moths with your hands. It will damage their wings.
- Very small insects (<2 mm long) can be collected with a damp artist's brush: dab the insect on the back and transfer to a collection container. Weevils can sometimes be coaxed from plants by rubbing a short piece of straw under their abdomen.

4.3.2 Collection of plant material

Collecting biological control agents in or on plant material is mostly self-explanatory.

- When gathering material for seedhead, stem, or root galls, open up some plant material to determine or confirm the presence of the biological control agent.
- Plant material infected with rusts should be collected when visible fruiting bodies are present to ensure infected material is collected.
- When excavating plants for agents contained in or on the roots, first loosen the soil with a spade or fork to prevent breaking the root open underground.
- Collect plant material when it is relatively dry; this will prevent unwanted moulding or deterioration in transport and storage. Wear heavy gloves to protect your hands from spines or prickles when necessary.

4.3.3 Aspirators

Vacuum suction aspirators can be used for collecting adult moths and other small adult insects.

- To construct an aspirator, attach a collection container with an intake tube to a screened tube connected to a low-powered vacuum source (Figure 37). A backpack type aspirator can be constructed with a leaf-blower/vacuum unit for the suction source. High-powered suction should not be used for most insects, which can be damaged by being pulled into the collection chamber at too great a speed.

Figure 37 Vacuum aspirator for insect collection

- When collecting adult moths, suck them head first into the collection tube while they are at rest on a plant. This will help prevent damaging their wings.
- Place some plant material or paper towel in the collection container for the insects to cling to.

4.3.4 Sweep nets

Cotton-bag sweep nets are effective for collecting a variety of insect biological control agents.

- Systematically walk the collection area, sweeping the plant surfaces in a back and forth motion. After an initial pass allow bees and wasps to escape from the bag and transfer the contents to a nylon mesh bag or other ventilated container. After giving the insects adequate time to recover, sweep the same area again to collect those agents that fell to the ground and have climbed back on the plants.
- Sort through the collected material as soon as possible to separate biological control agents from their predators and to clean out other unwanted organisms, plant material, and seeds inadvertently collected.

4.3.5 Beating trays and collection funnels

For scattered weeds, or where sweep nets may damage plants too greatly to support the remaining agents, beating trays and collection funnels can be used.

- Place a tray or funnel with its container below the target weed and shake the plant vigorously to dislodge biological control agents from the plant.
- Sort through the collected material as soon as possible to separate biological control agents from their predators and to clean out unwanted organisms, plant material, and seeds inadvertently collected.

4.4 Shipping and Handling Biological Control Agents

Biological control agents are living organisms and must be treated with care at all times. Measures should be taken to shelter them from environmental extremes, and to isolate them from toxins and other potentially lethal substances (such as pesticides and gasoline). In general, survival improves if handling and storage are minimized; agents should be collected and transported to their new location as quickly as possible.

The following subsections contain general guidelines for shipping biological control agents. Refer to individual agents for specific shipping and handling requirements. Recommendations referring to insects include free-living larvae and adults. Recommendations for plant material include plant material containing insect larvae and pupae, as well as plant or plant galls infested with mites, nematodes, rusts, and other pathogens.

4.4.1 Insects

- Keep insects in aerated containers or paper or cloth bags loosely filled with plant material for the insects to feed on and cling to. Avoid plastic bags because they can produce condensation and static charges that are harmful.
- Ship containers in an insulated carton, cooled with ice packs. Cool temperatures reduce insect activity and prevent damage caused by excessive movement. The coolers also protect them from excessive heat. Insects should not be stored or transported

in cold temperatures (less than 4°C) as they may damage or kill insect agents.

- To protect containers placed in the insulated coolers from moisture condensation and melting ice, wrap the ice packs in paper towel and enclose them in plastic bags. Insect containers placed in the shipping container should not be in direct contact with the ice packs.
- Provide good ventilation in the shipping containers with small enough holes to ensure that no insects escape.
- If shipping lasts for more than 2 days, frequently change the plant material inside the containers (provided for insects to feed on and cling to) to remove excrement and to provide fresh material for feeding.

4.4.2 Plant material

- Pack plant material containing biological control agents loosely in paper bags; plastic bags may increase humidity and condensation and promote undesirable fungal growth or decay in the plant material.
- Avoid crushing or tightly packing bags for shipment, because this will decrease aeration and promote anaerobic decay.
- Storage at 4°C will slow the decay of plant material. However, do not freeze plant material as it may kill or damage the biological control agents.

4.5 Releasing Biological Control Agents

4.5.1 Site selection

Because many biological control agents have specific habitat requirements, site selection is very important to their survival and effectiveness.

- Refer to individual agents for specific habitat requirements before site selection. For all releases, sites must have a large enough weed stand to support the agent's population and be free of excessive disturbance. Release sites should not be treated with herbicides, and should receive little or no grazing during the establishment of the agents.

- Attempt to match elevations and weed development at the collection and release sites to ensure that the insect's life cycle will synchronize with the plant phenology at the new site.
- Check release records to ensure a reasonable distance is maintained between releases, such that new releases are not redundant as a result of the natural spread of the agents. Wind-spread agents can move 50 km or more in a year, although for others the dispersal rate may be only a few metres per year. A field check to monitor for agent presence is also advisable.

4.5.2 Site identification

- Mark release sites with a stake, and tag them with a release site reference code. The code should be a maximum of 12 characters long and contain the following information:
  1. the biological control agent code. The codes are made up of the first two letters of the genus and species name of the agent;
  2. the Range Unit number in which the release is being made;
  3. the sequential release in that Range Unit for that year; and
  4. the year of the release.

For example, AGZO-3074–02-94 would be the coding for the second release of *Agapeta zoegana* in Range Unit 3074 in 1994.

- Release sites should be mapped at 1:20 000 and should be referenced to an air photograph; additional notes identifying local features can help relocate sites. Photoplots of release sites provide a quick means of recording additional release site information; they also provide a reference for future comparison of the efficacy of the weed control.
- Gather climatic and habitat information, according to the standard release form (Appendix 2) at the time of release and forward it to the provincial weed biological control data base. The current registry for weed biological control release information is:

  Weed Technician,
  B.C. Ministry of Agriculture, Fisheries and Food,
  162 Oriole Road, Kamloops, B.C. V2C 4N7

The information collected, together with the monitoring data, is important to the biological control program as it adds to the general knowledge of the agents and aids in refining program activities.

4.5.3 Release procedures

The following guidelines should be used for releasing biological control agents. Refer to individual biological control agents for specific release procedures. Recommendations for insects apply to free-living larvae and adults. Recommendations for plant material apply to plant material containing insect larvae and pupae, as well as plants containing rusts, mites, nematodes, and other pathogens.

Insects

- At the release site, place the shipping carton gently on the ground and leave it undisturbed for a few minutes before the insects are removed. Do not place new releases near obvious ant colonies or wasp nests to minimize predation losses.
- Carefully shake out the insects in an even distribution in the immediate area of the release location; flying insects should disperse themselves once the container lid is opened.
- Count and record the number of dead insects in the containers to determine the number of live insects released. Some insects feign death when disturbed, therefore, care should be taken to leave the container undisturbed for a few moments before discarding dead insects.

Agents in plant material

- Plant material containing biological control agents should be transported immediately to field sites when possible.
- Plants should be tied to a stake or confined in a field cage to prevent accidental removal or destruction. Do not place all the material in one pile; spread it into several locations to minimize predation and prevent parasite build-up.
- If the plant material contains mature seedheads and further weed infestation is possible, place the plant material in a container with holes drilled in the top, large enough to allow the biological control agents to disperse but small enough to prevent the seeds in the plants from dispersing.

4.6 Monitoring Biological Control Releases

Monitoring is conducted at various levels of intensity depending on the information desired. Monitoring biological control agents can be conducted to determine one or more of the following:

- presence at a given location;
- density per plant or area;
- amount and type of damage per plant or area; and
- direction, distance, and rate of movement from release point.

For most operational biological control programs, checking for presence will be the only monitoring function. If there is doubt as to whether a release has been made in an area before, or if it is possible that agents have naturally distributed themselves into an area, monitoring of the weed stand should be conducted before a new release is made. Biological control releases can fail at a given site during establishment for various reasons. New releases should therefore be monitored for establishment within 1–2 years to determine if a supplementary release is necessary.

Always record monitoring results and forward to the provincial weed biological control data base. Establishment information is important for planning future biological control activities, including the identification of potential collection sites for future redistributions.

The technique for determining presence will vary for each biological control agent; refer to individual agents for specific instructions. If monitoring for presence of agents requires destruction of plant material, remove and open plants only until the first agent is found. There may only be a few agents at a given site during the establishment phase and destroying too many plants and agents could be a serious setback to the agent's population.

4.7 Biological Control Agents

Aceria chondrillae (Acarina: Eriophidae)

DESCRIPTION AND LIFE CYCLE This tiny (0.2–0.3 mm long), gall-forming mite is yellowish orange and has two pairs of legs. Female mites feed on both vegetative and flower buds; the plant forms green galls composed of many small, deformed leaflets around infestations of several hundred mites. Eventually the galls stop growing, begin to dry, and turn to brown. Mites exit the dying galls and crawl or are windblown to infest new plant tissue and other plants. Flower buds are generally destroyed by the gall formation, reducing and sometimes eliminating seed production. Heavily galled plants display a deformed, stunted growth form; leaves and stems turn yellow and the plant is unable to compete effectively with surrounding vegetation. Generations can be completed in 10 days during the summer and new generations are produced up until plant growth is terminated by lack of moisture or fall frosts.

WEED ATTACKED Rush skeletonweed.

HABITAT Capable of tolerating the variety of habitats in which rush skeletonweed is found.

COLLECTION, SHIPPING, AND HANDLING Collect green galls in the early spring (May) and transfer to the release site immediately. Follow standard shipping and handling procedures for plant material containing biological control agents. Redistribute before fall frosts.

RELEASE Place or tie galls in bundles on the new rush skeletonweed. As the galls dry out, the mites will exit and distribute themselves onto new plant material.

MONITORING Determine presence, density, and movement by looking for galls on leaf and flower buds from April to September.

REFERENCE

Cheney, T.M., G.L. Piper, G.A. Lee, F.W. Barr, D.C. Thill, R.B. Hawkes, R.F. Line, R.R. Old, L.L. Craft, Jr., and E.B. Adams. 1981. Rush skeletonweed: biology and control in the Pacific Northwest. Current Information Series No. 585. University of Idaho, College of Agriculture, Cooperative Extension Service, Agriculture Experiment Station, Moscow, Idaho. 4 p.

Figure 38 *Aceria chondrillae* galls on rush skeletonweed

Agapeta zoegana L. (Lepidoptera: Cochylidae)

DESCRIPTION AND LIFE CYCLE Adults, 1–2 cm long, have yellow bodies with black stripes. Females have a larger body than do males, with a more rounded abdomen, and males have a pair of clasping pincers at the end of the abdomen. Adults emerge from mid-June to mid-August and mating begins almost immediately. Eggs are laid throughout the 10- to 14-day life span. Larvae hatch 7–10 days after the eggs are laid and migrate into the root crown. Larvae mine the root tissue just below the outer surface, leaving spiral trails covered by a thin, whitish web. Pupation occurs inside the web near the root crown in early fall, and the insect overwinters in this form.

WEEDS ATTACKED Diffuse knapweed and spotted knapweed; shows a preference for spotted knapweed.

HABITAT Prefers the mesic, cooler areas of the knapweed range in the Bunchgrass and Ponderosa Pine biogeoclimatic zones. Tolerates cold winter temperatures but requires a long growing season to develop; it therefore does not do well at elevations above 1000 m. Rarely found along roadsides or where knapweed is mowed regularly.

COLLECTION, SHIPPING, AND HANDLING Collect adult moths in late afternoon to dusk with vacuum aspirators as they emerge from July to August. Standard shipping and handling precautions for adult insects should be observed. Because of the short lifespan of *Agapeta* adults, they must be collected and transported within 2–3 days.

RELEASE Follow a standard release technique. *Pelochrista medullana* larvae may destroy *Agapeta* larvae when they occur on the same root; avoid releasing the two moths at the same site. Release the moths as soon after collection as possible.

MONITORING Presence and density are most effectively determined by the number of larvae per root. Dig and remove entire knapweed plant in early June. Lightly scrape the outer surface of the root to expose the spiral tunnelling and webbing from the crown to the tip of the root.

REFERENCE

Muller, H., D. Schroeder, and A. Gassmann. 1988. *Agapeta zoegana* (L.) (Lepidoptera: Cochylidae), a suitable prospect for biological control of spotted and diffuse knapweed, *Centaurea maculosa* Monnet de la Marck and *Centaurea diffusa* Monnet de la Marck (compositae) in North America. Canadian Entomologist 120: 109–124.

Figure 39 *Agapeta zoegana* moth

Figure 40 *Agapeta zoegana* larva

Agrilus hyperici (Creutzer) (Coleoptera: Buprestidae)

DESCRIPTION AND LIFE CYCLE Adults, brown with a metallic-purple or greenish sheen, are 4–5 mm long and elongate in shape. Adults emerge from the root crown in July and feed on terminal leaves. Mating begins immediately and eggs are laid near the base of living stems. Larvae tunnel down the stem and enter the root crown where they feed and develop until late fall. One to several larvae may be present on a single root. Larvae tunnelling reduces plant vigour and can decrease biomass by up to 20%. Larvae overwinter in the root and pupation occurs in mid- to late May.

WEED ATTACKED St. John's wort.

HABITAT These beetles are at the northern limit of their distribution in British Columbia. They need warm, dry habitats, as the larvae are prone to fungal attack at damp sites. They prefer large-stemmed St. John's wort plants to feed, develop, and reproduce on.

COLLECTION, SHIPPING, AND HANDLING Use sweep nets to collect adults in late June through July. The beetles are prone to flight, so quick search and capture must be used. Follow standard shipping and handling procedures for insects.

RELEASE A release of 25–50 adults by standard procedures is sufficient to establish a new colony.

MONITORING Check presence by one of the following methods: sweeping for adults in July, digging and observing roots for tunnelling scars, or cutting open crowns and root stocks in late fall to look for tunnelling and larvae. Tunnelling scars on the stem base appear as thin, brown lines, lightly scored into the stem surface. Early stages of the larvae are small (<1 mm long) and therefore difficult to see until they enlarge in the early summer.

REFERENCES

Campbell, C.L., J.P. McCaffrey, and H.W. Homan. 1987. Collection and redistribution of biological control agents of St. John's wort. Current Information Series No. 798. University of Idaho, College of Agriculture, Cooperative Extension Service, Agriculture Experiment Station, Moscow, Idaho. 4 p.

Harris, P. and D. Peschken. 1969. The status of biological control of the weed *Hypericum perforatum* in British Columbia. Canadian Entomologist 101:1–15.

Figure 41 *Agrilus hyperici* larva

Aphis chloris (Koch) (Hemiptera: Aphididae)

DESCRIPTION AND LIFE CYCLE Several forms of the 1–2 mm long aphid may be produced during an annual cycle depending on environmental conditions. Generally, cooler temperatures and shorter day lengths stimulate the production of males and egg-producing females in the fall. Eggs, yellow, turning shiny black with age, are laid on the base of flowering stems; the eggs require a cold period in the winter and then continue development the following spring. Eggs hatch in April or May, giving rise to wingless females. Under continued warm conditions, the self-reproducing females develop year round. Both the adults and larvae suck plant fluids from the plant root crown and stem. During the mid-summer, under crowded conditions, winged, fertile females develop and disperse to form new colonies.

WEED ATTACKED St. John's wort.

HABITAT This aphid is found over a wide geographic and climatic range in its native Europe, and is considered to be contiguous with St. John's Wort distribution in British Columbia.

COLLECTION, SHIPPING, AND HANDLING Collect whole plants infested with egg-producing females in mid-summer and transport in nursery containers. Ship to the release site as soon as possible, as the aphids require living plant material to feed on.

RELEASE Transplant the infested nursery plants into an infestation of St. John's wort. The aphids will disperse themselves onto adjacent plants to form new colonies.

MONITORING Aphid's presence can be observed on plant material throughout the summer months.

REFERENCES

Briese, D.T. 1988. Bionomics of *Aphis chloris* Koch (Hemiptera: Aphididae) for biological control of St. John's wort in Australia. Ecological Entomology 13:365–374.

Harris, P. and M. Maw. 1984. *Hypericum perforatum* L., St. John's wort (Hypericaceae). *In* J.S. Kelleher and M.A. Hulme (editors). Biological control programmes against insects and weeds in Canada 1969–1980. Commonwealth Agricultural Bureaux, Farnham, England. pp. 171–177.

Figure 42 *Aphis chloris*

Aphthona cyparissiae (Koch) (Coleoptera: Chyrsomelidae)

DESCRIPTION AND LIFE CYCLE Bronze-coloured adults, oval-shaped and 2–3 mm long, emerge in late June or early July and feed near the top of the shoot and at the leaf edges. The small triangle at the top of the wing cover (the scutellum) is brown, and thus the beetle can be distinguished from the similar *Aphthona nigriscutis*, which have black scutella. The beetles mate and egg laying occurs below the soil surface near the roots. Egg laying can continue until freeze-up. Eggs hatch in 2–3 weeks and the larvae burrow into the roots. Larvae build an overwinter cell in the soil and require a 4 month cold period to initiate further development. They resume root feeding in the spring and then pupate in the soil.

WEEDS ATTACKED Leafy spurge.

HABITAT Prefer open sites, hot summer temperatures, and moist sandy-loam soils where the height of flowering spurge is 60 cm or taller and no bare ground is visible. They appear to do best on the bottom section of valley slopes and in slightly depressed areas. They do not do well on northern aspects, in partial shade, in dry areas with partially bare ground, or on clay soils with organic matter content greater than 4%.

COLLECTION, SHIPPING, AND HANDLING Collect adults in late June to early July with a sweep net. Follow standard shipping and handling requirements for insects.

RELEASE A release of 200 adults is sufficient to establish a new colony. Adults prefer to be in a dense population, so do not scatter insects at the release point; deposit all the insects of a given release in a single spot.

MONITORING Adult presence can be determined with sweep nets in July. During the first few years, adults should be located within a few metres of the release point because their initial spread is slow. They will, however, fly readily and distribute themselves when spurge becomes depleted. If presence is detected 1 year after release, it almost always indicates establishment. In approximately half the cases in

which none were detected by sweeping 1 year after release, the beetles were present in subsequent years.

REFERENCE

Sommer, G. and E. Maw. 1982. *Aphthona cyparissiae* (Koch) and *A. flava* (Fahr.) (Coleoptera: Chrysomelidae): two candidates for the biological control of cypress and leafy spurge in North America. European Station Report, C.A.B. International Institute of Biological Control, Delemont, Switzerland. 42 p.

Figure 43
Aphthona cyparissiae

Figure 44
Aphthona cyparissiae larva

Aphthona czwalinae Weise (Coleoptera: Chrysomelidae)

DESCRIPTION AND LIFE CYCLE Black adults, 2.9–3.1 mm long, emerge throughout the spring, with high mortality among the early emergences. The main emergence occurs from June through to July. Adults have a relatively brief life span of 2–4 weeks, and mating begins immediately with egg laying within 1–2 weeks after emergence. Adults feed on leaf tissue and new shoots; small, young leaves can be completely consumed. Females normally lay the oval-shaped, yellowish eggs into crevices and holes in the soil surface, where the ovipositor does not come into contact with the soil. Eggs mature over a 16 day period and newly emerged larvae transfer to leafy spurge roots. Larvae are not readily distinguished from other *Aphthona* species; they show the typical elongated, whitish body with light brown head. Larvae feed on root tissue and develop over a period of at least 88 days. After the feeding period, larvae re-enter the soil and construct cells in which they hibernate. A 4 month cold period (<4°C) is required to initiate pupation and further development in the hibernation cell.

WEED ATTACKED Leafy spurge.

HABITAT This flea-beetle is most frequently associated with mesic moisture regimes and loam-textured soils, where the host plants are intermixed with other vegetation. The beetle is not generally found in open, dry sites.

COLLECTION, SHIPPING, AND HANDLING Collect adults with sweep nets in June or July. Follow standard shipping and handling requirements for insects.

RELEASE Follow standard release requirements for insects; a release of 200 adults is sufficient to establish a new colony.

MONITORING Adult presence can be determined with sweep nets in June or July. During the first few years, adults should be located within a few metres of the release point. A large area may have to be searched because these flea-beetles maintain very low densities.

REFERENCE

Gassmann, A. 1984. *Aphthona czwalinae* Weise (Coleoptera: Chrysomelidae): A candidate for the biological control of leafy spurge in North America. European Station Report, Commonwealth Institute of Biological Control, Delemont, Switzerland. 17 p.

Figure 45 *Aphthona czwalinae* adult

Aphthona flava Guill. (Coleoptera: Chrysomelidae)

DESCRIPTION AND LIFE CYCLE Orange-brown adults, 2–3 mm long, emerge in July and feed near the top of shoots and at the leaf edges. The flea-beetles mate, and females lay eggs below the soil surface near a root. Egg laying can continue until freeze-up. Eggs hatch in 2–3 weeks and the larvae burrow into the roots. Larvae build an overwinter cell in the soil and require a 4 month cold period to initiate further development. They resume root feeding in the spring and then pupate in the soil.

WEEDS ATTACKED Leafy spurge.

HABITAT Exact habitat preferences have not been determined. Preliminary information suggests that they prefer sites that have hot summer temperatures, are lightly shaded, and possess moister soil conditions than are associated with other *Aphthona* species. River benches and lake shores, or other areas with high water tables in valley bottoms, may be suitable. The beetle has been associated with cottonwoods (*Populus* spp.) and fairly widely spaced spurge plants.

COLLECTION, SHIPPING, AND HANDLING Collect adults with sweep nets in late July. Follow standard shipping and handling procedures for adult insects.

RELEASE Follow standard release procedures for insects; a release of 200 adults is sufficient to establish a new colony.

MONITORING Adult presence can be determined with sweep nets in July. During the first few years, adults should be located within a few metres of the release point.

REFERENCE

Sommer, G. and E. Maw. 1982. *Aphthona cyparissiae* (Koch) and *A. flava* (Fahr.) (Coleoptera: Chrysomelidae): two candidates for the biological control of cypress and leafy spurge in North America. European Station Report, C.A.B. International Institute of Biological Control, Delemont, Switzerland. 42 p.

Figure 46 *Aphthona flava*

Aphthona lacertosa Rosh. (Coleoptera: Chrysomelidae)

DESCRIPTION AND LIFE CYCLE Black adults, 3 mm long, can be distinguished from the similar *A. czwalinae* by the light to dark brown, rather than black, femur on the hind legs. Mating and egg laying begin soon after emergence in June and July. Females deposit their eggs in batches in the soil near a host plant; egg laying continues over a 2 month period while the adults feed on shoot and lower leaves. The developing larvae feed on root tissue, and leave the plant to form pupal cells in the soil in late fall. A 4 month cold period is required to initiate pupal development in the overwinter hibernation cells.

WEED ATTACKED Leafy spurge.

HABITAT This beetle has a wide adaptation to climatic conditions; it is generally more adapted to mesic-dry to moist conditions than are other *Aphthona* species. It is highly intolerant of spring flooding. It generally prefers loam to clay loam-textured soils and the host plant should be surrounded by a well-developed herbaceous community.

COLLECTION, SHIPPING, AND HANDLING Collect adults with sweep nets in June or July. Follow standard shipping and handling requirements for insects. The parasitic protozoan, *Nosema* sp., can cause high mortality in the larval populations: do not collect and redistribute adults from areas where this parasite is known to occur.

RELEASE Follow standard release requirements for insects; a release of 200 adults is sufficient to establish a new colony.

MONITORING Adult presence can be determined with sweep nets in June or July. During the first few years, adults should be located within a few metres of the release point.

REFERENCE

Gassmann, A. 1990. *Aphthona lacertosa* (Rosh.) (Coleoptera: Chrysomelidae): a candidate for the biological control of leafy spurge and cypress spurge in North America. European Station Report. International Institute of Biological Control, Delemont, Switzerland. 22 p.

Figure 47 *Aphthona lacertosa*

Aphthona nigriscutis Foudras (Coleoptera: Chrysomelidae)

DESCRIPTION AND LIFE CYCLE Adults, 2–3 mm long, oval shaped, and bronze coloured with a black dot at the tip of the wing cover (scutellum), emerge in late June or early July and feed near the top of the shoot and at the leaf tips. The beetles mate and egg laying occurs below the soil surface near a root. Eggs hatch in 2–3 weeks and the larvae burrow into the roots. Larvae build an overwinter cell in the soil and require a 4 month cold period to initiate further development. They resume root feeding in the spring and then pupate in the soil. In some releases, combined adult and larval feeding have reduced spurge vegetative cover by 95%.

WEEDS ATTACKED Leafy spurge.

HABITAT These beetles prefer open-canopied sites with hot, dry summer conditions. They appear to do best on coarse-textured, open soils with low organic matter content (<3%), particularly on southern slopes or knolls. They do not do well in shaded areas or in moist depressions. They prefer vegetation in which the height of spurge in flower does not exceed 50 cm, accompanied by bunchgrasses and some bare ground.

COLLECTION, SHIPPING, AND HANDLING Collect adults with sweep nets in mid-June to early-July. Follow standard shipping and handling procedures for insects.

RELEASE A release of 200 adults is sufficient to establish a new colony. Adults prefer to be in a dense population, so do not scatter insects at the release point. Instead, deposit all the insects of a given release in a single spot.

MONITORING Adult presence can be determined with sweep nets in July. During the first few years, adults should be located within a few metres of the release point because their initial spread is slow. They will, however, fly readily and distribute themselves when spurge becomes depleted. If presence is detected 1 year after release, it almost always indicates establishment. In approximately half the cases in

which none was detected by sweeping 1 year after release, the beetles were present in subsequent years.

REFERENCE

Gassmann, A. 1985. *Aphthona nigriscutis* Foudras (Coleoptera: Chrysomelidae): a candidate for the biological control of cypress and leafy spurge in North America. European Station Report, C.A.B. International Institute of Biological Control, Delemont, Switerland. 19 p.

Figure 48 *Aphthona nigriscutis*

Figure 49
Aphthona nigriscutis larva

Aplocera plagiata L. (Lepidoptera: Geometridae)

DESCRIPTION AND LIFE CYCLE These mottled-brown moths can produce two generations each year. Insects overwinter as larvae and begin feeding early in the spring (March to April); the caterpillar-style larvae defoliate plants. Pupation occurs in late spring and first-generation adults emerge in early summer. The mating and egg laying begin soon after emergence; eggs develop on the plant and newly emerged larvae feed on foliage.

WEED ATTACKED St. John's wort.

HABITAT Prefers dry, rocky habitats, open sandy places, and limestone regions. These moths are adapted to withstand both high and low temperature extremes. They are widely distributed in the East and West Kootenay areas.

COLLECTION, SHIPPING, AND HANDLING Adults are readily swept or aspirated from dead flower stalks in October. Follow standard shipping and handling for insects.

RELEASE Follow standard release procedures for insects.

MONITORING Determine presence by observing larvae or adults from spring through fall.

REFERENCE

Harris, P. and D. Peschken. 1969. The status of biological control of the weed *Hypericum perforatum* in British Columbia. Canadian Entomologist 101:1–15.

Figure 50 *Aplocera plagiata* moth

Figure 51 *Aplocera plagiata* caterpillar

Brachypterolus pulicarius L. (Coleoptera: Nitidulidae)

DESCRIPTION AND LIFE CYCLE Black adults, 1–2 mm long and elongate to oval in shape, emerge in May and feed on young stems. Mating occurs in June and females lay eggs into the flower buds. Larvae feed on reproductive organs in the flowers; older larvae will also feed on seeds. Larval feeding can reduce seed production by three-quarters or more. Larvae migrate into the soil in late summer to begin pupation, though some may remain in the flowers as larvae until freezing temperatures occur in late fall.

WEEDS ATTACKED Yellow toadflax and Dalmatian toadflax.

HABITAT These beetles are capable of inhabiting all areas where yellow toadflax or Dalmatian toadflax occur.

COLLECTION, SHIPPING, AND HANDLING Collect adults with sweep nets or by vacuum aspiration in early summer. Follow standard shipping and handling procedures for insects.

RELEASE Follow standard release procedures for insects.

MONITORING Monitor for presence in late spring to early summer using sweep nets. Open flowers and seedheads to look for larvae in late summer and fall.

REFERENCE

McClay, A.S. 1992. Effects of *Brachypterolus pulicarius* L. (Coleoptera: Nitidulidae) on flowering and seed production of common toadflax. Canadian Entomologist 124:631–636.

Figure 52 *Brachypterolus pulicarius*

Calophasia lunula (Hufn.) (Lepidoptera: Noctuidae)

DESCRIPTION AND LIFE CYCLE Adults are pale to dark brown with a white crescent marking and other white markings on the central portion of the wing. Adults are 12–14 mm long with a 27–30 mm wingspan. Adults emerge from May to August and live for 3–12 days. Mating begins immediately and egg laying starts after 1–2 days. Larvae, pearl-coloured with five yellow stripes along the back and sides, hatch in 7–11 days and begin feeding on leaves. Pupation occurs in the summer and continues until fall. Those that pupate in the beginning of summer can produce second-generation adults by late summer or early fall. A third generation is possible, though most larvae pupate and overwinter as second-generation pupae.

WEEDS ATTACKED Yellow toadflax and Dalmatian toadflax.

HABITAT Areas with warm summer temperatures are needed to complete larval development.

COLLECTION, SHIPPING, AND HANDLING Hand pick larvae from plants from mid-summer to fall. Moths can be collected using a vacuum aspirator or sweep net from May to August, although they are very fragile and susceptible to damage. Best collection times are late afternoon and dusk. Follow standard shipping and handling procedures for insects. Because of the short lifespan of adults, they must be collected and shipped within 1 or 2 days. If this is not feasible, larvae must be collected and redistributed.

RELEASE Follow standard release procedures for insects. Release as soon after collection as possible.

MONITORING Determine presence by observing larvae feeding on the plants in summer or by collecting adults with sweep nets from May to August.

REFERENCE

Karny, M. 1963. The possibilities of *Calophasia lunula* Hufn. (Lep.: Noctuidae) in the biological control of toadflax, *Linaria vulgaris*

Mill. Technical Bulletin No. 3. C.A.B. Commonwealth Institute of Biological Control, Delemont, Switzerland, pp. 1–26.

Figure 53 *Calophasia lunula* moth

Figure 54 *Calophasia lunula* caterpillar

Ceutorhynchus litura (F.) (Coleoptera: Curculionidae)

DESCRIPTION AND LIFE CYCLE Adults, 2–3 mm long, are mottled-grey with a white-cross marking on the back. Overwintered adults begin to emerge from hibernation coinciding with the rosette stage of Canada thistle. Females feed on leaf tissue and lay eggs into the mid-vein of rosette leaves. Within a few days the larvae enter and mine the main stems, and then move down to the root collar, leaving long black tunnels in the stem. In areas where the springs are long and cool, with protracted vegetative growth, the larvae will tunnel and feed in the root crown. They can achieve 90% or greater control. In areas where the spring is short and growth is rapid, larval feeding is confined to the stem and little damage is done to the thistle. Mature larvae burrow out of the plant and pupate in the soil. Adults emerge from late June into the early part of July; they feed on foliage and hibernate in leaf litter over the winter.

WEED ATTACKED Canada thistle.

HABITAT Prefers dense stands of thistle (5–10 plants per square metre) with bare soil surrounding the thistles rather than thick grass. Adults can withstand some spring flooding.

COLLECTION, SHIPPING, AND HANDLING Collect by sweeping green thistle plants on calm, warm, sunny days in August. Sweep vertically from the bottom of the plant upwards and put debris in a bucket. Weevils will feign death, but can be easily sorted when they begin moving. Vacuum aspirators can be employed on small bolting plants and rosettes. Follow standard shipping and handling requirements for insects.

RELEASE Follow standard release procedures for insects.

MONITORING Monitor establishment by cutting open stems on the largest Canada thistle plants to check for stem mining and larvae at the root crown in the first year. In the second and subsequent years after release, as weevil population density increases, check for larvae mining below the root crown.

REFERENCES

Peschken, D.P. and J.L. Derby. 1992. Effect of *Urophora cardui* (L.) (Diptera: Tephritidae) and *Ceutorhynchus litura* (F.) (Coleoptera: Curculionidae) on the weed Canada thistle, *Cirsium arvense* (L.) Scop. Canadian Entomologist 124:145–150.

Rees, N. 1990. Establishment, dispersal, and influence of *Ceutorhynchus litura* on Canada thistle (*Cirsium arvense*) in the Gallatin Valley of Montana. Weed Science 38:198–200.

Figure 55
Ceutorhynchus litura

Figure 56
Ceutorhynchus litura larva

Chaetorellia acrolophi White & Marq.
(Diptera: Tephritidae)

DESCRIPTION AND LIFE CYCLE Adults, dark bodied with yellow bands on body and wings, emerge in early June coinciding with the budding of spotted knapweed. Mating begins immediately and females lay eggs into flower buds throughout their 17 day life span. Larvae emerge 4–5 days after eggs are laid, and migrate into the centre of the flower buds. Pupation occurs 5–15 days after larvae hatch. *Chaetorellia* generally produce two generations per year, with a generation overlap in July. First-generation larvae and pupae are white and pupae are enclosed in a white pupal case covered with pappus hairs from the seeds; pupae emerge as adults in July, mate, and produce a second generation. Second-generation larvae and pupae are yellow, with pupae enclosed in a yellow pupal case covered with pappus hairs from the seeds. A third generation is possible, but rare. Second-generation larvae typically overwinter in the flower heads, consuming florets and seeds, and pupate in the spring.

WEED ATTACKED Spotted knapweed.

HABITAT Prefers south-facing slopes, and dry habitats. Generally associated with scattered plants, rather than dense stands of spotted knapweed.

COLLECTION, SHIPPING, AND HANDLING Collect by removing spotted knapweed seedheads containing larvae or pupae, and redistribute plants. Follow standard shipping and handling requirements for plant material containing biological control agents.

RELEASE Follow standard release procedure for biological control agents in plant material.

MONITORING Determine presence by breaking open spotted knapweed seedheads to look for larvae or pupae, from late summer through to the next spring. *Chaetorellia* larvae can be distinguished from *Urophora* by the colour of the pupal case: *Urophora* have brown pupal cases; *Chaetorellia* are white or yellow depending on the generation.

REFERENCE

Grippe, K. and K. Marquardt. 1989. *Chaetorellia acrolophi* White & Marquardt (Diptera: Tephritidae), a suitable candidate for the biological control of diffuse and spotted knapweed in North America. European Station Report. C.A.B. International Institute of Biological Control, Delemont, Switzerland. 29 p.

Figure 57 *Chaetorellia acrolophi* larvae in knapweed seedhead

Chrysolina hyperici (Forster) (Coleoptera: Chrysomelidae)

DESCRIPTION AND LIFE CYCLE Adults are metallic bronze-green coloured, 4–5 mm long, and emerge in early June. They feed on flower buds and terminal leaves until leaf drop in late July to early August. After leaf drop, adults aestivate in leaf litter until fall moisture reactivates them for mating; they require considerable moisture to break this dormant period. Mating occurs in the autumn, and females lay orange-coloured eggs on the basal foliage. Most overwinter as eggs, and larvae hatch in the spring, though some hatch in the fall, and have good winter survival (approximately 20%). Overwintering adults lay large numbers of eggs in the following spring. Larvae feed nocturnally on shoot tips and the basal and developing leaves. These beetles can be highly effective in controlling St. John's wort, and have reduced dense stands of several square kilometres to scattered plants. Larvae are fully developed by about mid-May, when they leave the plant to pupate in the soil. *Chrysolina* beetles can be distinguished from each other by the relative size of the beetle: *C. hyperici* are approximately two-thirds the size of *C. quadrigemina*.

WEED ATTACKED St. John's wort.

HABITAT Compared to *C. quadrigemina* these beetles are generally more tolerant of cooler, moist to wet summers, and areas with cold winters lacking continuous snow cover. They do not do well in shaded forest conditions.

COLLECTION, SHIPPING, AND HANDLING Adults will cluster along the ends of the stems; sweep in early to mid-June during the initial bloom of St. John's wort, or tap stems over a collection tray or funnel. Follow standard shipping and handling for adult insects.

RELEASE Releases of 200–1000 adults are sufficient to establish new colonies. Use standard release procedures for insects.

MONITORING Visual checks of upper stem for adult beetle clustering in June and July are adequate for determining presence.

REFERENCE

Campbell, C.L., J.P. McCaffrey, and H.W. Homan. 1987. Collection and redistribution of biological control agents of St. Johns wort. Current Information Series No. 798. University of Idaho, College of Agriculture, Cooperative Extension Service, Agriculture Experiment Station, Moscow, Idaho. 4 p.

Figure 58 *Chrysolina hyperici* and *Chrysolina quadrigemina* beetles

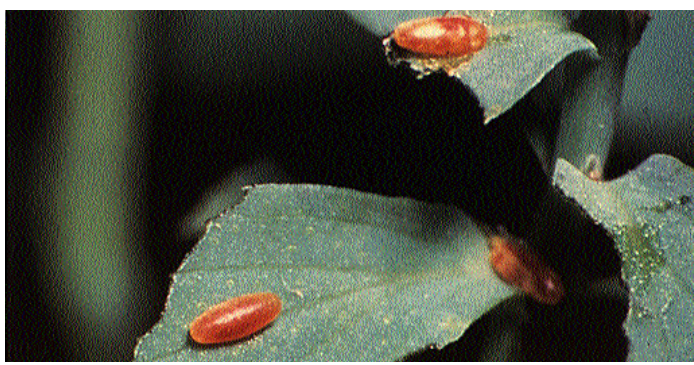

Figure 59 *Chrysolina spp.* larva

Chrysolina quadrigemina (Suffrain)
(Coleoptera: Chrysomelidae)

DESCRIPTION AND LIFE CYCLE Metallic bronze-, blue-, green-, or purple-coloured adults, 7 mm long, emerge in early June to coincide with flower bud development on St. John's wort. Adults feed on flower buds and terminal leaves until leaf drop in late July to early August. After leaf drop, adults aestivate in leaf litter until fall moisture reactivates them for mating. Mating occurs in the autumn, and females lay many orange-coloured eggs on the basal foliage. Most overwinter as eggs and larvae hatch in the spring, though some hatch in the fall, surviving if the winter is moderate. Larvae feed nocturnally on shoot tips, and on the basal and developing leaves. These beetles can be highly effective in controlling St. John's wort, and have reduced dense stands of several square kilometres to scattered plants. Larvae are fully developed by about mid-May, when they leave the plant to pupate in the soil. May frosts of −10°C without snow cover kill all surviving larvae and adults. *Chrysolina* beetles can be distinguished from each other by the relative size of the beetle; *C. hyperici* are approximately two-thirds the size of *C. quadrigemina*. Refer to *C. hyperici* photos for identification.

WEED ATTACKED St. John's wort.

HABITAT These beetles are generally more abundant in Mediterranean type climates. They do not do well in shaded forest conditions or areas with heavy summer rainfall, either of which prematurely break the summer dormancy.

COLLECTION, SHIPPING, AND HANDLING Adults will cluster along the ends of the stems; sweep in early to mid-June during the initial bloom of St. John's wort, or tap stems over a collection tray or funnel. Because males emerge before females, allow at least 1 week from the first emergence to ensure mixture of males and females. Follow standard shipping and handling for adult insects.

RELEASE Releases of 200–1000 adults are sufficient to establish new colonies. Use standard release procedures for insects.

MONITORING Visual checks of upper stem for adult beetle clustering in June and July are adequate for determining presence.

REFERENCE

Campbell, C.L., J.P. McCaffrey, and H.W. Homan. 1987. Collection and redistribution of biological control agents of St. Johnswort. Current Information Series No. 798. University of Idaho, College of Agriculture, Cooperative Extension Service, Agriculture Experiment Station, Moscow, Idaho. 4 p.

Cochylis atricapitana (Stephens) (Lepidoptera: Cochylidae)

DESCRIPTION AND LIFE CYCLE Adults are tan-coloured, with a dark, saddle-shaped mark across the upper surface of the wings. They are small (3 mm long), with a wingspan of 7 mm, very fragile, and active only at night. *Cochylis* are capable of multiple generations per year; it typically takes 33 days to complete a generation in the summer. Eggs are laid on the surface of the root crown where the white larvae hatch and mine into the crown tissue. Larvae feed on the upper root crown and rarely on the roots. Pupation occurs in the root; pupae change colour from white to tan as they develop.

WEED ATTACKED Tansy ragwort.

HABITAT These moths are adapted to all the habitats supporting tansy ragwort, though they are more effective in controlling the weed at higher elevations.

COLLECTION, SHIPPING, AND HANDLING Adults are too fragile and prone to damage for collection and redistribution. Collect larvae-infested roots throughout the summer. Transplant infested roots into nursery containers and keep the soil moist, but not saturated, during shipping and handling.

RELEASE Place the nursery containers directly at the release site and allow adults to emerge. Maintain moist conditions in the nursery containers during the emergence period. If livestock disturbance is possible, fence off the release area temporarily. A release of 50–100 larvae is sufficient to establish a new colony.

MONITORING Determine presence and density of larvae by observing the centre of the rosette root crown. Adults stay very close to the ground during the day, with little activity. Adult presence may sometimes be detected with the use of a sweep net brushed close to the ground.

Figure 60 *Cochylis atricapitana* moth

Figure 61 *Cochylis atricapitana* larval damage on tansy ragwort

Cyphocleonus achates (Fahr.) (Coleoptera: Curculionidae)

DESCRIPTION AND LIFE CYCLE Mottled grey-brown adults, 50–175 mm long, emerge in mid-July to early September and begin mating within 1–2 weeks with the early-emerged adults and immediately with later emergences. Females lay eggs in the root crown over their 10 week life span. Larvae hatch 10–12 days after eggs are laid and tunnel and feed in the root overwinter. Pupation occurs in the following spring.

WEEDS ATTACKED Diffuse knapweed and spotted knapweed; shows a preference for spotted knapweed.

HABITAT Prefer hot, dry conditions on well-drained, coarse-textured and sandy soils.

COLLECTION, SHIPPING, AND HANDLING Collect adults by hand picking from the plants. Weather conditions will determine location of the weevil. During hot weather, weevils will locate on the upper portions of the stems. During cool and wet weather, the weevils will bury themselves in the leaf litter and loose soil around the base of the plant. If disturbed, weevils may feign death and drop to the ground. Their mottled colour may camouflage them in the leaf litter. Follow standard shipping and handling procedures for insects.

RELEASE Follow standard release procedures for insects. Dense stands are generally required for release because the weevils do not fly, but distribute themselves by walking.

MONITORING Determine presence by locating adults or larvae. Adults can be observed on warm days on the upper stem, from June to August. Plants that have been attacked tend to bolt over two consecutive years. Dig up the entire root and cut it open, examining the central portion of root. Tunnelling damage in the later stages of larval development is extensive and easy to identify.

REFERENCE

Stinson, C.S.A. 1987. Investigations on *Cyphocleonus achates* (Fahr.) (Col.: Curculionidae), a possible biological agent of spotted

knapweed (*Centaurea maculosa* Lam.) and diffuse knapweed (*C. diffusa* Lam.) (Compositae) in North America. European Station Report. C.A.B. International Institute of Biological Control, Delemont, Switzerland. 37 p.

Figure 62
Cyphocleonus achates

Figure 63
Cyphocleonus achates larva

Figure 64
Naked pupa of *Cyphocleonus achates*

Eteobalea intermediella Riedl
(Lepidoptera: Cosmopterigidae)

DESCRIPTION AND LIFE CYCLE Black adults have yellow heads, metallic-gold flecks on the black wings, and a wingspan of 16–18 mm. *E. intermediella* and *E. serratella* can only be positively distinguished from one another by the male's genitalia (*E. serratella* being distinct), or the egg structure. Adults emerge in late spring and live approximately 2 weeks. Mating begins immediately and egg laying occurs on the leaf axils or stem base. Larvae hatch 9–10 days after egg laying; larvae bore into the stem and feed on small roots and the root crown. *E. intermediella* has two generations per year, with second-generation adults emerging in late fall. The second-generation larvae overwinter in the root and pupate in the following spring. Pupae are light brown, turning to black with age.

WEED ATTACKED Dalmatian toadflax.

HABITAT No information on habitat preference is currently available.

COLLECTION, SHIPPING, AND HANDLING Collect adults with aspirators or sweep nets; peak adult activity is 1–2 hours before sunrise and after sunset. Follow standard shipping and handling procedures for insects.

RELEASE Follow standard release procedure for insects.

MONITORING Monitor for adult presence in late spring at dusk or pre-dawn. Monitor larvae or pupae by digging roots and scraping the outer surface near the crown to reveal feeding tunnels.

REFERENCE

Saner, M., K. Groppe, and P. Harris. 1990. *Eteobalea intermediella* Riedl and *E. serratella* Treitschke (Lep., Cosmopterigidae), two suitable agents for the biological control of yellow and Dalmatian toadflax in North America. European Station Report. C.A.B. International Institute of Biological Control, Delemont, Switzerland. 39 p.

Figure 65 *Eteobalea intermediella* moth

Eteobalea serratella Treit. (Lepidoptera: Cosmopterigidae)

DESCRIPTION AND LIFE CYCLE Adults are black, with a yellow head and metallic flecks on the black wings; they have a 16–18 mm wingspan. *E. intermediella* and *E. serratella* can only be positively distinguished from one another by the male's genitalia (*E. serratella* being distinct), or the egg structure. Adults emerge in early summer and live for 9–17 days. Mating and egg laying at the stem base begins immediately after emergence. Larvae hatch 15–20 days after egg laying and mine into the root. Feeding occurs mainly in the root crown area of the plant. Larvae pupate in the fall and overwinter in this form.

WEED ATTACKED Yellow toadflax.

HABITAT No information on habitat preference in British Columbia is currently available. They prefer hot, dry sites in their native Europe.

COLLECTION, SHIPPING, AND HANDLING Collect adults with aspirators or sweep nets. Peak adult activity is 1–2 hours before sunrise and after sunset. Larvae can be collected by removing plants containing larvae. Follow standard shipping and handling procedures for insects.

RELEASE Follow standard release procedure for insects.

MONITORING Monitor for adult presence in late spring to attract moths at dusk or pre-dawn. Monitor larvae or pupae by digging roots and scraping the outer surface near the crown to reveal feeding tunnels.

REFERENCE

Saner, M., K. Groppe, and P. Harris. 1990. *Eteobalea intermediella* Riedl and *E. serratella* Treitschke (Lep., Cosmopterigidae), two suitable agents for the biological control of yellow and Dalmatian toadflax in North America. European Station Report. C.A.B. International Institute of Biological Control, Delemont, Switzerland. 39 p.

Figure 66 *Eteobalea serratella* moth

Figure 67 *Eteobalea serratella* larva

Galerucella calmariensis Linne
(Coleoptera: Chrysomelidae)

DESCRIPTION AND LIFE CYCLE Adults, red with black markings, 2–4 mm long, emerge from hibernation and feed on shoot tips and young leaves in April. Mating begins immediately with egg laying starting approximately 1 week later and continuing until the end of July. Larvae hatch 12 days after egg laying; larvae develop over a 2 week period, feeding initially on leaf and flower buds and then on all parts of the plant in the later stages of development. Mature larvae leave the plant and pupate in leaf litter and the upper portion of the soil. Adults emerge 9–11 days later. Adults emerging before August mate and lay eggs for a 1 month period. Adults feed on foliage and hibernate in the soil before winter.

WEED ATTACKED Purple loosestrife.

HABITAT Tolerates the variety of habitat conditions in which purple loosestrife is found.

COLLECTION, SHIPPING, AND HANDLING Collect with the sweep net technique and use standard shipping and handling procedures.

RELEASE Follow standard release procedures for insects. Take precautions not to dump the beetles in the water.

MONITORING Determine presence by looking for adults on foliage in April or August.

REFERENCE

Blossey, B. and D. Schroeder. 1991. Study of potential biological control agents of purple loosestrife (*Lythrum salicaria* L.). Final Report. European Station Report. C.A.B. International Institute of Biological Control, Delemont, Switzerland. 27 p.

Figure 68 *Galerucella calmariensis*

Figure 69 *Galerucella calmariensis* larvae

Galerucella pusilla (Duftsschmid)
(Coleoptera: Chrysomelidae)

DESCRIPTION AND LIFE CYCLE Adults, 2–4 mm long, and larvae very closely resemble *G. calmariensis.* Refer to *G. calmariensis* photos for identification. Adults emerge from hibernation and feed on shoot tips and young leaves in April. Mating begins immediately, with egg laying starting approximately 1 week later and continuing until the end of July. Larvae hatch 12 days after egg laying; larvae develop over the next 2 weeks feeding first on leaf and flower buds and then on all parts of the plant in the later stages of development. Mature larvae leave the plant and pupate in leaf litter and the upper portion of the soil. Adults emerge 9–11 days later. Adults that emerge before August mate and lay eggs for a 1 month period. Adults feed on foliage and hibernate in the soil before winter.

WEED ATTACKED Purple loosestrife.

HABITAT Egg laying is strongly curtailed by low temperatures. Tolerates the variety of habitat conditions in which purple loosestrife is found.

COLLECTION, SHIPPING, AND HANDLING Collect with the sweep net technique and use standard shipping and handling procedures.

RELEASE

Follow standard release procedures for insects. Take precautions not to dump the beetles in the water.

MONITORING Determine presence by looking for adults on foliage in April or August.

REFERENCE

Blossey, B. and D. Schroeder. 1991. Study of potential biological control agents of purple loosestrife (*Lythrum salicaria* L.). Final Report. European Station Report. C.A.B. International Institute of Biological Control, Delemont, Switzerland. 27 p.

Gymnaetron antirrhini Paykull (Coleoptera: Curculionidae)

DESCRIPTION AND LIFE CYCLE Grey adults emerge in May and feed on the young stems. Mating begins in June; eggs are laid into the ovary of flowers between the end of June and mid-August. Larvae hatch 12–17 days after egg laying and feed on the gall tissue the plant forms around the seeds. Pupation occurs 20–30 days later inside the seed head; pupation lasts 10–15 days. Adults emerge and feed on the plants before hibernation. Adults may overwinter in the seed capsule or in debris on the ground.

WEED ATTACKED Yellow toadflax and Dalmatian toadflax. Two strains of the beetle have been released in British Columbia; one is specific to yellow toadflax, and the other is specific to Dalmatian toadflax.

HABITAT Does not do well in areas with extreme cold winter temperatures.

COLLECTION, SHIPPING, AND HANDLING Collect adults using sweep nets from July to August. Follow standard shipping and handling procedures for insects.

RELEASE Follow standard release procedures for insects. *Brachypterolus pulicarius* larvae will feed on *Gymnaetron* larvae through early summer to August. Avoid releasing *Gymnaetron* in areas where *Brachypterolus* is abundant.

MONITORING Determine presence by using sweep nets from July to August.

REFERENCES

Groppe, K. 1992. *Gymnaetron antirrhini* Paykull (Col.: Curculionidae). A candidate for biological control of Dalmatian toadflax in North America. European Station Report. C.A.B. International Institute of Biological Control, Delemont, Switzerland. 39 p.

Smith, J.M. 1959. Notes on insects, especially *Gymnaetron* spp. (Coleoptera: Curculionidae), associated with toadflax, *Linaria vulgaris* Mill. (Scrophulariaceae), in North America. Canadian Entomologist 91:116–121.

Figure 70 *Gymnaetron antirrhini*

Figure 71 *Gymnaetron antirrhini* larval case. Note the spurs.

Hylemya seneciella Meade (Diptera: Muscidae)

DESCRIPTION AND LIFE CYCLE Adults, dull grey, 4–5 mm long, and covered in short hairs, emerge coinciding with bud formation on tansy ragwort. Mating and egg laying into the flower buds begins immediately. Larvae are white, and occur one per seedhead. Larvae eat receptacles and later in the summer feed on immature fruits; the larval feeding has marginal effects on tansy ragwort, resulting in approximately 2–5% seed reduction per year. Pupation begins in the fall and development continues overwinter.

WEED ATTACKED Tansy ragwort.

HABITAT *Hylemya* has distributed itself throughout the tansy ragwort infestations in the Fraser Valley, Vancouver Island, and coastal areas of British Columbia and does not appear to be selective of individual habitat types.

COLLECTION, SHIPPING, AND HANDLING Collect mature larvae in seedheads in the fall or winter and store in moist sand under refrigeration (4°C) until the following spring to allow pupation. Redistribution is not necessary in the Fraser Valley, Vancouver Island, or coastal areas of British Columbia.

RELEASE Timing the emergence of the flies to coincide with optimum tansy ragwort bud development in the field is key to successful establishment. Place stored plant material in the field just before peak bud formation. A release of 1000–1500 seedheads, with an average of 10–15% attack rate, is sufficient to establish a new population.

MONITORING During the first set of tansy ragwort flowers to set seed, look for dead flowers tied together with a brown pappus. Attacked flower heads have a hole in the receptacle. *Hylemya* is the only seedhead agent released on tansy ragwort.

REFERENCE

Frick, K.E. 1969. Behaviour of adult *Hylemya seneciella*, an anthomyiid (Diptera) used for the biological control of tansy ragwort. Annals of the Entomological Society of America 63:184–187.

Figure 72 *Hylemya seneciella* puparia in tansy ragwort seedhead

Hyles euphorbiae (L.) (Lepidoptera: Sphingidae)

DESCRIPTION AND LIFE CYCLE Brown adult moths have checkered pink, white, and black markings on the wings and can have up to an 8 cm wingspan. Adults emerge in the spring and mating and egg laying coincide with the floral bloom in leafy spurge. Larvae have plump, 10 cm long bodies, brightly coloured with a mixture of red, black, yellow, and white markings. Larvae feed on leaves and develop over a period of 42–72 days. Pupation occurs in the fall and hawkmoth overwinters in pupal form.

WEED ATTACKED Leafy spurge.

HABITAT Exact habitat requirements are not known for British Columbia. Preliminary information indicates that they require mild overwinter temperatures, although the moth has established well in Montana where it is exposed to fairly severe winter conditions.

COLLECTION, SHIPPING, AND HANDLING Hand pick larvae from plants from summer to fall. Follow standard shipping and handling procedures for insects.

RELEASE Follow standard release procedure for insects. Hawkmoth is highly susceptible to predation losses from ants; release sites should be carefully chosen to avoid large ant colonies.

MONITORING Determine presence by capturing adults with sweep nets, or by observing larvae feeding on spurge plants.

REFERENCE

Forwood, J.R. and M.K. McCarty. 1980. Observations on the life cycle of spurge hawkmoth. Transactions of the Nebraska Academy of Sciences 8:31–34.

Figure 73 *Hyles euphorbiae* moth

Figure 74 *Hyles euphorbiae* caterpillar

Hylobius transversovittatus Goeze
(Coleoptera: Curculionidae)

DESCRIPTION AND LIFE CYCLE Adult weevils emerge in April and feed on the developing loosestrife shoots. Egg laying begins in early May and continues to mid-September. Eggs are deposited on the shoot bases and in the soil near the roots. Larvae hatch 2 weeks after egg laying; those laid in the soil feed on root hairs and then burrow into the roots. Those laid on the stem mine the shoots for some time before tunnelling into the roots. Larval development can take from 1–2 years; larval development is arrested each time the attacked roots are flooded. Pupation occurs in the upper portion of the root stock. Most adults emerge between July and the end of August. The weevils feed on leaves and some mate and lay eggs. In late autumn they leave the plant and hibernate in the soil. Adults are long lived and may hibernate two or three seasons before they die.

WEED ATTACKED Purple loosestrife.

HABITAT Tolerates a wide range of environmental conditions and has excellent host-searching capacity, as indicated by its presence in small scattered stands of loosestrife in its native Europe.

COLLECTION, SHIPPING, AND HANDLING Adults are night active. Collection techniques have not been finalized. Follow standard shipping and handling procedures for insects.

RELEASE Follow standard release procedures for insects. Release near the end of the day or early evening to allow the weevils to begin feeding in their new location soon after release.

MONITORING Determine presence by pulling plants and opening roots to observe larvae. Open roots only until the first larva is found.

REFERENCE

Blossey, B. and D. Schroeder. 1991. Study of potential biological control agents of purple loosestrife (*Lythrum salicaria* L.). Final Report. European Station Report. C.A.B. International Institute of Biological Control, Delemont, Switzerland. 27 p.

Figure 75 *Hylobius transversovittatus*

Figure 76 *Hylobius transversovittatus* pupa

Larinus minutus Gyll. (Coleoptera: Curculionidae)

DESCRIPTION AND LIFE CYCLE Mottled-brown adults, 5–10 mm long, emerge from leaf litter at the base of plants 2–4 weeks before knapweed budding (early May to June). Mating coincides with the bud stage of knapweed and continues over the 5 to 14 week life span of the adults. Females first feed, then lay eggs into flower buds as they open. Larvae hatch within 3 days of egg laying; larvae consume the entire flower head contents. Larvae are fully developed within 1 month and pupation occurs in the flower head. Adults emerge from late September to October and feed for a short time before moving into the soil and plant litter for winter.

WEED ATTACKED Spotted knapweed.

HABITAT Does best in areas with hot, dry summers.

COLLECTION, SHIPPING, AND HANDLING Pick adult weevils from the flower buds in early summer, following the technique for hand picking insects. Alternatively shake top of the knapweed plants over a collection tray or funnel, or use a sweep net. Follow standard shipping and handling requirements for insects.

RELEASE Follow standard release procedure for insects.

MONITORING Check the release site in June and July for adult weevil presence. They will be conspicuously located on the upper part of the knapweed plant, congregating mostly on the flower buds. Count the number of weevils per plant to estimate population densities.

REFERENCE

Groppe, K. 1990. *Larinus minutus* Gyll. (Coleoptera: Curculionidae), a suitable candidate for the biological control of diffuse and spotted knapweed in North America. European Station Report. C.A.B. International Institute of Biological Control, Delemont, Switzerland. 31 p.

Figure 77 *Larinus minutus*

Figure 78 Seedhead damage by *Larinus minutus* larvae

Larinus obtusus Gyll. (Coleoptera: Curculionidae)

DESCRIPTION AND LIFE CYCLE Dark-brown adults begin to emerge from hibernation in mid-May. Mating begins at the end of May on open flower heads and is followed directly by females laying their yellow eggs into the flower heads; mating and egg laying can occur throughout the beetles' 5 to 6 month life span (occasionally adults may hibernate a second time and live a second season). Eggs hatch in 3–6 days after laying. After hatching, larvae feed on the flowers and seeds. Larval development is completed within 4–6 weeks and pupation occurs in the seedhead. Adults emerge in mid-July and feed briefly on foliage before moving to hibernation places in the soil around the root area.

WEEDS ATTACKED Diffuse knapweed and spotted knapweed; shows a preference for spotted knapweed.

HABITAT Warm, dry conditions are preferred during the mating season.

COLLECTION, SHIPPING, AND HANDLING Pick adult weevils from the flower buds in early summer, following the technique for hand picking insects. Alternatively shake top of the knapweed plants into a collection tray or funnel, or use sweep nets or vacuum aspiration techniques. Follow standard shipping and handling requirements for insects.

RELEASE Follow standard release procedure for insects.

MONITORING Check the release site in June and July for adult weevils. They will be conspicuously located on the upper part of the knapweed, congregating mostly on the flower buds. Count the number of weevils per plant to estimate population densities.

REFERENCE

Groppe, K. 1992. *Larinus obtusus* Gyll. (Col.: Curculionidae), a candidate for biological control of diffuse and spotted knapweed. Final report. European Station Report. C.A.B. International Institute of Biological Control, Delemont, Switzerland. 46 p.

Figure 79 *Larinus obtusus*

Figure 80 *Larinus obtusus* larva

Larinus planus (F.) (Coleoptera: Curculionidae)

DESCRIPTION AND LIFE CYCLE Dark-brown adults, 5–10 mm long, emerge from leaf litter at base of plants before Canada thistle budding (mid-June). Mating coincides with the bud stage of the thistle, 7–14 days after emergence. Females first feed on, then lay eggs into unopened flower buds that are less than 7 mm in diameter. Larvae hatch within a few days of egg laying and consume flower head contents over the course of summer. Attacked flower heads have a small brown mark near the base and appear bent and twisted. Pupation occurs in the flower head in mid-summer. Adults emerge from late August to September and feed for a short time before moving into the soil and plant litter for winter.

WEED ATTACKED Canada thistle.

HABITAT Adapted to the variety of habitats in which Canada thistle is found.

COLLECTION, SHIPPING, AND HANDLING Pick adult weevils from the flower buds and the leaf axils at the top of the thistle plant in early summer, following the technique for hand picking insects. Alternatively, shake top of thistle plants into a collection tray or funnel. Vacuum aspirators can also be used to collect this insect. Sweep nets will become tangled and torn in the thistle, and therefore should not be used. Do not collect thistles or redistribute thistle heads because they may contain parasites. Follow standard shipping and handling requirements for insects.

RELEASE A release of 100 adults is sufficient to establish a new colony. Follow standard release procedure for insects.

MONITORING Check the release site in June and July for adult weevils. They will be conspicuously located on the upper part of the thistle plants, congregating mostly on the flower buds. Count the number of weevils per plant to estimate population densities. Determine presence by opening brown, bent, or twisted flower heads to check for larvae in late summer.

REFERENCE

McClay, A.S. 1990. The potential of *Larinus planus* (Coleoptera: Curculionidae), an accidentally introduced insect in North America, for biological control of *Cirsium arvense* (Compositae). *In* Proceedings of VII International Symposium on Biological Control of Weeds, 6–11 March 1988, Rome, Italy. E.S. Delfosse (editor), pp.173–179.

Figure 81 *Larinus planus*

Figure 82 *Larinus planus* larva

Lobesia euphorbiana (Freyer) (Lepidoptera: Tortricidae)

DESCRIPTION AND LIFE CYCLE Mottled yellow, brown, and reddish-brown adult moths live for 3–7 days. Mating and egg laying occur at dawn and dusk. Females lay the flat, translucent yellow eggs singly on the lower leaf surface. Newly hatched larvae migrate to the leaf tip, and roll the leaf together to begin development. As the larvae develop, they tie together additional young leaves or florets at the plant growing tips in a silky webbing. The leaf ties impair leafy spurge growth and prevent flowering. Before pupation, the larvae spin a thick web in the tip of the leaf tie; pupation occurs in the leaf ties and second-generation adults emerge in late summer to early fall. Mating and egg laying begin immediately. Larvae, which are solitary and cannibalistic, develop in the fall and overwinter in this form.

WEED ATTACKED Leafy spurge.

HABITAT Prefers fringe forested areas, with mesic soil moisture regimes and shade. It also favours actively growing plants through the entire growing season, which provide the growing tips for larvae to tie together. The moth is generally found near water, such as a river or lake.

COLLECTION, SHIPPING, AND HANDLING Collect leaf ties containing larvae in the early to mid-summer. Follow standard shipping and handling for biological control agents in plant material. Adult moths are too short lived for collection and redistribution.

RELEASE Place one leaf tie per plant on spurge plants at the release site to allow the larvae to move into the new plant material. Connect the leaf material together with a fine thread such that the leaf ties are in contact with fresh plant material onto which the larvae can transfer. A release of 50 leaf ties is sufficient to establish a new colony.

MONITORING Determine presence by looking for larvae in leaf ties from the early summer through to fall.

REFERENCE

Harris, P. and J. Sirocco. n.d. *Lobesia (Lobesiodes) euphorbiana* (Frr.) (Lepidoptera: Oleuthreutinae): a candidate for the biological

control of leafy spurge in North America. Agriculture Canada, Regina Research Station, 36 p.

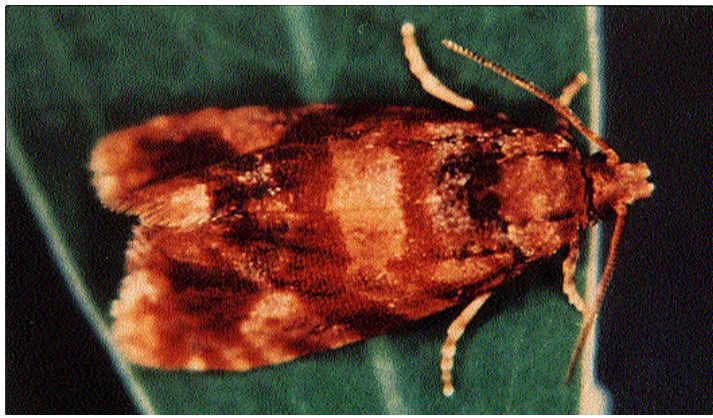

Figure 83 *Lobesia euphorbiana* moth

Figure 84 *Lobesia euphorbiana* larvae in leaf tie webbing

Longitarsus flavicornis Steph. (Coleoptera: Chrysomelidae)

DESCRIPTION AND LIFE CYCLE Copper-coloured adults, 2.5–3 mm long, become active in the spring and may remain active for more than a year feeding on foliage. Mating and egg laying begin immediately and continue over the summer. Eggs are laid into the surface layer of the soil and take approximately 42 days to develop. White, comma-shaped larvae mine into the root crown and down into the root core. Occasionally, larvae will also migrate up the stem. Larvae overwinter in the plant, pupate, and form adults in the following spring.

WEED ATTACKED Tansy ragwort.

HABITAT Prefer well-drained areas with a high density of plants because they redistribute themselves by walking. Larval development is best in areas with climates similar to that on southern Vancouver Island, with long fall periods and a mild winter.

COLLECTION, SHIPPING, AND HANDLING Collect adults in October when there are abundant new rosettes on which they actively feed. Collect using a vacuum aspirator or light sweep nets; as soon as the leaves are disturbed, the adults will begin jumping off the plants. Collection, therefore, must be done quickly and thoroughly. It can be done on the same area within a half hour, as the flea-beetles reposition themselves on the rosettes shortly after disturbance. Follow standard shipping and handling procedures for insects.

RELEASE Choose a dense stand of tansy ragwort for release. Approximately 1000 adults are preferred for a release. Follow standard release procedures for insects.

MONITORING To sample for larval presence and density, check the corky layers on the outside of the root crown on large roots; establishment and survival is best determined by adult presence on rosettes in October. Adult density is difficult to determine because the flea-beetles are easily missed and jump from plants when disturbed.

REFERENCES

Ireson, J.E., D.A. Friend, R.J. Holloway, and S.C. Paterson. 1991. Biology of *Longitarsus flavicornis* (Stephens) (Coleoptera: Chrysomelidae) and its effectiveness in controlling ragwort (*Senecio jacobeae* L.) in Tasmania. Journal of the Australian Entomological Society 30:129–141.

McEvoy, P.B., C. Cox, and E. Coombs. 1991. Successful biological control of ragwort, *Senecio jacobeae*, by introduced insects in Oregon. Ecological Applications 1:430–442.

Figure 85 *Longitarsus flavicornis*

Longitarsus jacobaeae (Waterhouse)
(Coleoptera: Chrysomelidae)

DESCRIPTION AND LIFE CYCLE Sandy-brown to yellowish adults, 2.5–3 mm long, emerge in the early summer. Adults feed briefly and then aestivate over the remainder of summer. Adults become active again in the fall and may remain active for more than a year, feeding on foliage if freezing does not occur. Mating and egg laying begin in the fall and continue until freeze-up; eggs are laid into the surface layer of the soil and take approximately 42 days to develop. White, comma-shaped larvae feed on the outer surface of lateral and central roots, leaving long grooves in the root. Larvae overwinter in the plant and pupate, with adults emerging the following spring.

WEEDS ATTACKED Tansy ragwort.

HABITAT These flea-beetles prefer well-drained areas with a high density of plants because they redistribute themselves by walking. Larval development is best in areas similar to that in the lower Fraser Valley with long fall periods and a mild winter. They also prefer lower elevations, but are not exclusive to them. In mild climates, larvae can withstand flooding by feeding on the petioles of the leaves rather than on the roots.

COLLECTION, SHIPPING, AND HANDLING Collect adults in October when there are abundant new rosettes on which they actively feed. Collect using a vacuum aspirator or sweep net; as soon as the leaves are disturbed, the adults will begin jumping off the plants. Collection, therefore, must be done quickly and thoroughly. It can be done on the same area within a half hour as the flea-beetles reposition themselves on the rosettes shortly after disturbance. Follow standard shipping and handling techniques for insects.

RELEASE Choose a dense stand of tansy ragwort for release. Approximately 1000 adults are preferred for a release. Follow standard release procedures for insects.

MONITORING To sample for larval presence and density, check the corky layers on the outside of the root crown on large roots;

establishment and survival is best determined by adult presence on rosettes in October. Adult density is difficult to determine because the flea-beetles are easily missed and jump from plants when disturbed.

REFERENCE

McEvoy, P.B., C. Cox, and E. Coombs. 1991. Successful biological control of ragwort, *Senecio jacobaea*, by introduced insects in Oregon. Ecological Applications 1:430–442.

Figure 86 *Longitarsus jacobaeae*

Figure 87 *Longitarsus jacobaeae* larva

Mecinus janthinus Germar (Coleoptera: Curculionidae)

DESCRIPTION AND LIFE CYCLE Black adults, elongate in shape, and 5 mm long, emerge in May and begin mating after a short feeding period. Egg laying starts in May or early June and lasts until mid-July; eggs are laid into cavities chewed into the shoots. Larvae hatch in 6–7 days and mine the centre of the shoot. Larvae feed on the shoot, develop over the next 3–5 weeks, and then pupate in the stem. Stems generally swell and crack with the developing larvae inside, and the stem portion above the larvae often dies. Pupal development occurs over the next 30–40 days and adults emerge approximately 2 weeks later. Adults overwinter in their pupal cells in the stem.

WEEDS ATTACKED Yellow toadflax and Dalmatian toadflax.

HABITAT Hot, dry conditions are preferred; grasslands or open forest with grassland are suitable. Large-stemmed plants generally support larval development for the entire growing season.

COLLECTION, SHIPPING, AND HANDLING Use light sweep nets to collect adults from May until July. Follow standard shipping and handling procedures for insects.

RELEASE Follow standard release procedures for insects.

MONITORING Adult weevils can be observed on plant material from May until July. To determine larvae, pupae, and unemerged adults' presence, cut open toadflax stems longitudinally, from June to the spring of the following year. Affected stems are swollen and cracked and often dead above the larvae.

REFERENCE

Jeanneret, P. and D. Schroeder. 1991. *Mecinus janthinus* Germar (Col.: Curculionidae): a candidate for the biological control of Dalmatian and yellow toadflax in North America. European Station Report. C.A.B. International Institute of Biological Control, Delemont, Switzerland. 36 p.

Figure 88 *Mecinus janthinus*

Figure 89 *Mecinus janthinus* larva

Metzneria paucipunctella Zeller
(Lepidoptera: Gelechiidae)

DESCRIPTION AND LIFE CYCLE Pale brown adults, 1 cm long, emerge in late May to early August, and live approximately 3 weeks. Mating begins immediately and eggs are laid into closed flower buds within 2–3 days. Larvae hatch in 10–12 days, coinciding with the opening of knapweed. Larvae are 4–5 mm long, cream coloured, with distinct body segments, a brown head capsule, and several pairs of legs. Larvae feed on the flower base (receptacle) and immature and mature seeds, overwintering in the seedhead. Pupation begins in April or early May and lasts for 3–4 weeks.

WEED ATTACKED Spotted knapweed.

HABITAT Does not tolerate severe winter conditions.

COLLECTION, SHIPPING, AND HANDLING Collect larvae by picking spotted knapweed stems with intact, infested seedheads in late summer and early fall, or in early spring (March to April) before emergence. Avoid storing in bulk; the native predatory mite *Pynotes* sp. will rapidly spread through the plant material.

RELEASE Select a release site at approximately the same elevation as the collection site, and avoid areas that are subject to frost pockets. *Metzneria* will not co-exist in the same seedhead as *Urophora affinis*; the moth larvae will consume up to two-thirds of the *Urophora* larvae.

MONITORING Check for adults with sweep nets in June and July. Check for establishment from October to May by examining the base of the seedhead for larvae. There will normally be signs of larval feeding in the attacked heads and several seeds may be webbed together. In the release year, you will likely encounter infested heads only within a few metres of the release point.

REFERENCE

Englert, W. 1971. *Metzneria paucipunctella* Zel. (Gelechiidae, Lepidoptera): a potential insect for the biological control of

Centaurea stoebe L. in Canada. Weed Projects for Canada Progress Report No. 28. European Station Report. Commonwealth Institute of Biological Control, Delemont, Switzerland. 12 p.

Figure 90 *Metzneria paucipunctella* moth

Figure 91 *Metzneria paucipunctella* larva in spotted knapweed seedhead

Pelochrista medullana (Strig.) (Lepidoptera: Tortricidae)

DESCRIPTION AND LIFE CYCLE Grey and mottled-brown adults, 14–21 mm long, emerge from mid-June to the end of July, with peak emergence in mid-July. Mating begins immediately and continues over their 12 to 13 day life span. Females begin laying eggs 2–3 days after mating begins. Eggs hatch in 7–9 days, and larvae migrate to the rosette and burrow into the root collar; larvae will only develop on plants in the rosette stage. Larvae become dormant over the winter, and briefly resume development in the spring before pupation.

WEEDS ATTACKED Diffuse knapweed and spotted knapweed; shows a preference for diffuse knapweed.

HABITAT The moth requires moderately moist sites with a dense stand of diffuse knapweed. It prefers habitats similar to the Ponderosa Pine biogeoclimatic zone in its native Europe. It has not established well in British Columbia.

COLLECTION, SHIPPING, AND HANDLING Vacuum aspirate adult moths. Because of the similarity of *Pelochrista* to many native moths, rearing and collection in tented plots is suggested to ensure correct identity. Follow standard shipping and handling techniques for insects.

RELEASE Follow standard release procedures for insects.

MONITORING Check roots in late August or September after larvae have established, or check in spring before emergence. Check the outside of the root for feeding damage, frass, larvae, pupae, or unemerged adults by lightly scraping dirt from the outer surface with a knife.

REFERENCE

Gassmann, A., D. Schroeder, and H. Muller. 1982. Investigations on *Pelochrista medullana* (Stgr.) (Lep.: Tortricidae), a possible biocontrol agent of diffuse and spotted knapweed, *Centaurea diffusa* Lam. and *C. maculosa* Lam. (Compositae) in North America. European Station Report. Commonwealth Institute of Biological Control, Delemont, Switzerland. 18 p.

Figure 92 *Pelochrista medullana* moth

Pterolonche inspersa Strg. (Lepidoptera: Pterolonchidae)

DESCRIPTION AND LIFE CYCLE Grey-white adults, 14–28 mm long, emerge from June to early September with peak emergence in mid-August. Mating begins immediately and egg laying starts within 5–9 days and continues over the 15 to 16 day life span. Eggs hatch 8–16 days after they are laid and larvae migrate down the root core and feed in the centre of the root. Up to four larvae will feed on the same root through the fall. Larvae overwinter in a silky cocoon on the root and resume development in the spring. Pupation occurs in late spring.

WEEDS ATTACKED Diffuse knapweed and spotted knapweed; shows a strong preference for diffuse knapweed.

HABITAT Requires hot, dry habitats with low to moderate densities of diffuse knapweed.

COLLECTION, SHIPPING, AND HANDLING Collect adult moths using vacuum aspirators. Because of the similarity of *Pterolonche* to many native moths, rearing and collection in tented plots is suggested to ensure correct identity. Follow standard shipping and handling techniques for insects.

RELEASE Follow standard release procedures for insects. *Pterolonche* larvae will consume *Sphenoptera* larvae and pupae and should not be released in new *Sphenoptera* area until the latter are established.

MONITORING Check roots in late August or September after larvae have established, or check in spring before emergence. Check the outside of the root for feeding damage, frass, larvae, pupae, or unemerged adults by lightly scraping dirt from the outer surface with a knife.

REFERENCE

Dunn, P.H., S.S. Rosenthal, G. Campobasso, and S.M. Tait. 1984. A petition for the release of *Pterolonche inspersa* Strg. (Lepidoptera: Pterolonchidae) in the United States as a biological control agent for *Centaurea diffusa* Lam. U.S. Department of Agriculture, Agriculture Research Service, Biological Control of Weeds Research Unit, Washington, D.C. 29 p.

Figure 93 *Pterolonche inspersa* moth

Figure 94 *Pterolonche inspersa* larva

Puccinia acroptili P. & H. Syd. (Uredinales: Pucciniaceae)

DESCRIPTION AND LIFE CYCLE Rust-coloured pustules form on the plants 12–16 days after inoculation. Stem and leaf infections occur; pustules cover the surface, impairing or preventing photosynthesis. Pustules produce spores that spread by wind and water and inoculate other plants.

WEED ATTACKED Russian knapweed.

HABITAT Capable of inhabiting all areas where Russian knapweed occurs.

COLLECTION, SHIPPING, AND HANDLING Collect plant material infected with rust. Follow standard shipping and handling procedures for biological control agents on plant material.

RELEASE Follow standard release procedures for biological control agents on plant material. *Puccinia* distributes itself well and can be found in most areas where Russian knapweed occurs. Check for presence before making a redistribution at a new location.

MONITORING Determine the presence and extent of attack by conducting visual checks of rust pustules on the plant material in August and September.

REFERENCE

Mortensen, K., P. Harris, and W.K. Kim. 1991. Host ranges of *Puccinia jaceae, P. centaureae, P. acroptili,* and *P. carthami,* and the potential value of *P. jaceae* as a biological control agent for diffuse knapweed *(Centaurea diffusa)* in North America. Canadian Journal of Plant Pathology 13:71–80.

Figure 95 *Puccinia acroptili* rust pustules on Russian knapweed

Puccinia chondrillina (Uredinales: Pucciniaceae)

DESCRIPTION AND LIFE CYCLE Rust-brown coloured pustules, surrounded by a yellow halo, infest upper and lower leaf surfaces of seedlings and rosettes produced from spring to the fall. Spores develop in the pustules and are dispersed by wind and rain to infest new plant material; new pustules form on the plants 12–16 days after inoculation. Seedling plants can be killed by heavy infections, and all infected plants show reduced growth, vigour, and reproductive potential. As rosette leaves die from the infection, the fungus can spread onto flowering stems and buds; these pustules are dark brown and remain dormant over the winter. In spring, the sexual stage of the fungus is produced; clusters of yellow fruiting bodies form on rosette leaves, which in turn produce airborne spores that initiate the rust-brown pustules.

WEED ATTACKED Rush skeletonweed.

HABITAT Capable of inhabiting all areas where rush skeletonweed occurs. Some varieties of rush skeletonweed are resistant to the fungal infection.

COLLECTION, SHIPPING, AND HANDLING Collect plant material infected with rust. Follow standard shipping and handling procedures for biological control agents on plant material.

RELEASE Follow standard release procedures for biological control agents on plant material. *Puccinia* distributes itself well and can be found in most areas where rush skeletonweed occurs. Check for presence before making a redistribution at a new location.

MONITORING Determine the presence, density, and extent of attack by conducting visual checks of rust pustules on the plant material in August and September.

REFERENCE

Cheney, T.M., G.L. Piper, G.A. Lee, W.F. Barr, D.C. Thill, R.B. Hawkes, R.F. Line, R.R. Old, L.L. Craft, Jr., and E.B. Adams. 1981. Rush skeletonweed: biology and control in the Pacific Northwest. Current Information Series No. 585. University of Idaho, College of Agriculture, Cooperative Extension Service, Agriculture Experiment Station, Moscow, Idaho. 4 p.

Figure 96 *Puccinia chondrillina* rust pustules on rush skeletonweed

Puccinia jaceae Otth. (Uredinales: Pucciniaceae)

DESCRIPTION AND LIFE CYCLE Rust-coloured pustules form on the plants 12–16 days after inoculation. A yellow halo forms around the pustules when they are small. The fungi forms moderate (15–20% of the surface area) infestations of stem and leaves. Rust pustules vary in size from 0.4 to 1.3 mm in diameter. The rust spreads by wind-spread spores throughout the growing period of knapweed.

WEEDS ATTACKED Diffuse knapweed and spotted knapweed.

HABITAT Capable of inhabiting all areas where diffuse knapweed and spotted knapweed occur.

COLLECTION, SHIPPING, AND HANDLING Collect plant material infected with rust. Follow standard shipping and handling procedures for plant material.

RELEASE Follow standard release procedures for biological control agents on plant material. *Puccinia* distributes itself well and can be found in most areas where knapweed occurs. Check for presence before making a redistribution at a new location.

MONITORING Determine presence and extent of attack by conducting visual checks of rust pustules on the plant material in August and September.

REFERENCE

Mortensen, K., P. Harris, and W.K. Kim. 1991. Host ranges of *Puccinia jaceae*, *P. centaureae*, *P. acroptili*, and *P. carthami*, and the potential value of *P. jaceae* as a biological control agent for diffuse knapweed (*Centaurea diffusa*) in North America. Canadian Journal of Plant Pathology 13:71–80.

Figure 97 *Puccinia jaceae* rust pustules on knapweed

Rhinocyllus conicus Froelich (Coleoptera: Curculionidae)

DESCRIPTION AND LIFE CYCLE Dark brown, oval-shaped adults, 3–7 mm long, become active in the spring and disperse to find thistles on which to feed. Adults feed on leaves until early summer when mating and egg laying begin. The weevils lay eggs on the underside of the thistle flower bud. Larvae hatch 6–9 days after egg laying and bore directly into the flower bud. Mature larvae form hard cells in the flower head in which they pupate; pupation lasts 8–14 days and adults begin emerging in mid-summer. Those emerging while day is more than 16 hours long complete a second generation. The majority, however, hibernate in soil litter over the winter. Adults can survive for up to 15 months; they are adept at finding isolated pockets of nodding thistle.

WEEDS ATTACKED Plumeless thistle, nodding thistle, and to a lesser extent Canada thistle. One strain also attacks bull thistle, but has not established well in British Columbia.

HABITAT Occupies a habitat that is contiguous with the current distribution of plumeless and nodding thistle.

COLLECTION, SHIPPING, AND HANDLING Collect flower heads after flowering: wearing gloves, pull off the first heads to turn brown, but before the wind-carried seed is released. Standard shipping and handling requirements should be followed. Because insects will complete their development quickly and emerge to hibernate, place the heads at the new site as quickly as possible.

RELEASE Follow standard release procedures for biological control agents in plant material.

MONITORING Check thistle flower buds for weevil eggs on the flower bracts in early summer, or open the first flowers to turn brown after flowering to check for larvae. Pupal chambers can also be found in old flower heads in the fall after adult emergence.

REFERENCE

Zwolfer, H. and P. Harris. 1984. Biology and host specificity of *Rhinocyllus conicus* (Froel.) (Col., Curculionidae), a successful

agent for biocontrol of the thistle, *Carduus nutans* L. Technical Communication No. 4. Commonwealth Institute of Biological Control, Delemont, Switzerland, pp. 36–62.

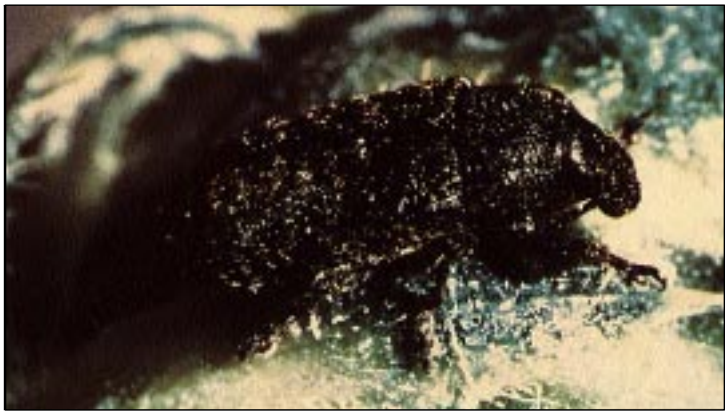

Figure 98 *Rhinocyllus conicus*

Figure 99 *Rhinocyllus conicus* larva

Sphenoptera jugoslavica Obenb. (Coleoptera: Buprestidae)

DESCRIPTION AND LIFE CYCLE Dark copper to black adults, elongate-oval shaped and 7–10 mm long, emerge in July, just before diffuse knapweed flowers form. Males emerge 1 week before females. Mating begins within a few days of female emergence and continues over their 4 week life span. Egg laying begins 5–12 days after mating. Larvae hatch 2–4 weeks after egg laying and burrow through the stem, down into the root crown and through the root core. Larvae overwinter in the root and begin pupation in mid-May of the following year. Pupae are initially white, and then darken to black.

WEEDS ATTACKED Diffuse knapweed and spotted knapweed; only rarely attacks spotted knapweed.

HABITAT Requires an arid environment with a summer drought period. Best adapted to dry subzones of the Bunchgrass and Ponderosa Pine biogeoclimatic zones. Sites with aspen, Douglas-fir, or lodgepole pine are likely too moist.

COLLECTION, SHIPPING, AND HANDLING Collect adults on hot, dry summer evenings from mid-July to mid-August with sweep nets. Because of the hardness of dried knapweed stems, canvas bag sweep nets should be used in place of the standard cotton. Adults are usually resting on knapweed foliage, which must be brushed firmly with the sweep net to be effective. Collection on rainy or cool days is ineffective because beetles position themselves near the ground. Follow standard shipping and handling procedures for insects.

RELEASE Follow standard release procedures for insects.

MONITORING Check roots in the spring following release by digging out an entire root and slicing it in half to check for larvae. Larvae are found in the centre of the root; infested roots will generally be swollen, but on large plants this may be inconspicuous.

REFERENCE

Zwolfer, H. n.d. Investigations on *Sphenoptera (Chilostetha) jugoslavica* Obenb. (Col: Buprestidae), a possible biocontrol agent of the

weed *Centaurea diffusa* Lam. (Compositae) in Canada. European Station Report, Commonwealth Institute of Biological Control, Delemont, Switzerland. 37 p.

Figure 100 *Sphenoptera jugoslavica*

Figure 101 *Sphenoptera jugoslavica* larva

Subanguina picridis Kirj. & Ivan (Nematoda: Tylenchidae)

DESCRIPTION AND LIFE CYCLE This nematode (not visible to the unaided eye) forms 5–12 mm diameter galls on the leaves, stem, and root collar. Adults are active in the plants during the active growing period of the knapweed. Nematode reproduction and early development occur in the plant galls. Juvenile nematodes are active in the plants until dying plant material desiccates, at which time they enter a stage of quiescence. This dormant period is broken by the return of moisture (typically the following spring), and the juveniles enter the soil out of the decaying plant material. Juveniles require at least 1 month of free-living conditions in the soil before they become infective. Those Russian knapweed plants that are attacked are typically slow growing and retain their active growing tissue (roots and shoots) at or near the soil surface for 2–5 weeks.

WEED ATTACKED Russian knapweed.

HABITAT Gall formation generally only occurs at sites with cool, moist spring weather.

COLLECTION, SHIPPING, AND HANDLING Collect plant material infected with nematode galls. Follow standard shipping and handling procedures for biological control agents in plant material.

RELEASE Follow standard release procedures for biological control agents in plant material.

MONITORING Look for stem and root galls from early to late summer. Positive identification of the nematode can be made in the laboratory under a microscope.

REFERENCE

Watson, A.K. 1986. The biology of *Subanguina picridis*, a potential biological control agent of Russian knapweed. Journal of Nematology 18:149–154.

Figure 102 *Subanguina picridis* stem gall on Russian knapweed stem

Terellia virens (Loew.) (Diptera: Tephritidae)

DESCRIPTION AND LIFE CYCLE Adults, clear-winged, with yellow or greenish yellow bodies, emerge about 4 weeks before spotted knapweed flowering. Mating and egg laying begin with the onset of hot, sunny weather and continue for the length of the adults' 48 day life. Yellow-brown larvae emerge within 3–5 days and move into the flower head to feed on seeds. Larvae develop and feed within a single, developing seed early in their development, later outgrowing the confines of the seed and feeding on others within the seedhead. *T. virens* has one and sometimes two generations per year. Most larvae overwinter in the seedhead and pupate in the spring, but some continue to develop, completing pupation in about 14 days, with second adult emergence in late summer. Pupae are yellow-brown and are enclosed within a yellow-brown case.

WEED ATTACKED Spotted knapweed.

HABITAT Prefers south-facing slopes and dry locations.

COLLECTION, SHIPPING, AND HANDLING Collect larvae by picking spotted knapweed stems with intact, infested seedheads in late summer and early fall, or in early spring before emergence. Avoid storing in bulk; the native predatory mite *Pynotes* sp. will rapidly spread through the plant material. Sweep nets can be used to collect adults. Follow standard shipping and handling procedures.

RELEASE Follow standard release procedures for biological control agents in plant material.

MONITORING Check for flies in late June to August by sweeping the release area; flower heads can be checked for larvae throughout the fall and spring. The yellow-brown *Terellia* larvae and pupae can be distinguished from *Urophora*, which have white larvae and pupae in a brown pupal case, and from *Chaetorellia*, which have white or yellow larvae, pupae, and pupal cases.

REFERENCE

Groppe, K. and K. Marquardt. 1989. *Terellia virens* (Loew.) (Diptera: Tephritidae), a suitable candidate for the biological control of diffuse and spotted knapweed in North America. European Station Report. C.A.B. International Institute of Biological Control, Delemont, Switzerland. 28 p.

Figure 103 *Terellia virens*

Figure 104 *Terellia virens* larvae in knapweed seedhead

Trichosirocalus horridus (Panzer)
(Coleoptera: Curculionidae)

DESCRIPTION AND LIFE CYCLE Brown, spherical-shaped adults, 3–4 mm long, emerge to feed on the upper and heads at the start of thistle bloom. Adults gather at the base of the flower buds to feed and mate. Mating and egg laying occur in early spring and are largely finished by the time balsam root *(Balsamorhiza sagittata)* is in flower. Larvae mine and feed on vegetative buds as they develop.

WEEDS ATTACKED Plumeless thistle and nodding thistle.

HABITAT Dense stands are required because weevils distribute themselves for egg laying by walking. They are generally capable of inhabiting all areas in which plumeless and nodding thistle occur. They are most effective in areas with long, cool springs.

COLLECTION, SHIPPING, AND HANDLING Collect adults by tapping the upper thistle stems over a tray; the beetles feign death and drop onto the tray. Follow standard shipping and handling procedures.

RELEASE Follow standard release procedures for insects.

MONITORING Check thistle flower buds early in the summer for weevils on flower bracts, or bend flowering thistle over a tray and tap the stem. The weevils will feign death and drop onto the tray. The rosette crown can also be checked for necrosis caused by the larvae in the spring. By pulling on the central leaves in the crown you can easily see the blackened necrotic crown area and sometimes the larvae.

REFERENCE

Harris, P. 1984. *Carduus nutans* L., nodding thistle and *C. acanthoides* L., plumeless thistle (Compositae). *In* Biological Programmes Against Insects and Weeds in Canada 1969–1980. Kelleher, J.S. and M.A. Hulme (editors). Commonwealth Agricultural Bureaux, London, England, pp. 115–126.

Figure 105 *Trichosirocalus horridus*

Tyria jacobaeae (L.) (Lepidoptera: Arctiidae)

DESCRIPTION AND LIFE CYCLE Adults, 0.5–2.5 cm long, with deep red (cinnabar) and black forewings, emerge in late spring. Mating begins soon after emergence and pale yellow eggs are laid on the underside of ragwort leaves. Cinnabar caterpillars, black and ringed with orange-gold bands, feed on foliage and buds over the entire tansy ragwort plant, from the onset of bolting to the bud stage. Larval movement increases with development and, in the latter stages, larvae move between plants; larvae take approximately 30 days to develop. Larvae can achieve up to 40% defoliation of tansy ragwort plants. Pupation takes place in ground litter, crevices, or small holes in the ground or decaying wood. The moth overwinters in the pupal stage.

WEED ATTACKED Tansy ragwort.

HABITAT Adapted to a wide variety of habitats in which tansy ragwort is found. Dense stands are preferred to allow larvae to move between plants. The cinnabar moth does not survive in water-logged sites or sites flooded in the winter.

COLLECTION, SHIPPING, AND HANDLING Collect by hand picking larvae or shaking larvae from plants into a collection tray or funnel. When plants are shaken some larvae may fall to the ground; however, they will quickly recover and climb onto the plants. Care should be taken not to walk on larvae that fall to the ground. Follow standard shipping and handling procedure for insects.

RELEASE Follow standard release procedure for insects. Take care not to walk on larvae that fall onto the ground at the release site.

MONITORING Check for caterpillars at release site in late June through July the year following release. Alternatively, look for the bright red moths in early to mid-spring.

REFERENCES

Issacson, D.L. 1973. A life table for the cinnabar moth, *Tyria jacobaeae*, in Oregon. Entomophaga 18:291–303.

McEvoy, P.B., C. Cox, and E. Coombs. 1991. Successful biological control of ragwort, *Senecio jacobaea*, by introduced insects in Oregon. Ecological Applications 1:430–442.

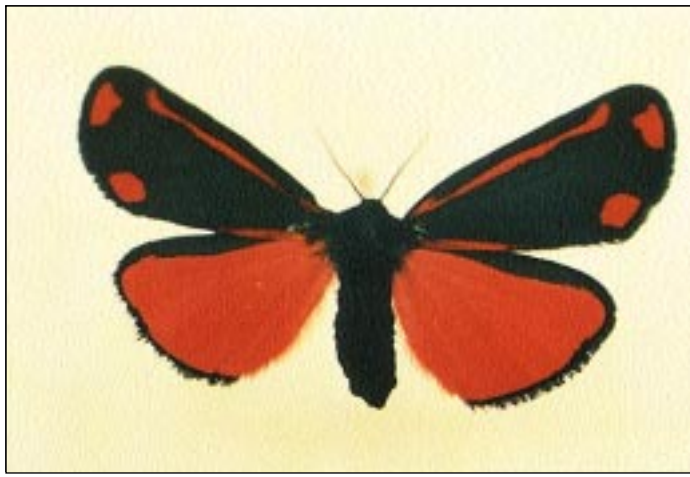

Figure 106 *Tyria jacobaeae* moth

Figure 107 *Tyria jacobaeae* caterpillars on tansy ragwort

Urophora affinis Frauenfeld (Diptera: Tephritidae)

DESCRIPTION AND LIFE CYCLE Adults, 1–3 mm long, are dark bodied, with clear wings faintly marked with a bar. The wings are often held together in line with the body while the fly is at rest. Females have a prominent black ovipositor. Adults emerge in early to mid-June as flower buds are developing. Mating begins immediately and egg laying starts 3 days later. Eggs hatch within 3–4 days and the larvae burrow into the flower head. The presence of the larvae stimulates the plants to form woody galls around the larvae. The energy needed to form galls reduces the seed and flower production in the plants. *Urophora affinis* presence can reduce seed production by 90%. Larvae feed on the inner tissue of the galls and usually overwinter in the larval form in the seedhead. Some of the early developing flies will pupate in mid-August and a second generation of adults will emerge approximately 14 days later. Most larvae, however, require a cold phase to induce pupation, which normally occurs in late spring to early summer the next year.

WEEDS ATTACKED Diffuse knapweed and spotted knapweed.

HABITAT Contiguous with diffuse and spotted knapweed distribution. It generally does better in mesic habitats and wetter years.

COLLECTION, SHIPPING, AND HANDLING Collect larvae by picking knapweed stems with intact, infested seedheads in the fall (September or October) or in early spring (March to May) before pupation. Avoid storing in bulk; the native predatory mite *Pynotes* sp. will rapidly spread through the plant material. Sweep nets can be used to collect adults in June and July.

RELEASE Follow standard release procedures for biological control agents in plant material. The fly establishes best on the species from which it was collected; use flies from diffuse knapweed for release on diffuse knapweed and likewise for spotted knapweed. *Urophora* is already present in most stands in British Columbia; check old seedheads for the presence of galls before making additional releases.

MONITORING Check for adult flies in June to July with sweep nets, or examine the mature flower heads for galls throughout the year. A woody gall from the current year will contain a larva; heads from the previous year will contain empty gall shells.

REFERENCE

Roze, L.D. and B.D. Fraser. 1978. Biological control of diffuse and spotted knapweed by *Urophora affinis* and *U. quadrifasciata* in British Columbia. *In* Proceedings of 1st Rangeland Congress, Denver, Colorado, pp. 664–666.

Figure 108
Urophora affinis female with prominent ovipositor

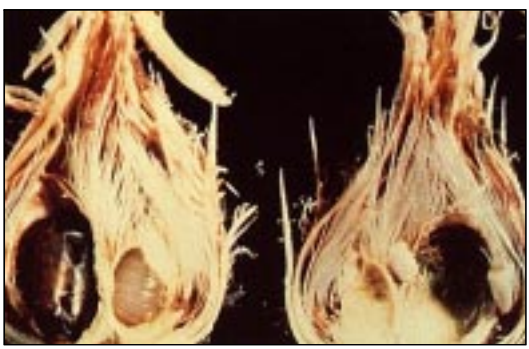

Figure 109 *Urophora affinis* larvae in woody seedhead gall

Urophora cardui (L.) Diptera: Tephritidae)

DESCRIPTION AND LIFE CYCLE Adults are black bodied, with clear wings marked with a ``W'' pattern. Females have a prominent ovipositor. Adults emerge from May to July and begin mating immediately. Females lay eggs into the growing tips of the thistle shoots 1–2 days after emergence. Eggs hatch in 4–8 days and larvae burrow into the stem tissue. Large galls form in the thistle's stem tissue about 15 days after egg laying and enlarge over a 50 to 60 day period. Galls contain 1–30 larvae, each enclosed in its own chamber. The larvae overwinter in the galls, pupating and emerging as adults in the following spring.

WEED ATTACKED Canada thistle.

HABITAT These flies are restricted to moist to wet low-elevation sites with at least partial shade. River edges and lake shores with a partial overstory of trees are sufficient.

COLLECTION, SHIPPING, AND HANDLING Collect larvae and pupae in gall tissue in late summer until snow cover. Follow standard shipping and handling procedures for biological control agents in plant material.

RELEASE Follow standard release procedures for biological control agents in plant material. Because females prefer to lay eggs into host plants 50–100 cm tall, a stand of this height would be beneficial.

MONITORING Adult flies are not readily visible on the plants and do not congregate in large numbers for sweep netting. To determine presence, look for new galls in July and August.

REFERENCES

Forsyth, S.F., D.P. Peschken, and A.K. Watson. 1986. Biological control of Canada thistle with *Urophora cardui* (L.). Canadex 641.613. Agriculture Canada, Ottawa, Ontario, 4 p.

Peschken, D.P. and J.L. Derby. 1992. Effect of *Urophora cardui* (L.) (Diptera: Tephritidae) and *Ceutorhynchus litura* (F.) (Coleoptera: Curculionidae) on the weed Canada thistle, *Cirsium arvense* (L.) Scop. Canadian Entomologist 124:145–150.

Figure 110 *Urophora cardui* larvae in Canada thistle stem gall

Urophora quadrifasciata (Meigan) (Diptera: Tephritidae)

DESCRIPTION AND LIFE CYCLE Adults are 1–3 mm long, black bodied, with black wings striped in a distinctive ``UV'' pattern. This fly usually holds its wings in a ``V'' shape from its body while at rest. Females have a prominent black ovipositor. Adult flies emerge in late June to early July as knapweed flower buds are developing. Mating begins immediately and continues over a 3 week period; egg laying begins 3 days later. Eggs hatch within 3–4 days and the larvae burrow into the flowers. The presence of the larvae stimulates the flower's ovary walls to form galls around the larvae. The energy needed to form galls reduces the seed and flower production in the plants. The larvae feed on the galls and almost entirely consume them, leaving only a thin, papery tissue. Larvae pupate inside the galls 20–25 days after hatching and a second generation of adults emerges in early to mid-August. The second generation overwinters as larvae inside the seedhead and emerges the following spring.

WEEDS ATTACKED Diffuse knapweed and spotted knapweed.

HABITAT Contiguous with diffuse and spotted knapweed distribution. Larvae are intolerant of severe winter conditions with partial or no snow cover.

COLLECTION, SHIPPING, AND HANDLING Collect larvae by picking knapweed stems with intact seedheads in infested areas in fall (September or October) or early spring (March to May) before pupation. Avoid storing in bulk; the native predatory mite *Pynotes* sp. will rapidly spread through the material. Sweep nets can be used to collect adults in June and July.

RELEASE Follow standard release procedures for biological control agents in plant material. The fly establishes best on the species from which it was collected; use those collected from diffuse knapweed for release on diffuse knapweed and likewise for spotted knapweed. *Urophora* is already present in most stands in British Columbia; check old seedheads for the presence of galls before making additional releases.

MONITORING Check for adult flies in late June to August with sweep nets, or examine mature flower heads for papery galls throughout the year. A gall from the current year will contain a larva, and heads from the previous year will contain empty gall shells.

REFERENCE

Roze, L.D. and B.D. Fraser. 1978. Biological control of diffuse and spotted knapweed by *Urophora affinis* and *U. quadrifasciata* in British Columbia. *In* Proceedings of 1st Rangeland Congress, Denver, Colorado, pp. 664–666.

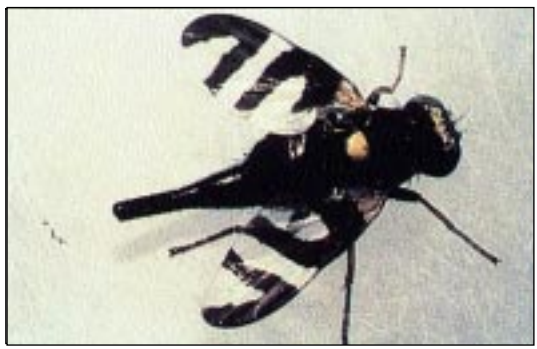

Figure 111
Urophora quadrifasciata female with prominent ovipositor

Figure 112
Urophora quadrifasciata larvae in papery seedhead gall

Urophora solstitialis L. (Diptera: Tephritidae)

DESCRIPTION AND LIFE CYCLE Emergence of the black-bodied adults, with a distinctive pattern on the wings, coincides with the flower budding on plumeless thistle in the late spring to early summer. Eggs are laid singly into developing floret tubes inside the immature flower buds in June or July. Larvae mine down the flower tube, through the ovule, and into the receptacle. The plant responds to larval feeding by developing gall tissue around the larvae in the receptacle. If multiple attacks occur in a single flower head, the galls will fuse together into a single large gall; in all circumstances the gall tissue hardens with age and often encloses ovules and other floral tissue. Early developing larvae pupate and adults emerge in late summer; mating and egg laying continue into the fall as long as suitable flower buds are available. Larvae overwinter in the galled seedheads and continue development in the spring.

WEEDS ATTACKED Plumeless thistle; occasionally attacks nodding thistle.

HABITAT No information on habitat preference is currently available.

COLLECTION, SHIPPING, AND HANDLING Collect larvae by picking knapweed stems with intact, galled flower heads in the fall, or in early spring before fly emergence.

RELEASE Follow standard release procedures for biological control agents in plant material.

MONITORING Check for adult fly presence in the summer with sweep nets, or examine mature flower heads for galls throughout the year. A gall from the current year will contain a larva; heads from the previous year will contain empty gall shells.

REFERENCE

Moller-Joop, H. and D. Schroeder. 1986. *Urophora solstitialis* (L.) (Diptera:Tephritidae): a candidate for the biological control of plumeless thistle (*Carduus acanthoides* L.) in Canada. Final Screening Report. European Station Report. Commonwealth Institute of Biological Control, Delemont, Switzerland. 23 p.

Figure 113 *Urophora solstitialis* female with prominent ovipositor

Urophora stylata (L.) (Diptera: Tephritidae)

DESCRIPTION AND LIFE CYCLE Adults, 4–8 mm long, are dark bodied with clear wings. The wings are marked with bands forming a ``D'' at the tip with a small break at the bottom; the band near the middle is often incomplete or broken. Females have a prominent ovipositor, 3–4 mm long. Adult males emerge in early June and establish territories over bolting thistle plants. Mating occurs before bloom on the thistle (July) and eggs are laid into the flower head. Larvae hatch after a week and burrow into the flowers where the surrounding tissue forms into a hard, woody gall. Several galls can form in a single flower head and will tend to coalesce to form a large gall with many compartments. Larvae overwinter in the gall and pupate in the following spring.

WEED ATTACKED Bull thistle.

HABITAT Capable of inhabiting all the areas where bull thistle is currently established. Fly colonies only survive, however, where there is a stable bull thistle population.

COLLECTION, SHIPPING, AND HANDLING Collect seedheads containing galls from late August to November; squeeze mature flower heads (wear gloves) to detect the hard galls, then collect them by pulling off the head. Follow standard shipping and handling procedures for biological control agents in plant material.

RELEASE Place the galls on the ground at the new location in the fall, or store over the winter in refrigeration (4° C) for release in early spring. Scatter the galls over a small area to reduce predation by mice. Keep refrigerated galls moist but do not let them mould. About 50 galls or 200 flies are adequate to establish a new colony.

MONITORING Check establishment by examining heads for galls; larvae can be seen if the galls are cut open.

REFERENCE

Harris, P. and A.T.S. Wilkinson. 1986. Biological control of bull thistle with *Urophora stylata* Fabr. Canadex 641.613. Agriculture Canada, Ottawa, Ontario.

Figure 114 *Urophora stylata* female with prominent ovipositor

Figure 115 *Urophora stylata* larvae in bull thistle gall

APPENDIX 1.
CURRENT STATUS OF BIOLOGICAL CONTROL AGENTS

Biological control agents approved for release in British Columbia are classified into one of three categories of availability:

- available for general distribution (G)
- pending release and distribution (P)
- under propagation or limited field distribution and not available for general distribution (N).

The following is the status of the biological control agents as of January 1, 1994:

Aceria chondrillae . . . . . N
Agapeta zoegana . . . . . G
Agrilus hyperici . . . . . N
Aphis chloris . . . . . N
Aphthona cyparissiae . . . . . G
Aphthona czwalinae . . . . . P
Aphthona flava . . . . . N
Aphthona lacertosa . . . . . P
Aphthona nigriscutis . . . . . G
Aplocera plagiata . . . . . G
Brachypterolus pulicarius . . . . . G
Calophasia lunula . . . . . N
Ceutorhynchus litura . . . . . N
Chaetorellia acrolophi . . . . . N
Chrysolina hyperici . . . . . G
Chrysolina quadrigemina . . . . . G
Cochylis atricapitana . . . . . N
Cyphocleonus achates . . . . . G
Eteobalea intermediella . . . . . N
Eteobalea serratella . . . . . N
Galerucella calmariensis . . . . . N
Galerucella pusilla . . . . . P
Gymnaetron antirrhini . . . . . G
Hylemya seneciella . . . . . N
Hyles euphorbiae . . . . . N

Hylobius transversovittatus . . . . . P
Larinus minutus . . . . . N
Larinus obtusus . . . . . N
Larinus planus . . . . . G
Lobesia euphorbiana . . . . . G
Longitarsus flavicornis . . . . . G
Longitarsus jacobaeae . . . . . G
Mecinus janthinus . . . . . G
Metzneria paucipunctella . . . . . G
Pelochrista medullana . . . . . N
Pterolonche inspersa . . . . . N
Puccinia acroptili . . . . . G
Puccinia chondrillina . . . . . G
Puccinia jaceae . . . . . G
Rhinocyllus conicus . . . . . G
Sphenoptera jugoslavica . . . . . G
Subanguina picridis . . . . . N
Terellia virens . . . . . N
Trichosirocalus horridus . . . . . G
Tyria jacobaeae . . . . . G
Urophora affinis . . . . . G
Urophora cardui . . . . . N
Urophora quadrifasciata . . . . . G
Urophora solstitialis . . . . . N
Urophora stylata . . . . . G

APPENDIX 2. BIOLOGICAL CONTROL RELEASE FORM

BIOLOGICAL CONTROL RELEASE RECORD

Site Number: _____

AGENT

1. Insect Specie: _____ Immediate Source: _____

Insect Origin: _____

2. Stage Egg Larva Pupa Adult Other _____

3. Collection _____ Y/M/D 4. Release _____ Y/M/D 5. Time. _____ 6. Number. _____

RELEASE

1. Target Weeds: _____ 2. Purpose: Biocontrol _____ Collection Site _____

3. LandOwner _____ Phone ( ) _____

4. Local Contact _____ Phone ( ) _____

5. Released By _____ Name _____ Organization

SITE

1. Forest District: _____ Range Unit: _____ No. _____

2. Location: _____

_____

3. BCGS (Forest Cover) Map No: _____

4. UTM System: Zone _____ Easting _____ Northing _____

5. Weed Density. <1 plant/m² _____ 2 - 5 plants/m² _____
6 - 10 plants/m² _____ > 10 plants/m² _____

6. Size of Infestation: < 001 ha _____ 0.01 - 0.04 ha _____
004 - 0.25 ha _____ 0.25 - 0.5 ha _____
05-1ha _____ >1ha _____

7. Weed Distribution: Continuous Stand _____ Scattered Patches _____

8 MAP REQUIRED FOR EACH RELEASE attached to this form
(1 15,000 or 1 20 000 Forest Cover Map with the release Site clearly marked)

BIOPHYSICAL DESCRIPTION

1. Slope(%) _____ 2. Aspect (deg.) _____ 3 Elevation (m) _____

4. Biogeoclimatic classification: Zone _____ Subzone _____ Variant _____ Site series _____

5. Comments: _____

_____

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