British Columbia Ministry of
Forests, Lands and Natural Resource Operations

Appendix G (*Tyria jacobaeae*) to the Operational Field Guide to the Establishment of Tansy ragwort biocontrol agents in British Columbia

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June 2013

Tyria jacobaeae

Information contained in this Field Guide is comprised of fact and field observations as of June 2013. Site specific experiences may vary.

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Citation

Turner, S., Cesselli, S. 2013. Operational field guide to the establishment of tansy ragwort biocontrol agents in British Columbia. Prov. B.C. Victoria, B.C.

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Tyria jacobaeae

The goal of the Ministry of Forests, Lands and Natural Resource Operations (FLNRO) is to reduce target invasive plant populations to ecologically and economically acceptable levels and to prevent their encroachment into new areas. Implicit in the use of biocontrol methods is the acknowledgment that invasive plant eradication is not achievable. Rather, biocontrol agent species and host invasive plant species exist in predator-prey relationships where the invasive plants are intended to be held at acceptable population levels with self-sustaining agent populations. Since the 1960's, several insect agents have been released against tansy ragwort: *Tyria jacobaeae* (foliar-feeding moth) – 1962; *Botanophila seneciella* (seed-feeding fly) – 1968; *Longitarsus jacobaeae* Italian strain (root-feeding flea beetle) – 1971; *Longitarsus flavicornis* (root-feeding flea beetle) – 1971; *Cochylis atricapitana* (root crown-feeding moth) – 1990; and *Longitarsus jacobaeae* Swiss strain (root-feeding flea beetle) - 2011.

Agent Description

Tyria jacobaeae **adults** are attractive bright red and brown/black moths 15 to 22 mm long with a wingspan of 27 to 35 mm (Rees et al. 1996) (Figure 2). Their forewings are black-grey with brilliant crimson red stripes on the upper and lower margins and two red dots near the tips while the hind wings are crimson. The brilliant colouring indicates the possibility of toxicity, therefore, discouraging predators. The **eggs** are 1 mm and are round with ribs (Harris undated e). The larvae are black with ringed orange-gold bands (Powell et al. 1994) (Figure 1. The **pupae** are dark reddish-brown and 20 to 25 mm long (Rees et al. 1996) (Figure 3).

Figure 1 - *Tyria jacobaeae* larvae on tansy ragwort

Figure 2 - *Tyria jacobaeae* adult on tansy ragwort

Life Cycle

Tyria jacobaeae has one generation per year. The **adult** moths emerge from pupation in late spring (May through June) and begin mating and egg-laying within two weeks (Rees et al. 1996). The females lay 73-285 **eggs** which are not large numbers compared to other insect species, in batches of 10-150 onto the underside of rosette basal leaves (Harris undated e; Peterson 1977; Stewart and Sampson 2009). Initially the eggs are yellow but they gradually turn transparent grey and hatch after several weeks. The **larvae** changes colour through their five instars, from grey-green in the first instar to black with ringed orange-gold bands in the second through fifth instars (Harris undated e; Powell et al. 1994). Larvae develop to their fifth instar in four to seven weeks and when mature, they measure 2.5 cm in length (Sheley and Petroff 1999; Harris undated e). The first instar feed aggressively on the undersides of the leaves before they make their way to adjacent leaves and bolting stems as they grow. They prefer to feed on flowers, leaves and tender stems are less preferred, but will also be heavily consumed when population numbers are high. Once the larvae have stripped the plant, they will crawl to additional plants to find more food (Harris undated e; Rees et al. 1996). Larvae must consume sufficient plant material to pupate and need to be at least 140 mg to fully develop, some growing to 260 mg (Harris undated e). Mature larvae leave the plant and prepare to pupate under stones, debris and in the soil near the plant community (Rees et al. 1996). *T. jacobaeae* overwinter as **pupae**.

Figure 3- ***Tyria jacobaeae*** **pupae**

Effect on Tansy ragwort

Adults do not feed on the plants. The **larvae** feed, in preferential order, on the flower buds, on leaves (often leaving the mid vein) starting with upper stem leaves, then lower stem leaves, and finally on rosette leaves and may even feed on the outer layer of the stem if food sources are insufficient (Figure 4). Peterson (1977) noted that 30-40 larvae can defoliate an entire plant. In B.C., sites on the coast and in the Okanagan have had populations of the agent build to this extent and higher, completely defoliating infestations. This feeding has varying effects on the plant population. Often it has been noted that the size of the plants may be reduced but not the number of flowering plants (P. Harris, A.T.S Wilkinson and J. H. Myers, unpublished data, undated, Canada). *T. jacobaeae* is able to reduce the fecundity of its host plant but does not have a direct effect on the cover nor biomass (McEvoy and Rudd 1993). Tansy ragwort plants that have been defoliated early in the growing season have a greater compensation capacity to rapidly regenerate than those defoliated later which is positively correlated with the amount of moisture available to the plants with late summer rains that fall after the larvae have begun to pupate (Cox and McEvoy 1983). This is unlike other invasive species such as bull thistle that is seriously damaged by defoliation (P. Harris, unpublished data, 1989, Regional District, Williams Lake). However, McEvoy and Cox (1991) later determine that precipitation in Oregon does not decrease the combined ability of *T. jacobaeae* and *L. jacobaeae* to control tansy ragwort infestations. It is speculated that plants in the dry interior Okanagan Valley should have a lower compensation capacity and may not regenerate as easily as those at the coast. The larvae also affect the plant's ability to photosynthesize and replenish energy reserves in the roots, potentially leading to plant death in winter conditions. However, if a plant can build up enough energy reserves, then winter damage may not occur, despite the defoliation. Sites in Nova Scotia and PEI experienced plant defoliation and decreases in plant density and complete plant elimination at sites with no grazing but in B.C. the moth alone was not able to control tansy ragwort at the initial release sites on the coast. The difference appears to be in the length of recovery time of tansy ragwort after defoliation. In the Maritimes, there are about two months between defoliation and when the first winter frosts occur while at the B.C. coast, there are about four months. Decreased root reserves and colder winters explain the success of the agent in the east (Harris 1973). Again, *T. jacobaeae* may be more effective in the drier, shorter growing season and cooler winters of some parts of the B.C. Interior. There has been an observed significant decline in tansy ragwort plants at one of the *T. jacobaeae* release sites in the Okanagan Valley after only four years. Those plants that do regenerate from defoliation and are able to produce flowers, have lower seed viability than those with seeds produced in early-flowering plants (Sheley and Petroff 1999). A key effect of this agent is the decrease in seed production which becomes even more effective when competing vegetation exists with the tansy ragwort as the plants' seeds do not germinate nor do the seedlings survive with competition (Coombs 1988; Harris 1973). A reduction in seed also reduces the potential for seeds to enter and remain dormant in the soil for future outbreaks and the chance to create an infestation elsewhere. This complements the effect of *L. jacobaeae* on the target plant (Coombs 1988; McLaren et al. 2000). *T. jacobaeae*'s effect on the plant can decrease if the pupae are attacked by disease as was found in Montana where two diseases were discovered affecting the pupae. It is speculated that in cooler temperatures where the pupae remain in the soil longer, their potential to disease exposure is greater ((G. Markin, unpublished data, 1998, Montana). In Victoria Australia, despite their best efforts to handle *T. jacobaeae* or place it in the recommended habitat, other factors may have prevented establishment such as disease, predation and ill adapted European biotypes for Victoria. As well, plant nutritional factors were considered to be a contributing factor (McLaren et al. 2000). Tansy ragwort plants may continue to survive but remain as rosettes for several years if they are damaged, nutritionally impoverished or subjected to strong competition (Thompson and Harris 1986) *T. jacobaeae's* effect on tansy ragwort may simply decrease when populations decline as a result of decreased food. In turn, the tansy ragwort may be able to resurge from seeds accessed in the seed bank, from plants that escaped predation or from those with root reserves still viable (particularly if *L.*

Figure 4 - Defoliated stalk of tansy ragwort

jacobaeae is not present). In these cases it may be necessary to re-introduce *T. jacobaeae* when the plant density builds again.

Agent Behaviour

T. jacobaeae appears to be affected by seasonal temperatures. In cooler and wetter than normal spring months, pupation can be delayed, causing the adults to emerge later and delaying the ovipositing and larvae stages beyond normal emergence dates and peak periods. In turn, moths have been seen in late fall in colder areas in the U.S.A. such as the Cascade Mountains or some areas along the coast (Rees et al. 1996). **Adults** are hard to capture but can be observed resting on the plants during the day. They can be highly active, take flight when approached and have long irregular-patterned flights before resting. However, they do not travel far to find a mate (Peterson 1977). They are attracted to light and their peak flights occur at dawn and dusk. When populations are high, the adults migrate in mass flight (Harris undated e). The **larvae** tend to congregate at the tops of plants (Figure 5) and drop from the plants when they are disturbed where they remain suspended by silken threads. When it is safe to do so, they climb up the thread and return to feeding. Larvae have been known to travel up to 800 m to find food when plant densities decrease (Harris 2005). Feeding on tansy ragwort causes larvae to store toxins which discourage vertebrate predation, however they are consumed by other insects and even initial establishment in B.C. was thought to be prevented by the predation of carabid beetles. They are also prone to attack by parasitic nosema (Harris undated e).

Figure 5- Multiple *Tyria jacobaeae* feeding on tansy ragwort

Dispersal Behaviour

T. jacobaeae may appear to not be capable of dispersing easily, however, this species is appearing to do so in B.C. The **adults** are considered to be weak fliers (Harris undated e). The **larvae** will transfer by crawling to nearby plants in search of food when a plant has become stripped (Rees et al. 1996). In Oregon, the populations did not increase in density or spread significantly for 5 years (McLaren et al. 2000). It is important that the moth infest large populations of plants and have corridors of plants available for it to disperse along.

Collecting

T. jacobaeae are typically collected for redistribution as **larvae**. All instars can be collected, but it is best to collect later instar, larger larvae (20mm long x5 mm wide). They should not be handled without gloves as the larvae are sensitive to the oils on human hands. (Peterson 1977). They are lightly encouraged or gently shaken from plants into containers. When large quantities congregate on plant terminals, the plants can be tipped over the containers and gently shaken to remove the larvae. The collection containers should be well ventilated and the surface area large enough so the larvae are not piled several deep, especially when smaller larvae may be mixed in with larger larvae. It is helpful to provide stiff stems for the larvae to climb and separate themselves. One liter containers can be used for 25-50 larvae. Four liter containers can be used for up to 400 larvae. Containers should be cleaned after 24 hours and new food provided. Include as many floral buds as possible and lots of leafy growth attached to stems. Collection container sizes for storage is variable depending on the number of larvae collected. In ideal conditions of plentiful food, no crowding, cool, dry and not shaken about, larvae can be kept for a few days. However, as larvae require significant care and food, it is best to release them as soon as possible. Collect larva starting mid to late June through to mid July on Vancouver Island and in the Fraser Valley and one to two weeks later in the Okanagan Valley**. Adult** moths can be collected but it is not recommended. If this is done, only 20-100 are kept in relatively small containers and fluffed-up tissue added so they can hide and prevent flight to decrease damage to their wings. They must be kept cool, dry and not shaken. Collections should consist of even numbers of males and females if possible, erring on the side of more females. Take care not to allow agents to escape during transport. Large numbers of *T. jacobaeae* can be difficult to collect as tansy ragwort infestations are often controlled within a few years.

Releasing

T. jacobaeae moths/larvae should be released as soon as possible. Establishment success is higher when habitat conditions of the collection site are matched to the habitat of the release site. When this is not the case, it is recommended to increase the number of agents to be released to compensate for mortality. A matched habitat release in general should be 500 **larvae**, however, establishment has been successful with less. A release into unmatched habitat should be a minimum of 1000 larvae, considerably less than the average larvae release quantities in Tasmania of 8000 (McLaren et al. 2000). If releasing **moths**, Rees et al. (1996) recommend using 20 to 100. Release agents into sites with the preferred site characteristics listed below. Always check for and avoid if possible potential disturbance factors (described below) at the new site before releasing.

Monitoring

Monitor for **larvae** as per the Handling Cycle table above. More specifically, monitor throughout the Fraser Valley, lower mainland, and Vancouver and Gabriola Islands from mid-June through to mid-July, as populations decrease after mid-July. Monitoring for larvae in the southern interior typically occurs throughout July, and even early August. As well, larvae feeding evidence can be observed during their feeding period and for several weeks after the larvae have stopped feeding and moved into their pupation phase. During the feeding period, floral buds and leaves appear to have significant chewed edges, somewhat resembling grasshopper feeding and unlike the shot-hole feeding in the middle of leaves made

Figure 6 - *Tyria jacobaeae* feeding "residue" on tansy ragwort plant (feces and molts)

by *L. jacobaeae*. Plants can appear blackened as the larvae discard their molted skins and deposit feces on the plants (Figure 6). Take care not to walk on larvae travelling between plants.

Monitor for **adults** as per the Handling Cycle table (page 20). More specifically, monitor throughout the Fraser Valley, in early June through late August, with peak periods in early to mid-July. Adults can be found in the field during the day on the plants where the upper foliage tends to shade them while they rest on the lower plant parts. Adults can be observed either when they rest on the foliage or when they are encouraged to take flight by walking through an infestation during the day. Monitor for moths dispersed into sites with the preferred site characteristics listed below.

Preferred Site Characteristics

Site Size

Large sites (minimum 0.5 ha) with high plant densities will ensure longevity and may assist with successful long term establishment.

Plant Density

High plant density is necessary to fulfill the feeding requirements of the larva stage and allow the larvae to travel to new plants when they have stripped the ones they occupy. Rees et al. (1996) describe necessary plant density as being greater than 4 plants/m^2 while in B.C. the recommendation is closer to a minimum of 6 plants/m^2. An abundant continuous supply of bolting plants each year is necessary to ensure a continuous increase in population.

Ground Cover

In situations where plant density is low and larvae density is high, the larvae may find it necessary to move from one feeding area to another to fulfill their feeding requirements. Significant ground cover may be a hindrance to larvae crawling to adjacent plants.

Competing Vegetation

T. jacobaeae have been found at sites with plenty of plant competition including tall grasses, shrubs and various forbs (Figure 7).

Figure 7 - Various sites with plant competition

Gabriola Island photos dispersal location

Chute Lake Road

Cedar Hill Regional Park

Shade

T. jacobaeae are typically found in open, sunny areas such as meadows, fields and road edges. They can be found on plants under closed canopy when few plants are present, however, it has been noted that they tend to not persist in shade such as under trees or in steep canyons, or wet locations (P. Harris, A.T.S Wilkinson and J. H. Myers, unpublished data, undated, Canada).

Slope

Adults and larvae do not appear to have a preference for slope as they have been found on gentle and steep slopes as well as flat areas in ideal habitat. Consider using the slope of a potential site to promote other desirable conditions (e.g. see Aspect).

Aspect

Adults and larvae do not appear to have a preference for a particular aspect in ideal habitat. Where the habitat is less ideal, release agents onto flat areas or into sunny south aspects.

Elevation

In Great Britain establishment of the moth has been described as requiring warm sunny sites at elevations up to 1000 m (Rees et al. 1996) However, in B.C., the moth has been able to establish at elevations as low as 7 m and as high as 1144 m.

Temperature

No specific reference to temperature in the literature was discovered, nor measured in B.C. Of note, the agent originates from Europe to central Asia and the source of moths for B.C. came from Switzerland (Harris 2005).

Moisture Regime

In Oregon, sites along the coast did not establish well, presumably due to high rainfall (200 to 250 cm annually) (Hawkes 1980). Areas that flood also do not establish well. Conversely, sites that have prolonged dry periods, especially during the moth's pupation period, are undesirable (see Soil Moisture Regime for details).

Soil Moisture Regime

Dry locations will cause the larvae to dehydrate and lose body weight (Harris undated e). The pupae can lose up to 1/3 of their mass before they will die. Conversely, too much moisture will cause the larvae/pupae to detrimentally absorb water (Harris 2005). For example, McLaren et al. (2000) noted waterlogging during the winter pupation period was an issue for site establishment. Do not release *T. jacobaeae* onto sites where water pools on the ground while the agent is pupating (fall through early spring). Established releases and positive dispersal locations in B.C. are restricted to hygric and subhygric areas situated on lower slopes, valley bottoms and plains on the lower mainland and Vancouver Island, i.e. water receiving areas or where the water table is high beneath. However, these sites also have coarse, well-drained soils. In the Southern Interior, the moth has established on mid and lower slopes in submesic, mesic, subhygric and hygric locations. These features may be more a reflection of where the plant grows. It is important then to ensure sites do not flood or otherwise have overly wet conditions which can be detrimental to the pupae (McLaren et al. 2000).

Soil Texture and Compactness

T. jacobaeae has been found established in B.C. at sites with minimal top soil over bedrock, with coarse soils that provide good drainage (rail lines, road edges) and at sites with organic build up. Additionally, research has found that dense soil with low porosity can affect survival of soil inhabiting **larvae** by restricting their movement (Potter et al. 2004).

Snow Cover

T. jacobaeae has been found established in B.C. at sites with substantial dry snow cover (Southern Interior), heavy wet snow (Nanaimo) or no snow in mild coastal conditions (lower mainland).

Disturbance

T. jacobaeae would be less successful at sites that are mowed when flowers are present as the floral buds and upper plant parts are preferred by the larvae. Additionally, excavation would not only disturb the plants and agents feeding on them in the summer, but winter excavation would disturb pupae development. Do not release *T. jacobaeae* where ants and aphids are present (Rees et al. 1996) nor spiders or where cattle are likely to trample the site.

Biogeoclimatic Ecosystem Classification Zones

T. jacobaeae has been released in and, thereafter, dispersed further into various Biogeoclimatic Ecosystem Classification (BEC) zones (see the Field Guide for a definition and more information). Included below are the BEC zones the moth has been found to populate in the province to date. Note that some of the release sites have not been monitored due to lack of access or destroyed sites so percentages of establishment could be higher.

Figure 8 –Established releases

BEC	Release[a]	Dispersal[b]
CDF mm	5/7 (71%)	16/16 (100%)
CWH dm	4/4(100%)	5/6 (83%)
CWH ds1		0/2 (0%)
CWH xm1	7/17 (41 %)	9/9 (100%)
IDFdm1	1/3 (33%)	2/2 (100%)
IDF xh1	1/1 (100%)	

[a] # sites with establishment/ # release sites

[b] # sites with *T. jacobaeae* /sites monitored

General Location in Province

T. jacobaeae has been released and found established in four general areas of the province including: in the Fraser Valley; on Vancouver Island; on several coastal islands; and in the Okanagan. The most easterly established release in the Fraser Valley is near Seabird Island. To date this population has not self-dispersed to the lower mainland fringe of the tansy ragwort infestation near Hope (approximately 21 km away). Older established populations have been found significantly dispersed while younger populations are also beginning to disperse. On Vancouver Island the moth has dispersed from Nanaimo south to Duncan as well as on Gabriola and Salt Spring Islands. On the lower mainland it is dispersing throughout the Langley, Abbotsford, Chilliwack, Agassiz and Delta areas and in the Okanagan it is beginning to disperse in the Chute Lake area.

Figure 9 – Nanaimo release site: Before images taken July 19, 2006. After images taken mid-July 2010

Before

After

Before

After

Recommendations

T. jacobaeae is well suited to attack dense populations of tansy ragwort in preferred habitat. It may take a few years for the population numbers to increase to the point of controlling the target plant on a site. However, when plant densities decline, the agent numbers will also decrease, perhaps even disappear from some localized sites. As seed banks and roots are not directly attacked by this agent, the plant may resurge again in the future. For this reason, it is best to release this moth in conjunction with other biocontrol agents. Recent cool wet springs have been favourable for many plant species, including tansy ragwort. With a resurgence of the plant, there should be a resurgence of *T. jacobaeae* numbers in subsequent years, especially with a warmer, drier spring, as they move through their predator-prey cycle and potentially give rise to collectable numbers. Alternatively, the agent may require re-introduction into areas in which it was formerly plentiful if it became locally extirpated in the past due to lack of its food plant or to areas where the agent has not been able to re-distribute itself due to a lack of corridors with suitable habitat. Monitoring release sites should be the first step to determine if the agent is still present and at what level. Sufficient dispersal monitoring should also take place prior to further releases of the moth to ensure efforts are not wasted. As tansy ragwort infestations in coastal B.C. are controlled within a few years by the combination of agents, it is necessary to regularly search for new collection sites. Releases of the agent into further sites in the B.C. interior should be attempted, even into the wet areas of Haida Gwaii, however, successful control may not be achieved without the establishment of additional, root-feeding agents. Collections for sites further north than the Okanagan Valley would be best done from the Okanagan Valley where the agent has spent a generation or two adapting to the different conditions rather than returning to the coast to collect.

Handling Cycle

Although the agent in its various forms can be found outside the sequences described below, the weeks indicated for monitoring and collecting have been found to be the most productive.

Biocontrol agent ↓	Activity of interest	Jan 1-15	Jan 16-31	Feb 1-15	Feb 16-28	Mar 1-15	Mar 16-31	Apr 1-15	Apr 16-30	May 1-15	May 16-31	Jun 1-15	Jun 16-30	Jul 1-15	Jul 16-31	Aug 1-15	Aug 16-31	Sep 1-15	Sep 16-30	Oct 1-15	Oct 16-31	Nov 1-15	Nov 16-30	Dec 1-15	Dec 16-31
Tyria jacobaeae	Life cycle	pupa								adult		adult/larva		larva			pupa								
	monitor									adult				larva		other									
	collect													larva											
	Notes	Monitor OTHER indicates the opportunity to monitor for presence only, extensive foliar feeding is typical of *T. jacobaeae*																							

For general information regarding redistribution of biological agents, please refer to Module 1.9: Biological Treatment & Monitoring of the IAP Reference Guide, located at:
http://www.for.gov.bc.ca/hra/plants/RefGuide.htm

For more detailed information on collecting, shipping, releasing methods and equipment, please refer to the document Biological Agent Handling Techniques, for the collecting, shipping and releasing in BC, which is located at:
http://www.for.gov.bc.ca/hra/plants/downloads/HandlingTechniquesV2.pdf