HISTORY AND ECOLOGY IN NORTH AMERICA

Sharlene E. Sing[1], Rosemarie A. De Clerck-Floate[2], Carol B. Randall[3], and Ivo Toševski[4]
[1] USDA Forest Service–Rocky Mountain Research Station, [2] Agriculture and Agri-Food Canada, [3] USDA Forest Service–Forest Health Protection, [4] CABI Switzerland

Brachypterolus pulicarius
Toadflax flower-feeding beetle

Brachypterolus pulicarius is an accidentally introduced toadflax-feeding beetle previously redistributed for biological control of toadflaxes.

CLASSIFICATION

RANKING	SCIENTIFIC NAME	COMMON NAME
Kingdom	Animalia	Animals
Phylum	Arthropoda	Arthropods
Class	Insecta	Insects
Order	Coleoptera	Beetles
Family	Kateretidae	Short-winged flower beetles
Genus	*Brachypterolus*	
Species	*Brachypterolus pulicarius* (Linnaeus)	Toadflax flower-feeding beetle

DESCRIPTION

Eggs appear milky white at first, becoming yellow just before hatching. Larvae are yellow and up to 7 mm long. The larval head capsule starts out dark brown to black and wider than the abdomen, but by the third instar, lightens to a golden brown and becomes more slender than the body (**Fig. 1a**). Pupae are up to 3 mm long and 2 mm wide. Adults are 2–3 mm long and somewhat oval-shaped with short elytra (hardened outer wings) that do not completely cover their abdomens (**Fig. 1b**). Adults are shiny dark brown to black or sometimes black with brown mottling, and they have maroon feet and antennae.

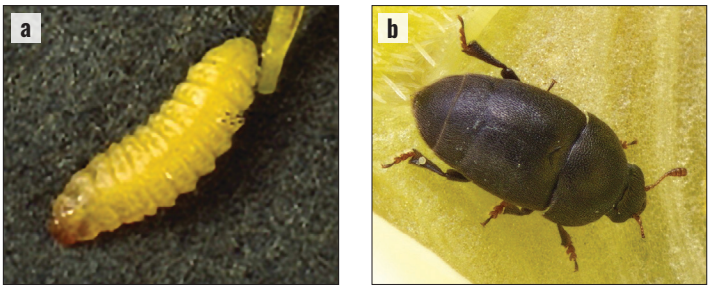

Figure 1. *Brachypterolus pulicarius* (a) larva; (b) adult (a: Daniel K. MacKinnon, Colorado State University, Bugwood.org, CC BY-3.0 US; b: Иван Тисленко, iNaturalist.org CC BY-NC 4.0)

LIFE CYCLE

Adults emerge in late spring (**Fig. 2**) and feed on young toadflax shoot tips. Females lay eggs singly into unopened toadflax buds, just beneath the folded petals. Larvae feed on pollen, anthers, ovaries, and immature seeds. They develop through three instars and drop to the soil in fall to overwinter as pupae in soil or plant litter. There is one generation per year.

HOST SPECIES IN NORTH AMERICA

Yellow (preferred) and Dalmatian toadflax

DAMAGE

Adult feeding can delay flowering and reduce the number of healthy flowers (and thereby seeds) produced by yellow toadflax. At high densities (**Fig. 3**), adult feeding increases branching and reduces the height of Dalmatian toadflax

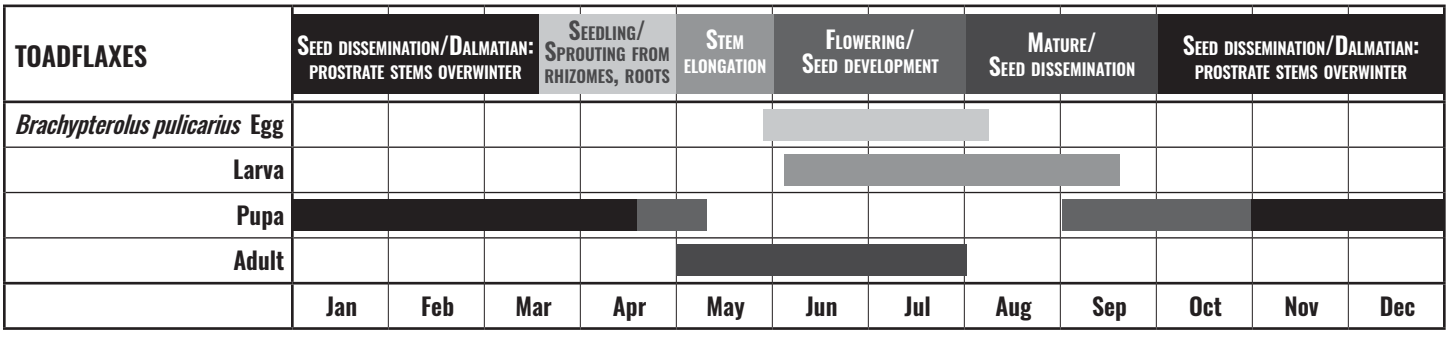

Figure 2. Schematic life cycle of *Brachypterolus pulicarius* and toadflaxes in North America. Bars indicate the approximate length of activity for each life stage; dates will vary depending on local conditions. Black bars represent the inactive and/or overwintering periods. There is typically one generation per year.

plants. Injury from larval feeding is generally more significant, reducing seed output by more than 75% in attacked flowers. Seeds surviving to maturity in attacked flowers are smaller, lighter weight, and less viable. Decreasing seed output does not kill existing plants but can help reduce the rate of spread and genetic diversity of toadflax populations.

Figure 3. High densities of *Brachypterolus pulicarius* adults on a Dalmatian toadflax plant (Susan Turner, British Columbia Ministry of Forests, Bugwood.org CC BY-3.0 US)

FIELD IDENTIFICATION

Adults may be observed around toadflax flowers throughout spring (**Fig. 3**). Because larvae feed completely within flowers, they can be difficult to detect unless flowers are dissected. At least seven other beetle species are established on toadflaxes in North America. Adult *B. pulicarius* can be differentiated from these others by its lack of a snout and its distinctive oval body shape; the other toadflax beetles are weevils and have long snouts with more rectangular or round-shaped bodies (**Table 1**).

PREFERRED HABITAT

The toadflax flower-feeding beetle is well adapted to a variety of environmental conditions and can be found throughout the majority of toadflax infestations in North America.

HISTORY AND CURRENT STATUS

Brachypterolus pulicarius is native to Europe and was unintentionally introduced to North America. In the USA, it was first reported on yellow toadflax in New York in 1919. In Canada, it was first recorded on Dalmatian and yellow toadflax in western provinces in 1950. The beetle has since been approved for redistribution within the USA and has spread naturally and with human help throughout both the USA and Canada on both toadflax species. Different *B. pulicarius* biotypes (or strains) were believed to have evolved to specialize on either yellow toadflax or Dalmatian toadflax; however, a recent study found no genetic basis for this claim. This beetle prefers and performs better on yellow toadflax, even for individuals collected from Dalmatian toadflax. Its use of Dalmatian toadflax, therefore, remains incidental in both the USA and Canada.

In the USA, *B. pulicarius* is more common on yellow toadflax, and has largely been recorded from western states, although it is likely established in more northeastern states than what has been documented in the literature (**Fig. 4**). On Dalmatian toadflax in the western USA, the abundance of this beetle is variable. High densities can stunt plant height, though its overall impact to flowering and seed production is minimal at most sites. This beetle is more abundant on yellow toadflax, on which it can delay flowering and reduce seed production by 80–90% at some locations. However, its overall impact to yellow toadflax is still considered minimal.

Although common and abundant on yellow toadflax in Canada, *B. pulicarius*'s impact is surmised to be limited due to the persistence of yellow toadflax infestations. It is found sporadically on Dalmatian toadflax in Canada but appears to be too rare to have any major impact on seed production. In both countries, the impacts of *B. pulicarius* on hybrid toadflax have not yet been studied

NONTARGET EFFECTS

Adult *B. pulicarius* have been observed feeding on the pollen of many plant species, including dandelion, clovers, wild mustards, strawberry, apple, and dogwood. This feeding causes little to no impact.

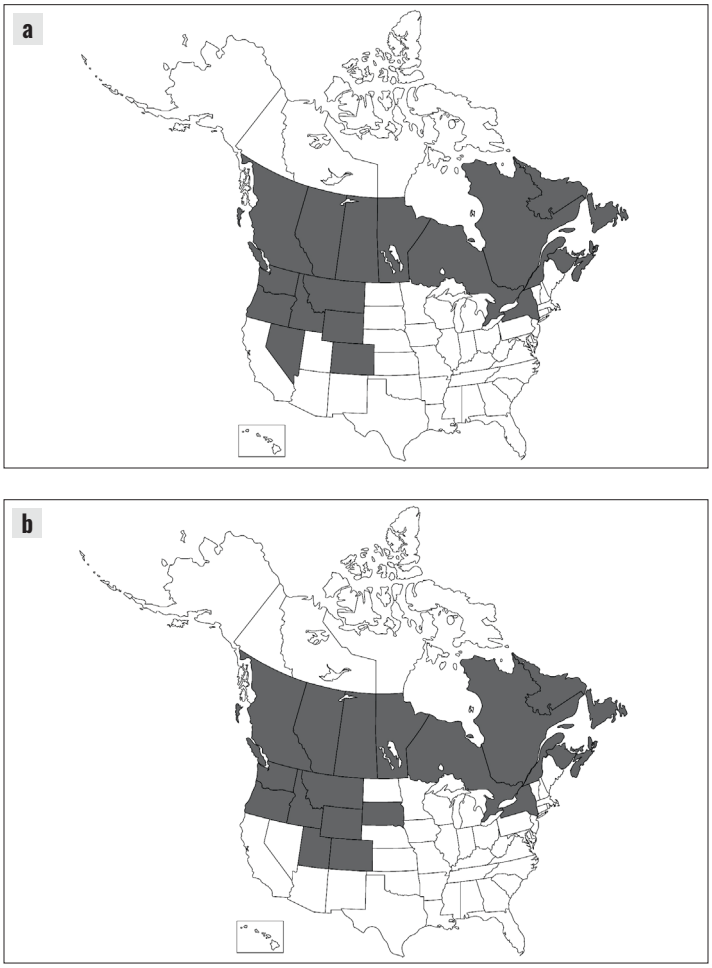

Figure 4. *Brachypterolus pulicarius* reported distribution on (a) Dalmatian toadflax and (b) yellow toadflax in North America (Winston et al. 2022). This beetle is more prevalent on yellow toadflax than Dalmatian toadflax and is anecdotally reported as established on yellow toadflax in other northeastern states in the USA not specified in the literature and not represented here.

Calophasia lunula
Toadflax defoliating moth

Calophasia lunula is a biological control agent approved in North America for release against toadflaxes.

CLASSIFICATION

RANKING	SCIENTIFIC NAME	COMMON NAME
Kingdom	Animalia	Animals
Phylum	Arthropoda	Arthropods
Class	Insecta	Insects
Order	Lepidoptera	Moths and butterflies
Family	Noctuidae	Owlet moths
Genus	*Calophasia*	
Species	*Calophasia lunula* (Hufnagel)	Toadflax defoliating moth

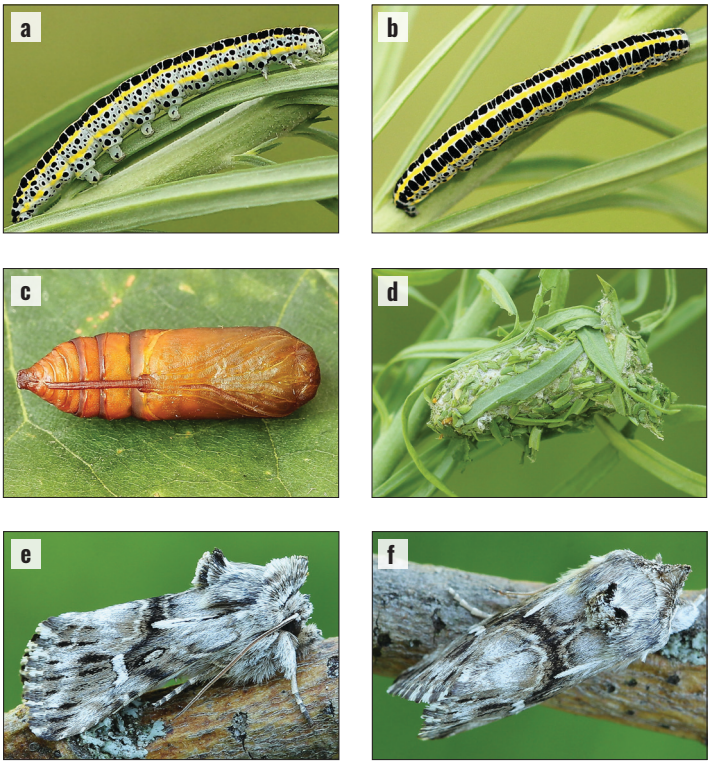

Figure 5. *Calophasia lunula* (a) late-instar larva from side; (b) late-instar larva from above; (c) pupa; (d) cocoon; (e) adult from side; (f) adult from above (a–f: Andrey Ponomarev, iNaturalist.org CC BY-NC 4.0)

DESCRIPTION

Eggs are pale yellow, strongly ribbed, and slightly conical. Larvae (caterpillars) are gray initially, but by the final instar, they are pale gray with vivid yellow stripes and black spots (**Fig. 5a,b**). Final instar larvae reach a maximum length of 4.6 cm. Pupae are reddish-brown (**Fig. 5c**) within green cocoons made of silk and chewed leaves (**Fig. 5d**). Adults are a mottled gray-brown with light and dark markings on the wings (**Fig. 5e,f**) and are 1–1½ cm long with a wingspan of 2½–3 cm.

LIFE CYCLE

Adult moths emerge in late spring (**Fig. 6**) and feed on the nectar of toadflaxes and other plant species. Females lay an average of 100 eggs singly on toadflax foliage and, less frequently, on toadflax flowers. Larvae feed on young, tender leaves but will consume older and tougher lower stem leaves as plants become increasingly defoliated (**Fig. 7**). Larvae nearing the end of the fifth instar move to the base of toadflax plants and spin cocoons of silk, chewed leaves, and soil (**Fig. 5d**) that they attach to stem bases, plant litter, or soil. There are 1–3 generations per year, depending on weather conditions and the length of the growing season. At northern latitudes and high elevations, 1–2 generations are most common; three may occur in warmer locales, at lower elevations, and in regions with longer growing seasons. The moth overwinters as a pupa within the cocoon (**Fig. 6**).

HOST SPECIES IN NORTH AMERICA

Dalmatian and yellow toadflax

DAMAGE

Severe defoliation of seedlings and one-year-old plants can be fatal. Older, larger plants can usually rebound from defoliation, although defoliated plants are less vigorous and

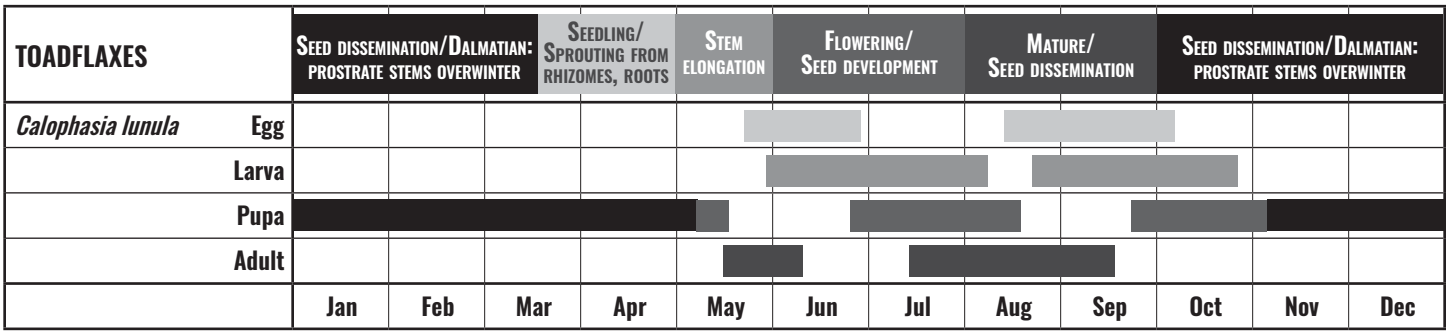

Figure 6. Schematic life cycle of *Calophasia lunula* and toadflaxes in North America. Bars indicate the approximate length of activity for each life stage; dates will vary depending on local conditions. Black bars represent the inactive and/or overwintering periods. There are 1–3 generations per year, but most frequently 1–2 in North America.

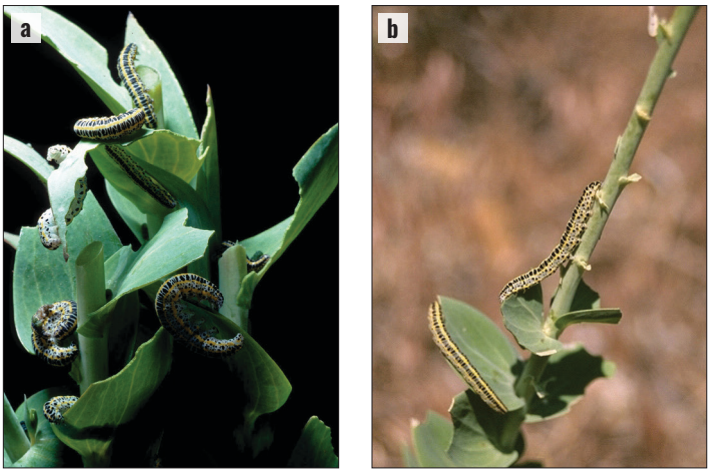

Figure 7. *Calophasia lunula* larvae on Dalmatian toadflax: (a) feeding on leaves; (b) defoliating a stem (a: Laura Parson, University of Idaho, Bugwood.org CC BY-3.0 US; b: Susan Turner, British Columbia Ministry of Forests, Bugwood.org CC BY-3.0 US)

may produce fewer flowers. Complete defoliation of an entire patch of toadflax by this moth has not been documented.

FIELD IDENTIFICATION

Where established, larvae can be observed feeding, often in groups, on toadflax foliage throughout summer and fall (**Fig. 7**). Their conspicuous coloration helps differentiate them from any other species. Because other insects sometimes feed on toadflax leaves and stems, in the absence of *C. lunula* larvae, defoliated plants are not confirmation the species is present.

PREFERRED HABITAT

This defoliating moth prefers warm, dry sites with coarse-textured soils. Establishment can be limited in cold climates, at northern latitudes, and at high elevations. Caterpillars are most often found in relatively sparse toadflax infestations.

HISTORY AND CURRENT STATUS

Calophasia lunula is native to Europe and Asia. Individuals from Switzerland were released in Canada beginning in 1962 on both Dalmatian toadflax and yellow toadflax. After limited establishment only in Ontario, individuals from the former Yugoslavia were released in Canada beginning in 1989. Both populations established. The progeny of moths that established from the Swiss release were later redistributed from Ontario to the USA in 1968 and were released on both Dalmatian and yellow toadflax in a handful of western states.

In the USA, this moth is established on both Dalmatian and yellow toadflax (**Fig. 8**). Although populations are generally limited throughout the USA, they are moderate in Idaho and abundant in Washington, and localized population explosions occasionally occur. Feeding by high densities of *C. lunula* larvae can cause substantial toadflax defoliation; however, complete defoliation of an entire toadflax patch has not been documented. Overall, larval feeding typically decreases leaf area but does not disrupt the photosynthetic capacity sufficiently to have a significant impact on attacked plants.

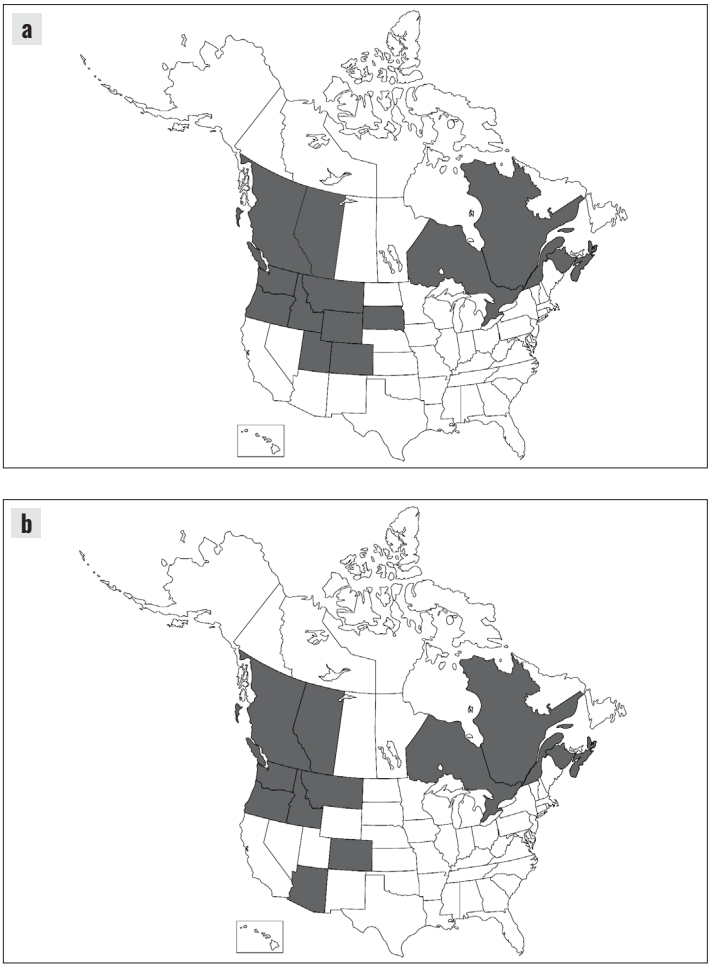

Figure 8. *Calophasia lunula* reported distribution on (a) Dalmatian toadflax and (b) yellow toadflax in North America (Winston et al. 2022; R. DeClerk-Floate, personal observation). Note: historical records for *C. lunula* in Canada lumped both toadflax species together, so this agent may only be established on one toadflax species in some provinces instead of both as reported in the maps.

In Canada, *C. lunula* is again established on both Dalmatian and yellow toadflax in southern regions (**Fig. 8**), but its spread north is limited by the colder climates, and its impact is limited for the same reasons as in the USA. Parasitism may also limit populations in some parts of Canada. The impacts of *C. lunula* on hybrid toadflax have not yet been studied in North America.

NONTARGET EFFECTS

Calophasia lunula caterpillars are known to feed and develop on plants related to toadflaxes, including non-native ornamentals and one native North American species, *Sairocarpus virga*. Because *C. lunula* poses a risk to nontarget plant species in the USA, some land managers have ceased collecting and redistributing this defoliating moth. **Caution should be taken during its redistribution, especially in areas with desirable snapdragon species present.**

Mecinus janthiniformis & *M. janthinus*
Toadflax stem-mining weevils

Mecinus janthiniformis & *M. janthinus* are closely related biological control agents approved in North America for release against toadflaxes.

CLASSIFICATION

RANKING	SCIENTIFIC NAME	COMMON NAME
Kingdom	Animalia	Animals
Phylum	Arthropoda	Arthropods
Class	Insecta	Insects
Order	Coleoptera	Beetles
Family	Curculionidae	Weevils
Genus	*Mecinus*	
Species	*Mecinus janthiniformis* Toševski & Caldara *Mecinus janthinus* Germar	Dalmatian toadflax stem-mining weevil Yellow toadflax stem-mining weevil

DESCRIPTION

These species are morphologically very similar. Eggs are white and oval-shaped. Larvae are C-shaped, creamy-white with brown head capsules, and are up to 5 mm long (**Fig. 9a**). Pupae are typically creamy white with conspicuous appendages and a long snout (**Fig. 9b**). Adults are bluish-black (rarely greenish-black), elongated, and have long snouts and elbowed antennae (**Fig. 9c,d**). Newly emerged adults may have a subtle metallic sheen that becomes more dull black with age. *Mecinus janthinus* adults are smaller (2.4–3.4 mm vs. 3.2–6.0 mm long), and their snouts are less abruptly curved than *M. janthiniformis*. Otherwise, these two species are nearly identical.

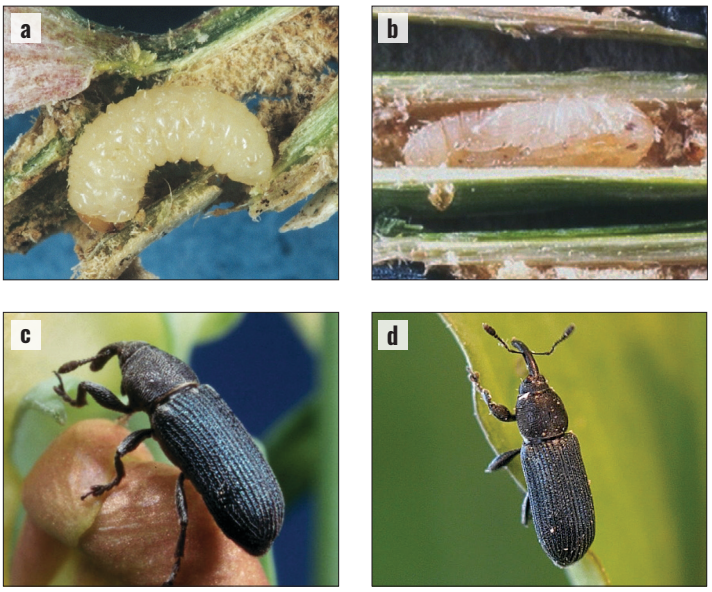

Figure 9. *Mecinus* spp. (a) larva; (b) pupa; (c,d) adults (a: Rosemarie De Clerck-Floate, Agriculture and Agri-Food Canada; b,c: Bob Richard, USDA APHIS PPQ [a–c Bugwood.org CC BY-3.0 US; d: Travis McMahon, MIA Consulting)

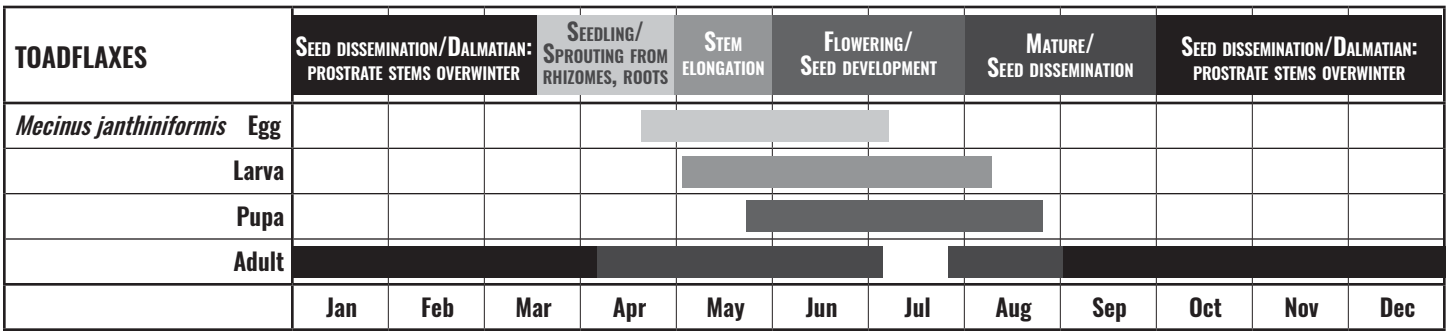

Figure 10. Schematic life cycle of *Mecinus janthiniformis* and toadflaxes in North America. Bars indicate the approximate length of activity for each life stage; dates will vary depending on local conditions. Black bars represent the inactive and/or overwintering periods. There is typically one generation per year.

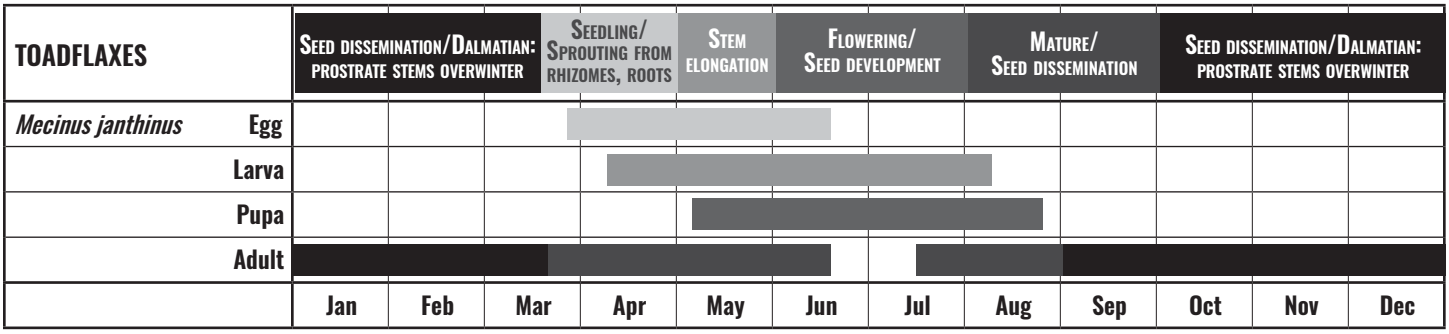

Figure 11. Schematic life cycle of *Mecinus janthinus* and toadflaxes in North America. Bars indicate the approximate length of activity for each life stage; dates will vary depending on local conditions. Black bars represent the inactive and/or overwintering periods. There is typically one generation per year.

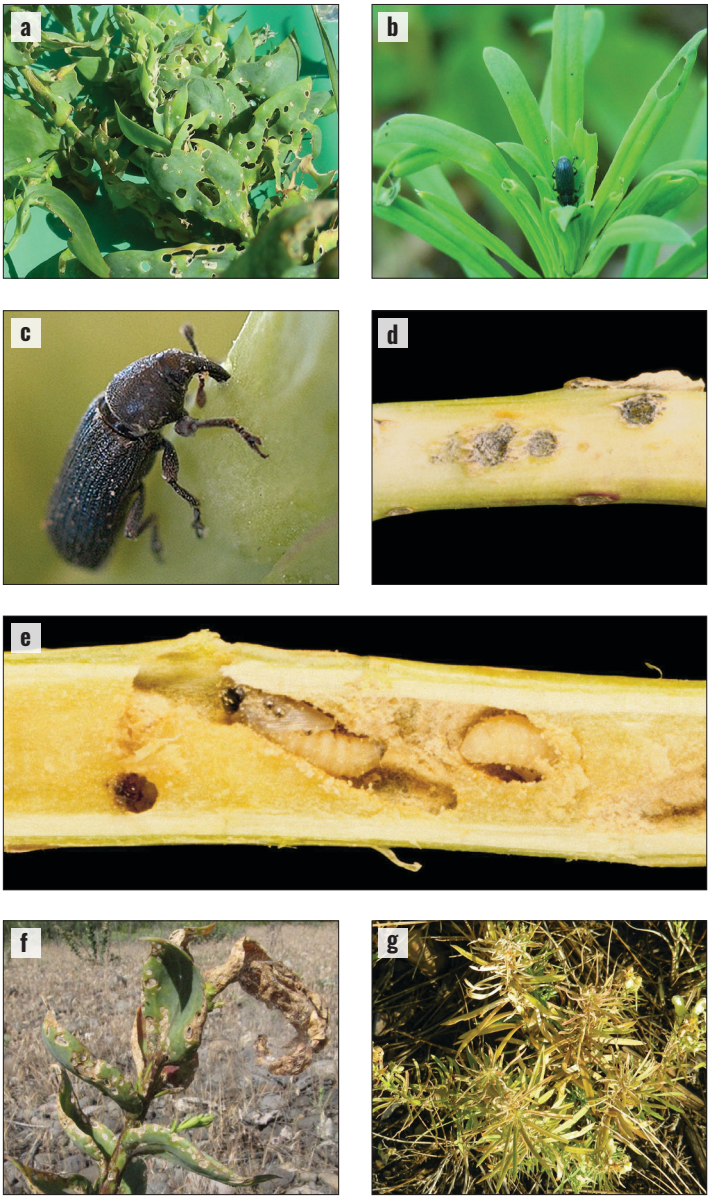

Figure 12. *Mecinus* spp. (a) adult feeding damage to Dalmatian toadflax; (b) adult feeding damage to yellow toadflax; (c) adult chewing an oviposition hole; (d) oviposition scars; (e) larva, pupa, and larval mines; (f) damage to Dalmatian toadflax; (g) yellow toadflax stems dying from larval mining (a,b,g: Sharlene E. Sing, USDA Forest Service RMRS; c: Travis McMahon, MIA Consulting; d,e: Laura Parsons, University of Idaho, Bugwood.org CC BY-3.0 US; f: Jennifer Andreas, Washington State University Extension)

LIFE CYCLE

Adults emerge from overwintering within the previous year's toadflax stems in early spring and immediately begin feeding on new toadflax shoot tips. In the native range, *Mecinus janthinus* emerges a few weeks earlier than *M. janthiniformis* (**Fig. 10,11**). The timing of spring emergence of adult weevils in North America varies significantly due to the influence of site-specific characteristics such as latitude, elevation, aspect, and residual snow cover. Adult feeding on toadflax shoot tips and leaves produces a distinctive shot hole injury pattern, which tends to be more conspicuous on Dalmatian toadflax (**Fig. 12a,b**). Females chew holes into toadflax stems and lay eggs singly (60–160 in a lifetime under lab conditions), covering eggs with chewed plant tissue (**Fig. 12c,d**). Larvae feed through three instars in short tunnels chewed inside the toadflax stems (**Fig. 12e**). *Mecinus janthinus* tends to mine lower in toadflax stems than *M. janthiniformis*. Pupation occurs in mid-summer in chambers located in the larval feeding tunnels. Development to adulthood occurs by late summer, with adults overwintering inside the pupal chambers. There is one generation per year, with all development from egg deposition to adult emergence the following spring taking place in the same toadflax stem.

HOST SPECIES IN NORTH AMERICA

Mecinus janthiniformis prefers Dalmatian toadflax, and *M. janthinus* prefers yellow toadflax.

DAMAGE

Adult weevils consume/chew on the growing tips of toadflax shoots, stems, and leaves, producing a distinctive shot hole injury pattern (**Fig. 12a,b**). This damage weakens the plant, can suppress flowering and seed production, and severely stunts shoots. Large aggregations of *M. janthiniformis* adults feeding on new toadflax shoot growth can result in significant injury to shoot tips and leaves; heavily attacked shoot tips may turn brown and shrivel (**Fig. 12f**). Larval mining (**Fig. 12d**) severs water/nutrient-conducting tissues, causing desiccation and death (**Fig. 12g**). Larval feeding also likely depletes nutrient reserves in the roots, which is important for the year-to-year persistence of individual plants. Repeated, yearly attack by both adults and larvae can lead to striking reductions in toadflax plant density.

FIELD IDENTIFICATION

Adults may be observed on toadflax stems and leaves throughout spring and early summer. Because larvae feed completely within stems, they can be difficult to detect unless stems are dissected (**Fig. 12e**). Toadflax stems infested with *Mecinus* spp. can often be readily broken off at points where larval feeding inside has weakened the stems. At least six other beetle species are established on toadflaxes in North America. *Mecinus* spp. can be differentiated from the other toadflax weevil species by their elongated shape, compared to the more rounded bodies of *Rhinusa* spp. Adult *Brachypterolus pulicarius* do not have the snouts of the *Mecinus* and *Rhinusa* weevils (**Table 1**).

PREFERRED HABITAT

Mecinus janthiniformis is well adapted to a variety of environmental conditions and can be found on many Dalmatian toadflax infestations in North America. The overwintering of adults within dead Dalmatian toadflax stems, which typically stand above snow cover, exposes

the weevils to extremes in fluctuating ambient temperature and humidity. Adult mortality can reach 75–100% where temperatures drop lower than -18.5°F (-28°C); however, affected populations can rebound over time. *Mecinus janthinus* prefers milder, low-elevation sites in its native range compared to *M. janthiniformis*. The North American distribution and habitat preferences of *M. janthinus* are still being determined; however, successful yellow toadflax biological control with *M. janthinus* has been observed at elevations above 7,000 ft (2,180 m), and establishment so far has been confirmed at latitudes of up to 53.5°N in central Alberta, Canada.

HISTORY AND CURRENT STATUS

What was originally released in the USA and Canada as *Mecinus janthinus* was recently discovered to be a mixture of *M. janthinus* and the closely related *M. janthiniformis*. The true *M. janthinus* is native to Europe and Asia and individuals sourced from France and Germany were released in 1991 on Dalmatian and yellow toadflax in Canada. Established individuals were redistributed to Dalmatian and yellow toadflax in the USA beginning in 1996. *Mecinus janthiniformis* is native to southeastern Europe, and individuals were reportedly introduced from the Republic of Macedonia and released in Canada on Dalmatian toadflax in 1992 and then redistributed to yellow toadflax in 2000. Redistributions of *M. janthiniformis* were made from Canada to both Dalmatian and yellow toadflax in the USA post 1996 in mixes with the true *M. janthinus*. Most of these redistributions were made in western states.

Field surveys and lab-based experiments have determined that *M. janthiniformis* prefers Dalmatian toadflax. *Mecinus janthiniformis* is currently established in northwestern North America (**Fig. 13a**) where it has reduced Dalmatian toadflax populations dramatically at some locations. Surveys and studies have similarly found that *M. janthinus* prefers yellow toadflax. *Mecinus janthinus* was initially slower to establish, especially at sites with short growing seasons and heavy persistent snow. However, at other sites, this species is becoming widespread, having a high impact on yellow toadflax locally (**Fig. 13b**), and appears to be establishing well in new areas. The impacts of *Mecinus* spp. on hybrid toadflax have not yet been fully determined.

NONTARGET EFFECTS

None reported

COMMENTS

Mecinus spp. weevils are strong fliers and can easily disperse throughout toadflax-infested areas. Dalmatian toadflax has live prostrate stems that persist even under snow over winter, providing a food supply and little incentive for newly emerged adult *M. janthiniformis* to disperse in spring. Because there is no equivalent overwintering rosette produced by yellow toadflax, adult *M. janthinus* emerging in spring are left marooned without a food supply and readily disperse to seek out host plants.

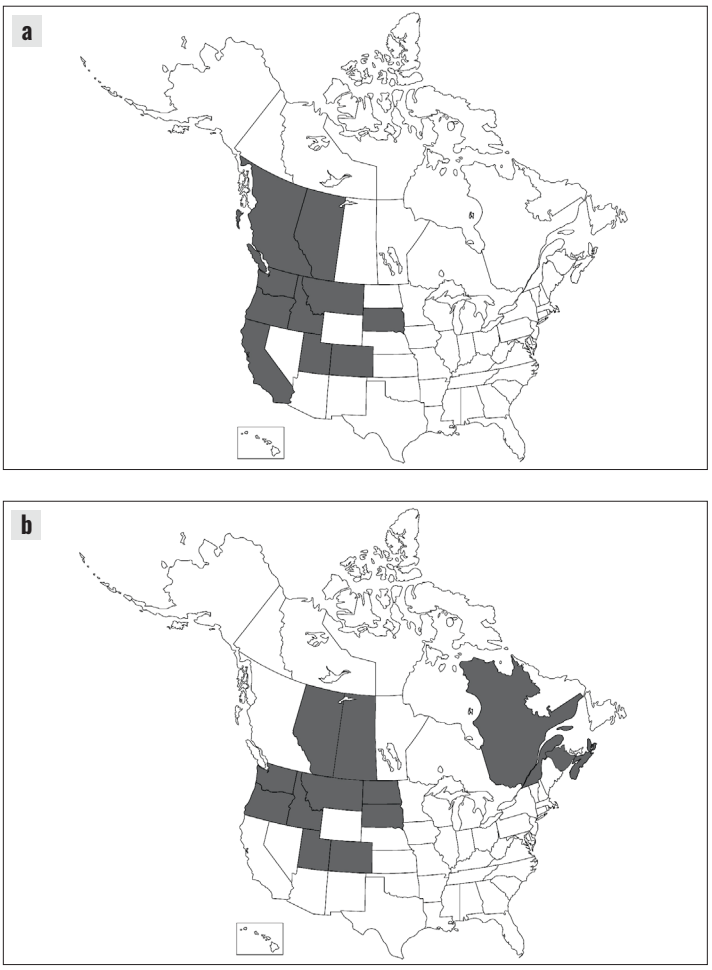

Figure 13. North American reported establishment of (a) *Mecinus janthiniformis* on Dalmatian toadflax; (b) *Mecinus janthinus* on yellow toadflax; Note: because the identification of *M. janthiniformis* has only recently been made, sorting the establishment status of each *Mecinus* species on the two toadflax species is a work in progress in North America (Winston et al. 2022, R. De Clerck-Floate unpub. data).

Rhinusa antirrhini & *R. dieckmanni*

Toadflax seed-galling weevils

Rhinusa antirrhini is a biological control agent approved in North America for release against toadflaxes. *Rhinusa dieckmanni* is a closely related Dalmatian toadflax seed-galling weevil also present and likely approved for release in North America as a Dalmatian toadflax-adapted strain or biotype of *R. antirrhini*.

SYNONYMS

***Rhinusa antirrhini*:** *Gymnetron antirrhini* (Paykull)

CLASSIFICATION

RANKING	SCIENTIFIC NAME	COMMON NAME
Kingdom	Animalia	Animals
Phylum	Arthropoda	Arthropods
Class	Insecta	Insects
Order	Coleoptera	Beetles
Family	Curculionidae	Weevils
Genus	*Rhinusa*	
Species	*Rhinusa antirrhini* (Paykull) *Rhinusa dieckmanni* (Behne)	Yellow toadflax seed-galling weevil Dalmatian toadflax seed-galling weevil

DESCRIPTION

These species are morphologically very similar. The eggs are oval and flattened. Larvae are C-shaped, creamy yellow with dark brown head capsules, and are up to 4 mm long (**Fig. 14a**). Pupae are dark gray, typically 2½ mm long, and have two tiny 'horns' protruding from the top of the thorax (see arrow in **Fig. 14b**). Adults are gray to black and covered in dense, short hairs (**Fig. 14c**). They have a long, distinctly curved, and pointed snout and a wide body (**Fig. 14d**). Adults collected from yellow toadflax, likely *Rhinusa antirrhini*, are typically 2½–3 mm long, while those developing on Dalmatian toadflax, *likely R. dieckmanni*, are up to 5 mm long.

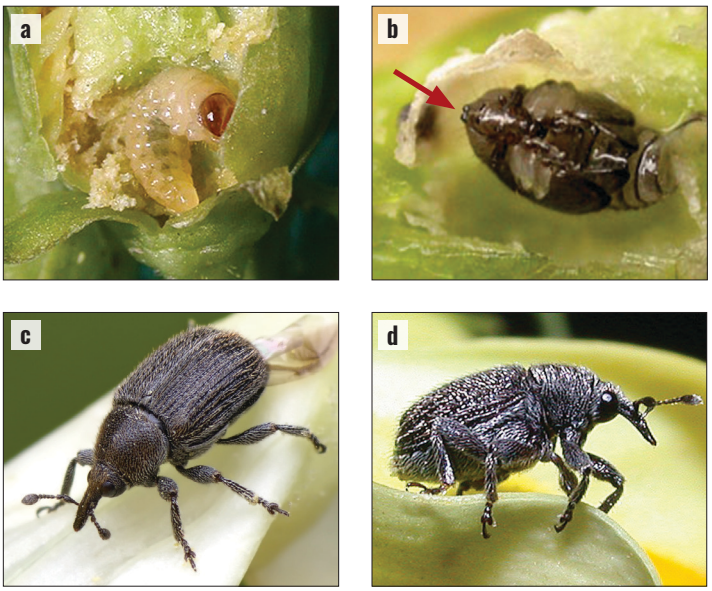

Figure 14. *Rhinusa antirrhini* (a) larva feeding within a seed capsule; (b) pupa, arrow points to "horns" on top of the thorax; (c,d) adult (a,d: Ivo Toševski, CABI Switzerland; b: © Arnold Grosscurt CC BY-NC-SA 4.0; c: Иван Тисленко, iNaturalist.org CC BY-NC 4.0)

LIFE CYCLE

Overwintering adults emerge in late spring and feed on toadflax shoot tips, leaf buds, and young leaves. As toadflax flowers open, adults feed on pollen and flower tissue. Females lay 40–50 eggs singly inside flower ovaries; this oviposition triggers the development of galls of enlarged seed tissue. Larvae feed on the modified seed tissue through three instars. Pupation occurs within seed capsules, with adults emerging in late summer or early fall (**Fig. 15**) to overwinter in plant litter. There is one generation per year.

HOST SPECIES IN NORTH AMERICA

Rhinusa antirrhini prefers yellow toadflax, and *R. dieckmanni* prefers Dalmatian toadflax.

DAMAGE

Adult feeding (**Fig. 16a**) on toadflax foliage and flowers is typically insignificant. Female's egg deposition triggers the development of a spur (bump) on the seed capsule (see red arrow, **Fig. 16b**). The growing spur pushes the egg into the developing toadflax seeds, triggering the formation of a gall. The gall causes the 8–17 seeds closest to the egg to grow up to 10 times their normal size and turn a watery, pale yellow color. As a result, attacked capsules can be easily identified (**Fig. 16c**). Abnormal seeds are not viable, and larval feeding destroys additional seeds within attacked capsules. Decreasing seed output does not kill existing plants but can help reduce the rate of spread and genetic diversity of toadflax populations.

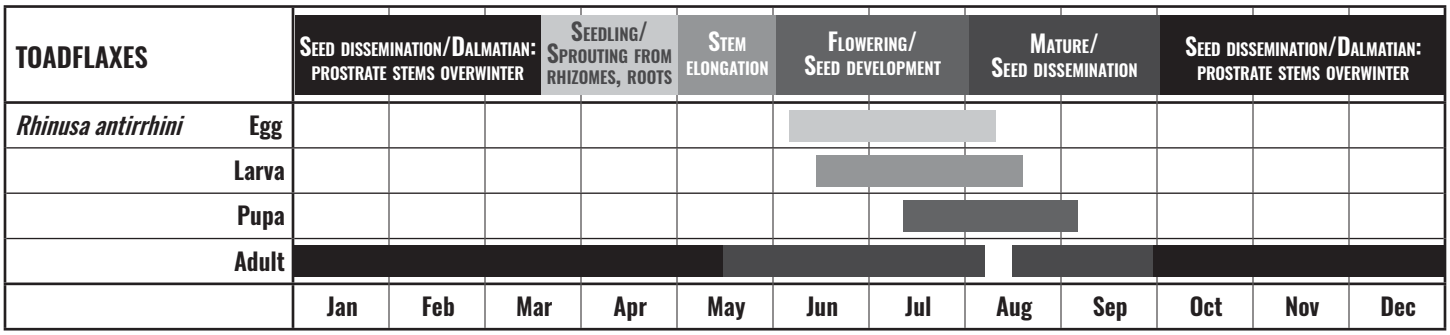

Figure 15. Schematic life cycle of *Rhinusa antirrhini* and toadflaxes in North America. Bars indicate the approximate length of activity for each life stage; dates will vary depending on local conditions. Black bars represent the inactive and/or overwintering periods. There is typically one generation per year. *Rhinusa dieckmanni*'s presence in North America as a separate species and not only a biotype of *R. antirrhini* has only been recently confirmed; life cycle details therefore have not yet been characterized.

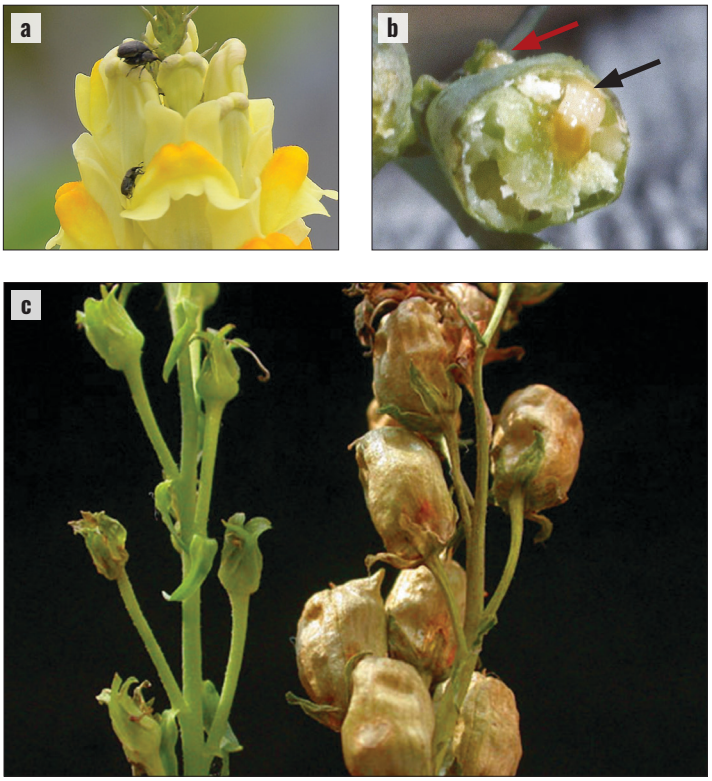

Figure 16. *Rhinusa antirrhini* (a) adults on yellow toadflax flowers; (b) larva in seed capsule, red arrow points to "spur" while black arrow points to the larva; (c) normal, unattacked seed capsules (left) and galled, swollen seed capsules of attacked yellow toadflax (right) (a: Mark Olivier, iNaturalist.org CC BY-NC 4.0; b: Eric Coombs, Oregon Department of Agriculture, Bugwood.org CC BY-3.0 US; c: © Arnold Grosscurt CC BY-NC-SA 4.0)

FIELD IDENTIFICATION

Adults may be observed feeding on toadflax shoots, leaves, and flowers throughout the growing season (**Fig. 16a**). Because larvae feed completely within seed capsules, they aren't visible to the eye unless the capsule is dissected (**Fig. 16b**). However, their feeding causes seeds to swell to 10 times their normal size, resulting in large, swollen seed capsules (**Fig. 16c**) that can be readily identified. At least six other beetle species are established on toadflaxes in North America (**Table 1**). The closely related and unintentionally introduced *Rhinusa neta* also feeds on toadflax seeds. *Rhinusa antirrhini /R. dieckmanni* differ in that their pupae have tiny "horns" that are more pronounced (**Fig. 14b**) than the small bumps on *R. neta*. Adult *R. antirrhini/R. dieckmanni* have a more pointed and curved snout than *R. neta* and are dark grayish-black (**Fig. 14c,d**) while *R. neta* adults are a lighter gray to brown (**Fig. 27**). *Rhinusa antirrhini/R. dieckmanni* and *R. neta* differ from *R. linariae* and *R. pilosa* in their location of attack. *Rhinusa antirrhini/R. dieckmanni* and *R. neta* adults feed on flowers and shoot tips and larvae feed on seeds. *Rhinusa linariae* adults feed on stems and larvae feed internally on root tissues that have been modified through galling. Similarly, *R. pilosa* adults feed externally on stems, but their larvae feed internally on modified (galled) stem tissues. *Mecinus* spp. adults have more elongated bodies compared to *Rhinusa* spp. Adult *Brachypterolus pulicarius* do not have the snouts of the *Mecinus* and *Rhinusa* weevils (**Table 1**).

PREFERRED HABITAT

The habitat preferences of *R. antirrhini/R. dieckmanni* are unknown. *Rhinusa antirrhini* is distributed throughout most yellow toadflax infestations in North America, indicating it is well adapted to a variety of conditions. The distribution of *R. dieckmanni* in North America is unknown at this time, but it appears to be strongly host-specific on Dalmatian toadflax.

HISTORY AND CURRENT STATUS

Rhinusa antirrhini is native to Europe, Asia, and the Mediterranean. It was unintentionally introduced to North America and was first documented on yellow toadflax in the eastern USA in 1909 and in eastern Canada by 1917. It spread naturally and via intentional redistributions throughout the

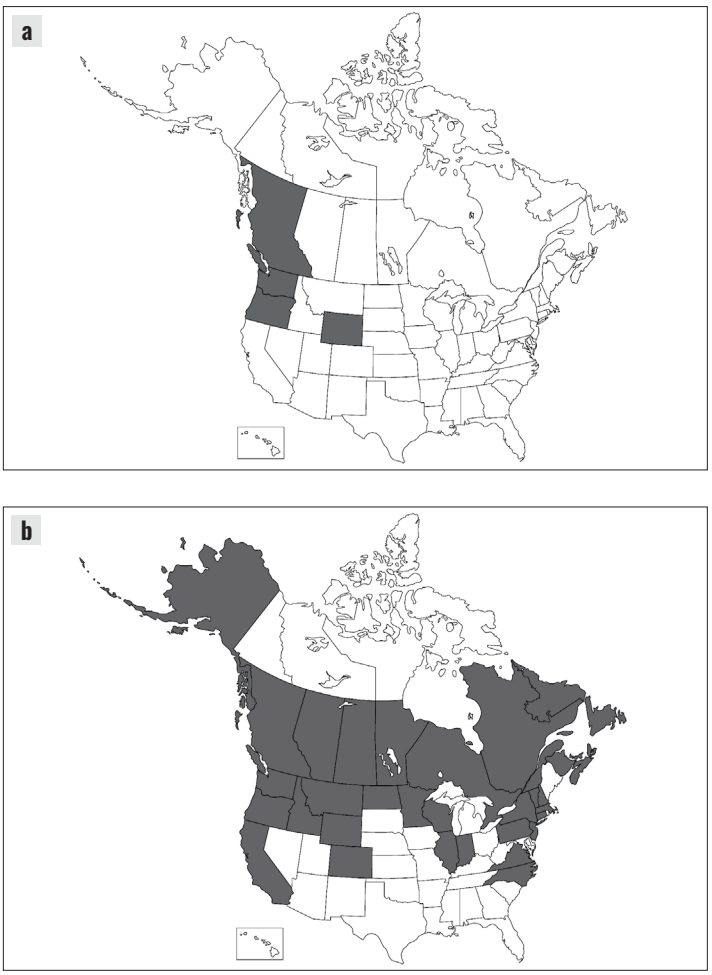

Figure 17. *Rhinusa antirrhini* reported distribution on (a) Dalmatian toadflax and (b) yellow toadflax in North America (Winston et al. 2022). This beetle is more prevalent on yellow toadflax than Dalmatian toadflax and is anecdotally reported as established on yellow toadflax in other northeastern states in the USA not specified in the literature and not represented here. It has yet to be fully assessed for current distribution within Canada. The distribution of *R. dieckmanni* in North America is unknown at this time.

USA and Canada on both yellow and Dalmatian toadflax. An additional strain thought to be of *R. antirrhini* was intentionally introduced from the former Yugoslavia and released on Dalmatian toadflax in western Canada in 1993 and the western USA in 1996. This is the likely source of *R. dieckmanni* recently confirmed to be established on Dalmatian toadflax in southwestern Montana.

These weevils are established on both Dalmatian and yellow toadflax in the USA and Canada (**Fig. 17a,b**), although they are most abundant on yellow toadflax. Impacts on Dalmatian toadflax and hybrid toadflax have largely not been studied. On yellow toadflax in the USA, larval feeding destroys some seeds in attacked capsules, and seed reductions between 85 and 90% have been reported in Washington; however, seed reduction is typically much lower. Attack rates from 30 to 40% in Oregon had minimal impacts on plant density. In Canada, widespread distribution of *R. antirrhini* has yet to lead to satisfactory control of yellow toadflax, and although the weevils are becoming more widespread on Dalmatian toadflax, their impact on that species is also likely limited. Competition between *Rhinusa antirrhini/R. dieckmanni* and *Brachypterolus pulicarius* prevents these species from having an additive impact in many locations.

NONTARGET EFFECTS

None reported

Rhinusa linariae
Toadflax root-galling weevil

Rhinusa linariae is a biological control agent approved in North America for release against toadflaxes.

SYNONYMS

Gymnetron linariae Panzer

CLASSIFICATION

RANKING	SCIENTIFIC NAME	COMMON NAME
Kingdom	Animalia	Animals
Phylum	Arthropoda	Arthropods
Class	Insecta	Insects
Order	Coleoptera	Beetles
Family	Curculionidae	Weevils
Genus	*Rhinusa*	
Species	*Rhinusa linariae* Panzer	Toadflax root-galling weevil

DESCRIPTION

Eggs are pale yellow, smooth surfaced, and pear-shaped (**Fig. 18a**). Larvae are C-shaped, creamy white with brown head capsules, and up to 4 mm long. Pupae are dark gray and typically 2½ mm long. Adults are small and black with pronounced, curved snouts (**Fig. 18b**). They are covered in dense, short hairs and are up to 2½ mm long.

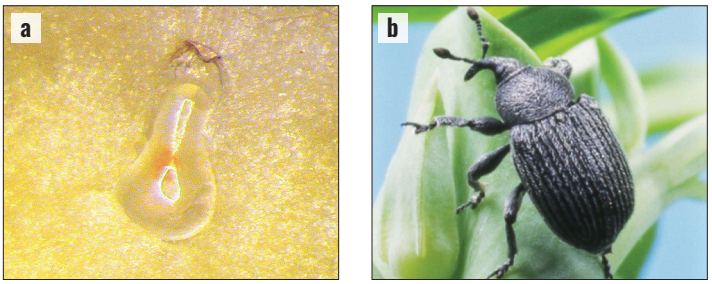

Figure 18. *Rhinusa linariae* (a) egg within a root gall; (b) adult (a: Ivo Toševski, CABI Switzerland; b: Bob Richard, USDA APHIS PPQ, Bugwood.org CC BY-3.0 US)

LIFE CYCLE

Overwintering adults emerge in spring (**Fig. 19**) and feed on new toadflax shoots, consuming stem tissues. Females lay eggs singly into pockets chewed into toadflax roots and root crowns, triggering gall formation (**Fig. 20**). Larvae feed on galled root tissue through three instars. Pupation occurs in galls with new adults emerging in mid- to late summer. Adults often feed briefly on toadflax stems and then overwinter in soil or plant litter. Some new, fully developed adults remain within the root galls throughout the fall and winter, and do not emerge until the following spring. There is one generation per year.

HOST SPECIES IN NORTH AMERICA

Confirmed established only on yellow toadflax to date.

DAMAGE

In European field studies, between 20 and 100 galls per plant were found on the roots of attacked yellow toadflax. Adjacent individual root galls can fuse into gall complexes comprised of up to 40 individual galls (**Fig. 20a,b**). Root galls disrupt the transport of nutrients and water to and from the roots. Root galls may also act as a metabolic sink, directing root nutrients to the developing galls and ultimately to the *R. linariae* larvae that feed on the gall tissues, thereby robbing the toadflax plant of essential nutrients for normal plant growth. Adult feeding also decreases nutrient reserves, though the overall impact of adults has not been formally studied.

FIELD IDENTIFICATION

Adults may be observed feeding on new toadflax shoots in spring and early summer. Larval presence can be confirmed by observing the formation of galls on toadflax roots (**Fig.**

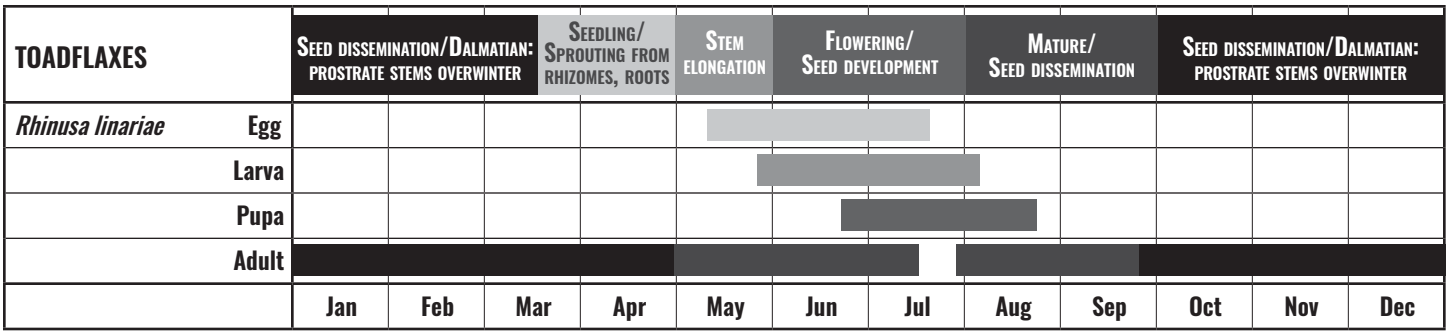

Figure 19. Schematic life cycle of *Rhinusa linariae* and toadflaxes in North America. Bars indicate the approximate length of activity for each life stage; dates will vary depending on local conditions. Black bars represent the overwintering periods. There is typically one generation per year.

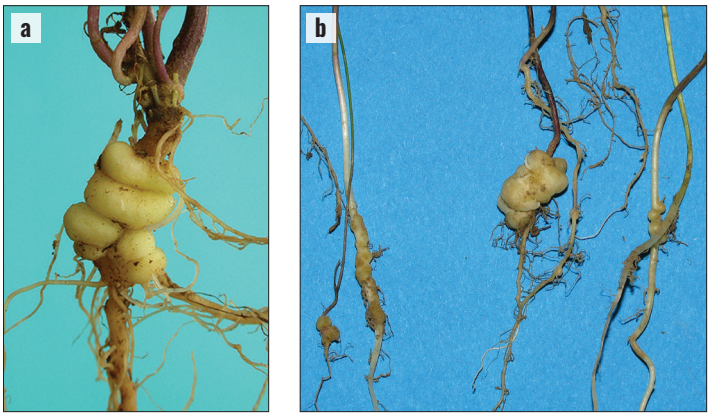

Figure 20. *Rhinusa linariae* galls on yellow toadflax roots (a,b: Ivo Toševski, CABI Switzerland)

20). At least seven other beetle species are established on toadflaxes in North America (**Table 1**). Adult *R. linariae* have short, dense hair on their bodies while *R. pilosa* have longer, upright hairs (**Fig. 22b,c**). *Rhinusa linariae* can be differentiated from the other toadflax *Rhinusa* beetles by the location of attack on host plants. *Rhinusa linariae* adults attack toadflax stems, and their larvae attack the roots; *R. antirrhini/R. dieckmanni* and *R. neta* adults attack toadflax flowers and shoot tips, and their larvae attack the seeds. In addition, *R. linariae* has a more pointed and curved snout than *R. neta* and is black while *R. neta* is gray to brown (**Fig. 27**). *Mecinus* spp. adults have more elongated bodies compared to *Rhinusa* spp. Adult *Brachypterolus pulicarius* do not have the snouts of the *Mecinus* and *Rhinusa* weevils (**Table 1**).

PREFERRED HABITAT

The overall habitat preferences of *R. linariae* in North America are unknown because confirmed established populations are restricted to limited sites in British Columbia. In Europe, *R. linariae* does well in grassland habitats, is rarely found in subalpine habitats, and is absent from alpine zones.

HISTORY AND CURRENT STATUS

Rhinusa linariae is native to Europe. In the USA, individuals sourced from Germany were released on Dalmatian and yellow toadflax in western states beginning in 1996, but these failed to establish. Populations from central and southern Europe and southern Russia were released on both Dalmatian and yellow toadflax in western Canada beginning in 1996, and these successfully established on yellow toadflax (**Fig. 21**). In British Columbia, *R. linariae* populations are slow to build, so redistributions are made every 2–4 years. Though this weevil is only moderately widespread, where it is established its populations are high and have heavy impact locally. After the original USA introductions failed, weevils established in British Columbia were redistributed to yellow toadflax in the western USA in 2008 and again in 2015. The 2008 releases failed to establish, but yellow toadflax plants in the area where weevils were released in 2015 produced root galls in 2016. No root galls or *R. linariae* were observed during a systematic survey at the same site in 2019, although *Mecinus janthinus* and yellow toadflax plants were present. Field establishment in the USA can therefore not be confirmed.

NONTARGET EFFECTS

None reported

Figure 21. *Rhinusa linariae* reported distribution on yellow toadflax in North America (Winston et al. 2022). This beetle failed to establish on Dalmatian toadflax in North America.

Rhinusa pilosa
Yellow toadflax stem-galling weevil

Rhinusa pilosa is a biological control agent approved in North America for release against yellow toadflax.

CLASSIFICATION

RANKING	SCIENTIFIC NAME	COMMON NAME
Kingdom	Animalia	Animals
Phylum	Arthropoda	Arthropods
Class	Insecta	Insects
Order	Coleoptera	Beetles
Family	Curculionidae	Weevils
Genus	*Rhinusa*	
Species	*Rhinusa pilosa* (Gyllenhal)	Yellow toadflax stem-galling weevil

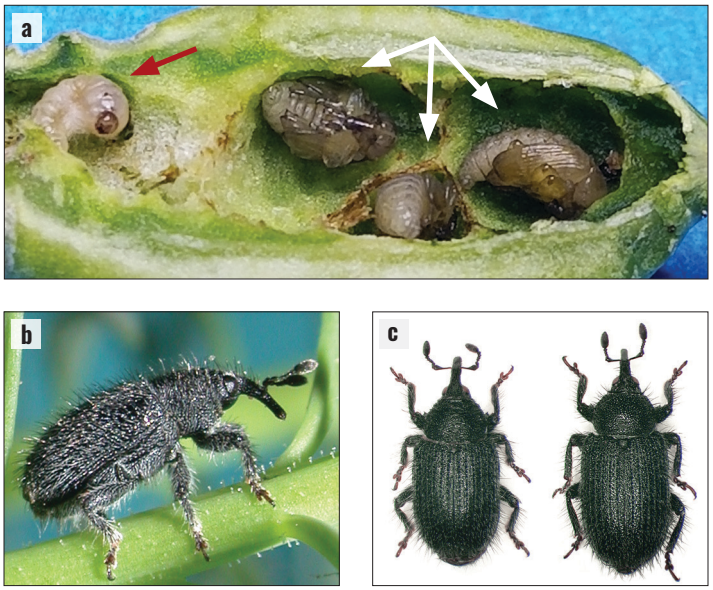

Figure 22. *Rhinusa pilosa* (a) larva (red arrow) and pupae (white arrows); (b) adult on yellow toadflax; (c) adult male (left) and adult female (right) (a: Rose DeClerck-Floate, AAFC; b,c: Ivo Toševski, CABI Switzerland)

DESCRIPTION

Eggs are very small, 0.36 mm in diameter, greenish-white in color, and round in shape. Larvae are C-shaped and creamy white with brown head capsules (**Fig. 22a**, red arrow). Adults are black, 4.3–5.5 mm long, and covered in upright hairs (**Fig. 22b,c**). They have a distinctive curved profile, and the snout gives this weevil its characteristic hook-nosed appearance.

LIFE CYCLE

Overwintered adults emerge in early spring (**Fig. 23**). Females lay eggs in actively growing tips of yellow toadflax stems, triggering the formation of conspicuous stem galls that typically house several larvae inside (**Fig. 24**). Larvae feed on nutrient-rich inner gall tissues through three instars before pupating, also within the gall. New adults remain in the gall for a period of time in early summer-mid fall and feed on remnant gall tissues before chewing their way through the gall wall to exit. Feeding continues on host shoots for a brief period before adults move to the soil where they become inactive. Once temperatures cool consistently in late autumn, adults feed extensively on toadflax re-growth before overwintering in soil or plant litter. There is one generation per year.

HOST SPECIES IN NORTH AMERICA

Yellow toadflax

DAMAGE

Growth of *R. pilosa*'s large, fleshy stem galls (**Fig. 24**) diverts nutrients and water needed for normal plant growth and reproduction to feed its developing offspring. In this way, *R. pilosa* stunts vegetative (shoot) growth, reduces reproductive output, and generally impairs the invasiveness of yellow toadflax.

FIELD IDENTIFICATION

Adults may be observed feeding on new toadflax shoots in spring and early summer and on toadflax re-growth in late summer. The presence of egg-laying female weevils can be

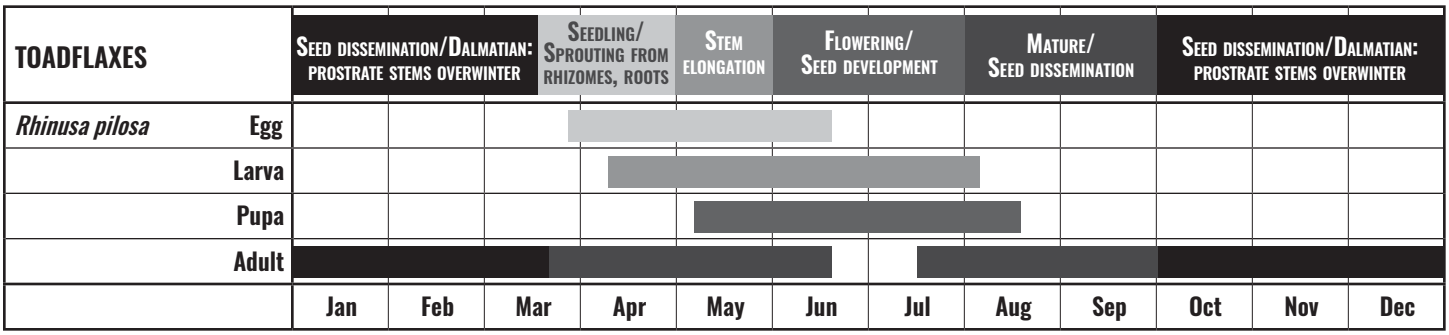

Figure 23. Schematic life cycle of *Rhinusa pilosa* and toadflaxes in North America. Bars indicate the approximate length of activity for each life stage; dates will vary depending on local conditions. Black bars represent the overwintering periods. There is typically one generation per year.

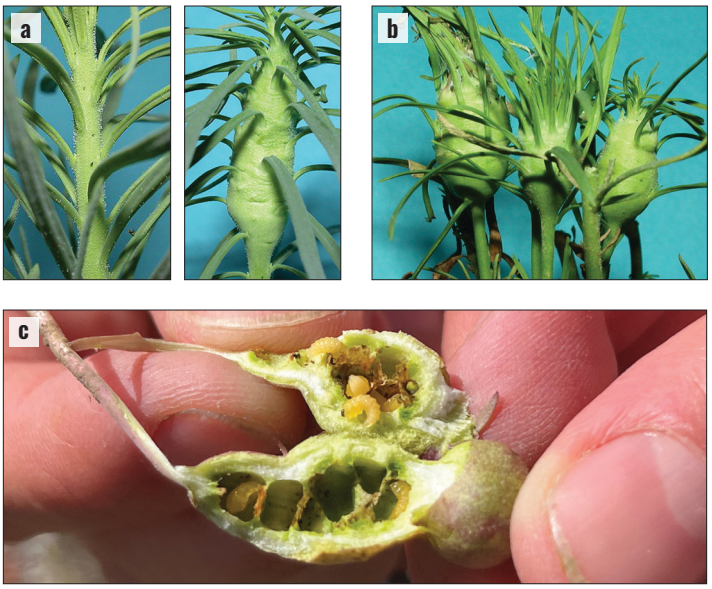

Figure 24. *Rhinusa pilosa* galls (a) devlopment over one week (oviposition at left, 7 days later at right); (b) mature galls; (c) mature gall dissected to reveal *R. pilosa* larvae feeding inside (a,b: Ivo Toševski, CABI Switzerland; c: Rose DeClerk-Floate, AAFC)

confirmed by the formation of galls on toadflax stems (**Fig. 24**). Because gall production is stimulated by deposition of oviposition fluid in the stem, which can occur without the insertion of an egg, not all galls contain developing larvae. At least seven other beetle species are established on toadflaxes in North America (**Table 1**). Adult *R. pilosa* have longer, upright hairs on their bodies (**Fig. 22b,c**) while *R. linariae* have short, dense hairs (**Fig. 18b**). *Rhinusa pilosa* can be differentiated from the other toadflax *Rhinusa* beetles by the location of attack on host plants. *Rhinusa pilosa* adults and larvae attack toadflax stems; *R. antirrhini/R. dieckmanni* and *R. neta* adults attack toadflax flowers and shoot tips, and their larvae attack the seeds. In addition, *R. pilosa* has a more pointed and curved snout than *R. neta* and is black while *R. neta* is gray to brown (**Fig. 27**). *Mecinus* spp. adults have more elongated bodies compared to *Rhinusa* spp. Adult *Brachypterolus pulicarius* do not have the snouts of the *Mecinus* and *Rhinusa* weevils (**Table 1**).

PREFERRED HABITAT

Initial releases made at sites across Canada have established best in western regions (**Fig. 25**). There are also early indications that the weevil may prefer higher elevations and moist habitats. In its native Europe, this weevil does well in a variety of habitats throughout the range of yellow toadflax.

HISTORY AND CURRENT STATUS

Rhinusa pilosa is native to Europe. Individuals from Serbia were released on yellow toadflax in Canada beginning in 2014 and in Montana, USA beginning in 2019, with Oregon and South Dakota receiving shipments in 2021 and Idaho and Wyoming in late 2022. As this weevil was only recently confirmed established in Canada (**Fig. 25**), it is still too early post release to determine its overall abundance and impact. In 2022 in the USA, weevils were confirmed to have successfully overwintered and produced abundant galls at multiple sites in Montana, and early results in South Dakota are encouraging.

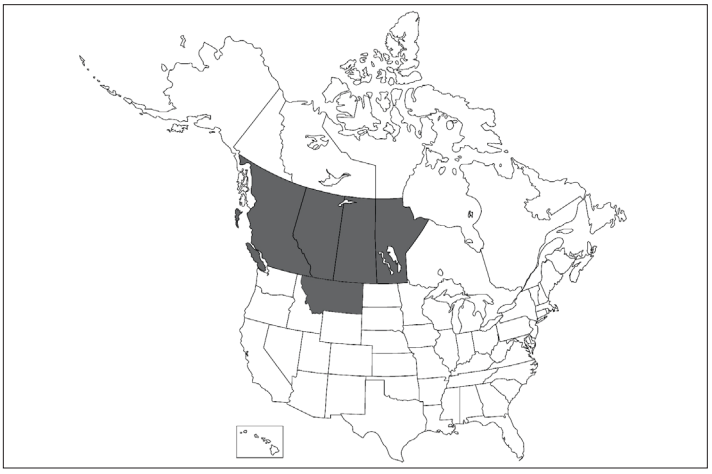

Figure 25. *Rhinusa pilosa* reported distribution on yellow toadflax in North America (Winston et al. 2022)

NONTARGET EFFECTS

None reported

NON-ESTABLISHED SPECIES

Eteobalea intermediella & *E. serratella* (Lepidoptera: Cosmopterigidae)

DESCRIPTION AND LIFE CYCLE

Both species are very similar, differing mainly in their egg appearance, egg-laying behavior, and number of generations per year. Adults are slender, 8–10 mm long, and are black with white and yellow spots (**Fig. 26a,b**). Adults emerge in late spring, and females lay up to 180 eggs in loose strings of 3–8. *Eteobalea intermediella* lays eggs in the lower leaf axils or on the base of yellow toadflax and non-flowering Dalmatian toadflax stems. *Eteobalea serratella* lays eggs at the base of yellow toadflax stems or on the soil surface at the base of toadflax stems. The pattern on the surface of *E. intermediella* eggs is net-like while the surface of *E. serratella* eggs has a ridged appearance, marked by fine parallel lines or furrows. Larvae bore into the root crown where they feed on tissue inside tunnels they carve and line with silk. Larvae are cream-colored with brown head capsules (**Fig. 26c**). They develop through five instars and are up to 12 mm long. *E.*

serratella has one generation per year while *E. intermediella* has two; second generation adults emerge in mid-summer. Mature larvae of both species overwinter in roots then pupate in spring inside cocoons within the root crown (**Fig. 26d**).

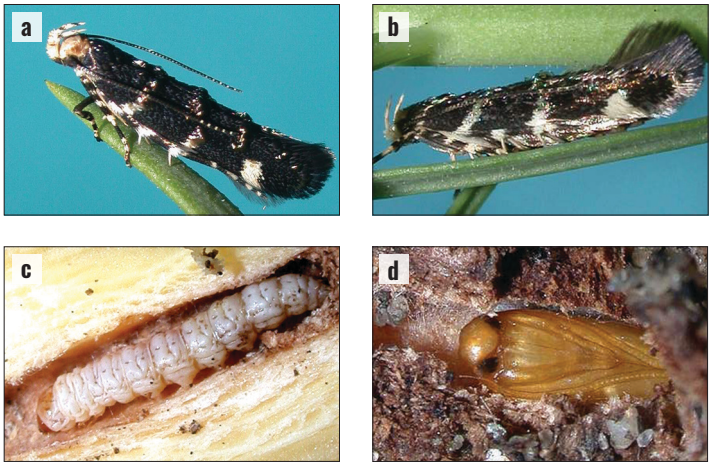

Figure 26. *Eteobalea* spp. (a) *E. intermediella* adult; (b) *E. serratella* adult; (c) *E. intermediella* larva; (d) *E. intermediella* pupa (both c,d in Dalmatian toadflax root); (a–d: Ivo Toševski, CABI Switzerland)

HISTORY AND CURRENT STATUS

Both species are native to southern Europe. In the USA, *Eteobalea intermediella* from the former Yugoslavia and *E. serratella* from Italy were introduced against both Dalmatian and yellow toadflax in Montana beginning in 1996. In Canada, *E. intermediella* from Serbia was released on Dalmatian toadflax beginning in 1991, and *E. serratella* from Italy was released on yellow toadflax beginning in 1992. To date, it appears that all introductions have failed to establish in both the USA and Canada.

UNAPPROVED BIOCONTROL AGENTS

One accidentally introduced species is established on toadflaxes in North America, and **it is illegal to intentionally move this species to new areas in the USA.** Care should be taken when transferring approved agents in the USA to ensure that this unapproved species is not also included in transferred material.

Rhinusa neta (= *Gymnetron netum*)

(Coleoptera: Curculionidae)

DESCRIPTION AND LIFE CYCLE

Overwintering adults emerge in late spring and feed on toadflax shoot tips, leaf buds, and young leaves. Adults are gray or brown (**Fig. 27a,b**) with a snout that is somewhat blunt and only slightly curved and not tapered or pointed. Adults are covered in dense, short hairs and are typically 3 mm long. As toadflax flowers open, adults feed on pollen and flower tissue. Females lay 40–50 eggs singly inside flower ovaries. Larvae feed on seed tissue through three instars. Larvae are C-shaped, creamy-white with light brown head capsules, and are up to 4 mm long. Pupation occurs within seed capsules, with adults emerging in late summer or early fall to overwinter in soil or plant litter. There is one generation per year.

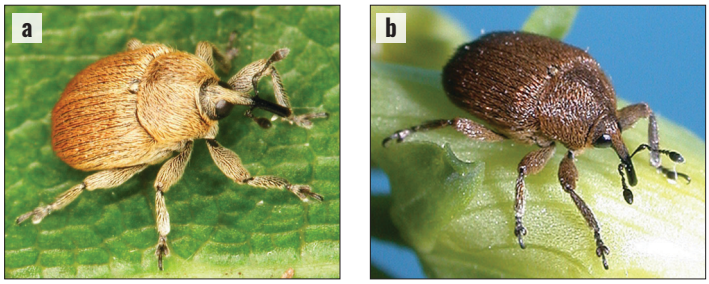

Figure 27. *Rhinusa neta* adults (a: Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org CC BY-3.0 US; b: Ivo Toševski, CABI Switzerland)

HISTORY AND CURRENT STATUS

This beetle is native to Europe. It was unintentionally introduced to North America and was discovered on both Dalmatian and yellow toadflax in the eastern USA in 1937 and in Canada by 1957. It has not been intentionally redistributed in either country. In the USA, *R. neta* now occurs on both toadflaxes in several states, but typically only in scattered populations. In Canada, it is more widespread on yellow toadflax, but only found sporadically on Dalmatian toadflax. In both countries, *R. neta* prefers yellow toadflax over Dalmatian toadflax. Larval feeding destroys a high proportion of seeds in attacked capsules, though overall attack rates on yellow toadflax are typically limited in the USA. Even in Canada, where yellow toadflax attack rates are higher, satisfactory control has yet to be achieved. **It is not approved for redistribution in the USA.**

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Table 1. Key traits for differentiating introduced natural enemies established on toadflaxes in North America.

	SPECIES	APPROVAL STATUS	HOSTS	ATTACK	ADULT DESCRIPTION	ADULT
BEETLES	*Brachypterolus pulicarius*	Approved in the USA and Canada	Yellow (preferred) and Dalmatian	Adults: feed on shoot tips Larvae: feed on flowers, seeds	Oval, dark brown to black, short elytra, body 2–3 mm long	
	Mecinus janthiniformis & *M. janthinus*	Approved in the USA and Canada	Dalmatian and yellow	Adults: feed on stems and foliage Larvae: mine stems	Bluish-black, elongated, long snouts, elbowed antennae, body 2.4–6 mm long	
	Rhinusa antirrhini & *R. dieckmanni*	Approved in the USA and Canada*	*R. antirrhini*: yellow (preferred) and Dalmatian *R. dieckmanni*: Dalmatian	Adults: feed superficially on shoots, new leaves, flowers Larvae: feed on seeds, forming swollen galls seeds	Gray to black with dense short hairs, snouts curved and pointed, body wide, body 2½–5 mm long	
	Rhinusa linariae	Approved in the USA and Canada	Established only on yellow toadflax in North America	Adults: feed on stem tissue Larvae: feed on root gall tissue	Black with dense short hairs, snouts very curved, body 2½ mm long	
	Rhinusa neta	Not approved in the USA	Yellow (preferred) and Dalmatian	Adults: superficially feed on flowers Larvae: feed on seeds	Gray or brown with dense short hairs, snouts somewhat blunt, only slightly curved, not pointed, body ≤3 mm long	
	Rhinusa pilosa	Approved in the USA and Canada	Yellow toadflax	Adults: feed on stems and stem gall tissue Larvae: feed on stem gall tissue	Black with long, dense upright hairs, snouts give hook-nosed appearance, body curved and ≤4 mm long	
MOTH	*Calophasia lunula*	Approved in the USA and Canada, but caution should be used releasing this moth near desirable snapdragon species	Dalmatian and yellow	Adults: superficially feed on nectar Larvae: feed externally on leaves and stems	Mottled gray-brown with light and dark markings on wings, 1–1½ cm long, 2½–3 cm wingspan	

***** *Rhinusa dieckmanni* has not been formally petitioned or permitted for release in the USA under that name. A petition was submitted and a permit was approved for field release of the Dalmatian toadflax strain or biotype of *R. antirrhini*.

Photo credits: *Brahypterolus pulicarius*: Иван Тисленко, iNaturalist.org CC BY-NC 4.0; *Mecinus* spp.: Bob Richard, USDA APHIS PPQ, Bugwood.org CC BY-3.0 US; *Rhinusa antirrhini, R. neta, R. pilosa*: Ivo Toševski, CABI Switzerland; *R. linariae*: Bob Richard, USDA APHIS PPQ, Bugwood.org CC BY-3.0 US; *Calophasia lunula*: Andrey Ponomarev, iNaturalist.org CC BY-NC 4.0)

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