British Columbia Ministry of
Forests, Lands and Natural Resource Operations

Appendix I (*Cochylis atricapitana*) to the Operational Field Guide to the Establishment of Tansy ragwort biocontrol agents in British Columbia

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Cochylis atricapitana

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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Cochylis atricapitana – Province of B.C.

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Cochylis atricapitana

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

Cochylis atricapitana **adults** are fragile, 3 mm long moths with a wingspan of 7 mm (Powell et al. 1994) (Figure 1). Harris (2003b) records the wingspan to be 12-16 mm. Their forewings are whitish to tan with a light pink hue in the white which is more pronounced in the females (Harris 2003b). The forewings also have irregular brown, black and gray marks which Ireson (1999) describes as a band of 1mm wide brownish blotch that runs diagonally across the middle and end of the forewings. The hind wings of the male moths are white with gray lines while the females' are dark gray. A dark tuft of scales (0.3 mm long) projects upward from behind the head. The oval, flat **eggs** measure 0.5 x 0.3 mm, are translucent white and gradually change to yellow. New **larvae** are creamy white with a black head and the body darkens with age (Figure 2). **Pupae** are light brown, measure 7 x 1.5-2.0 mm and are enclosed in a creamy white silken cocoon that changes to pink (Ireson 1999; Harris 2003b).

Figure 1 - *Cochylis atricapitana* adult (Powell et al. 1994)

Figure 2 - Cochylis atricapitana larvae

Life Cycle

The **adult** moths emerge from pupation in spring (May-June) or summer (July to August) as they are capable of multiple generations each year (Schroeder et al. 1989). The sex ratio of males to females is 1:1 (Ireson 1999). Females will oviposit an average of 158 **eggs** each but will oviposit as many as 355 (McLaren 1992) singularly or sometimes in pairs typically along the secondary and tertiary veins on the underside of leaves. Developing **larvae** can be observed through the egg surface (Ireson 1999). Incubation at 24^{o}C will cause the larvae to hatch after five days. Larvae develop through five instars which take approximately 33 days depending on the temperatures. First generation larvae (summer) mine under the epidermis of the leaves then into leaf-veins, petioles and the stems where they may move upwards into the flowers (Schroeder et al. 1989). Development and pupation may take place in the stem (Ireson 1999). Alternatively, these older larvae may leave the stem and climb externally up the plant to mine the developing shoots or flower buds. Here the spring larvae complete development and pupate (Schroeder et al. 1989). Feeding in the stem causes it to swell and an obvious hole and yellowish-brown cocoon is left behind when the moth exits (Kimber 2013). Second generation (autumn) eggs are laid on rosette leaves and the hatching larvae mine the rosette leaves downward to the root crown, feeding and developing until hibernation. If the autumn generation overwinters as the fourth instar, feeding resumes the following spring when they feed on the root crowns or when they make their way upward into the lower central shoot area to pupate. If they overwinter as the fifth instar, they move into the soil and pupate the following spring (Schroeder et al. 1989). As the new **adults** exit, they discard their pupal case at the exit point, which may be from the root crown, stem, bud or soil (Ireson 1999). This process takes 40 days for completion (Ireson et al. undated).

Effect on Tansy Ragwort

Adults do not feed on the plants. **Larvae** attack full-grown plants and rosettes during separate generations. High density attack of *C. atricapitana* can have significant impact on its host plant (Schroeder et al. 1989). The first generation larvae feed on leaves, stems and flowers. The second generation larvae feed on the lower stems and root crown, but rarely on the roots (Harris 2003b). Larvae feeding on the various plant parts has different effects on tansy ragwort: feeding down the leaf vein can cause the leaf to die which interferes with floral development; feeding and development in young stems causes them to thicken and suppresses flowering while feeding on older stems can kill them; feeding on flower buds can prevent flowering and decrease seed produced; feeding on rosette root crowns causes them to stop growing or die and creates blackening or browning at the rosette center; and, feeding on bolted root crowns and in stems cause stems to brown and die and plants may produce stunted bolts (Harris and Schroeder 1989; P. Harris, pers. comm. June 1994; Ireson 1999; Harris 2003b; S. Cesselli, pers. comm. Oct. 2012). However, if the plants have enough reserves, they can produce root buds in response to attack (Harris undated a). Plants that regenerate produce less foliage and no flowers while big rosettes that have sustained repeated attack in the autumn frequently perish the following spring when under attack again (Schroeder et al. 1989). Measurements in Australia showed *C. atricapitana* stunted growth, reduced ragwort heights, killed rosettes and reduced the diameter of live rosette tissues (McLaren et al. 2000). Tansy ragwort plants may continue to survive but remain as a rosette for several years if they are damaged, nutritionally impoverished or subjected to

strong competition, but secondary attack by fungi, bacteria and some insects accessing the plant following attack by *C. atricapitana* can also lead to plant death (Thompson and Harris 1986; Ireson 1999).

Figure 3 - Cochylis atricapitana larvae and feeding damage

Agent Behaviour

During the day, **adults** are inactive, remaining close to the ground near or on the plants, taking flight near dusk and becoming active during the night (Schroeder et al. 1989). On rare occasions they have been found on rosettes in August. Nocturnal adults may be drawn to a black light. **Larvae** will exit a dying/drying up root and transfer to a new plant root (P. Harris pers. comm. August 2001).

Dispersal Behaviour

In Australia, dispersal was found to vary in different locations. In Victoria, Australia, the maximum dispersal at a site was 100 m in three years while populations took 11 years to develop before more significant dispersal began, for example, one release made in 1987 had dispersed over 10 km^2 by 1999. Conversely, in Tasmania, Australia, the maximum dispersal at a site was 200 m in three years (McLaren et al. 2000). Harris (2003) notes the moth spread 15 km in five years in Nova Scotia. In B.C., the agents have been found to disperse between 7 and 7.5 km in both Abbotsford and Chilliwack.

Collecting

C. atricapitana are collected for redistribution as **larvae** inside infested plants. When transplanting tansy ragwort plants in June through July, ensure the stems are not broken or clipped as the larvae/pupae may be in the length of the stems, from near the flowers or close to the root crown. When transplanting tansy ragwort plants in September through early March, accomplish this before the fifth instar larvae exit the plants to pupate in the soil (Schroeder et al. 1989). According to historic B.C. records, late autumn collections appear to be less successful to collect and transplant larvae infested plants than spring. Ensure soil is retained around the roots and kept moist but not saturated to decrease the stress on the plants. If plants are plentiful, it is useful to dissect a few to ensure the plants are infested and to determine the average quantity of larvae being collected to transfer to a new location. However, root crown feeding larvae in their early instars may easily be confused with *L. jacobaeae* root feeding larvae (Harris pers. comm. June 1994). Later instar *C. atricapitana* larvae are more readily identifiable as their Lepidoptera shape is more apparent, they are larger and are found in the root crown. If the collection site also has *L. jacobaeae* present, collecting plants with first generation *C. atricapitana* larvae in the spring and early summer may be best so as to not disturb the *L. jacobaeae* which do not begin ovipositing until early fall. Collection of **adult** *C. atricapitana* would be best (P. Harris pers. comm. August 2001), but has not been performed to date in B.C. due to the difficulty of locating significant quantities of the moth in the dark, although they can be attracted with a black light. *C. atricapitana* is also easily bred in a greenhouse (Harris undated b).

Releasing

A minimum of 50-100 **larvae** (Harris undated b) or 50 infested plants should be transplanted for a release of *C. atricapitana* (Ireson et al. undated). It is always preferable for the agents to be collected and redistributed within the same type of habitat. If the recipient site is within a different habitat/BEC zone, it would be advisable to use larger numbers to transfer to compensate for the stress on the population as much as possible. Ensure the soil around the infested plants is kept moist but not saturated during transplanting and the plants revisited to determine if they require more water to survive. This is especially important for sites that are in dry habitats where the plants may die quickly. However, larvae will leave dying roots to find healthy plants should the transplants not survive. If solid pots are used for transporting the plants, dig these into the ground such that the top of the pot (where the soil within the pot should reach) is flush with the surrounding soil, or remove the plants and dig them into the ground as the larvae may have difficulty exiting the pot. If nursery containers are used that break down over time, ensure there is sufficient soil within the containers so the larvae may exit from the top and keep them moist so they do break down or remove the plants as well and place them into the ground. If the plants survive in the pots, the larvae may remain in the potted plants, pupate and exit as adults. At sites where *T. jacobaeae* are present in large numbers, their aggressive feeding of the flower buds, leaves and upper stems may negatively impact the flower and stem generation of *C. atricapitana* larvae. Sites should be investigated for *T. jacobaeae* before *C. atricapitana* is released to ensure large numbers of the cinnabar moth are not present. However, releasing two or more biocontrol agents that attack tansy ragwort plants via different modes and during varying times of the year, can increase their efficacy than if released alone (McLaren et al. 2000).

Monitoring

Adults may be monitored in early May and August but they can be difficult to find due to their size and markings and their behavior (see Agent Behavior section). Look for them on the ground near the plant or on their host, both rosettes and bolted plants. **Larvae** should be monitored for in midsummer from late June to late July. *C. atricapitana* larvae that feed on leaves and stems do so by mining these plant parts in contrast to the readily distinguishable *T. jacobaeae* larvae with unique feeding from large cuts in leaves, often leaving the mid-vein, to defoliating whole plants in large numbers. The entrance of the *C. atricapitana* larvae into the plant can be distinguished by small tunnel entrances at the leaf bud in the axils of side shoots where fine fecal matter is often left behind. If pupation has occurred within the stem and the moth has exited, a pupal case may protrude from the tunnel opening. Attacked plants may have blackened and wilted flower buds or the flower crown may have multiple stems as a result of attack on the stem (Ireson 1999). *C. atricapitana* larvae can be easily found in dissected root crowns or tunneling can be seen in cut open stems or root crowns. Both *C. atricapitana* and *L. jacobaeae* larvae create brown-coloured root crowns which can be seen when basal leaves are pulled away from the root crown. Tunnels filled with frass will be evident, indicating the former or current presence of larvae. The wilted appearance of side shoots can also indicate larval damage to the root crown (Ireson et al. undated). When plants are excavated in the spring, slender white-coloured larvae or feeding damage can be observed in or on plant roots. This feeding evidence and early instar larvae can easily be confused with *L. jacobaeae*. It is advised to monitor for larvae later in the season (end of July) when *C atricapitana* larvae can be distinguished as Lepidoptera (P. Harris pers. comm. June 1994). Flea beetle larvae have three pairs of true legs on the thoracic segments while the moths and butterfly larvae have pairs of prologs, typically on most of the abdominal segments. With a hands lens these could be seen as a ring of crochets or hooks on the short cylinder body. As well, any late-developing *L. jacobaeae* larvae should be feeding on the outside of the roots and root crown (P. Harris pers. comm. Aug. 2002). *C. atricapitana* and *L. jacobaeae* can co-exist as they typically feed in different locations on the root (Harris 2003b).

Preferred Site Characteristics

Site Size

Ideally, *C. atricapitana* release sites should be 250 m^2 – 500 m^2 with plants occurring either in a continuous stand and uniform distribution or in a continuous clumping pattern to develop a collection site. With larger sites, it can be more difficult to find the agent when their numbers are low. Sites should have a corridor of plants to allow the agent to self-disperse as the main infestation declines.

Plant Density

Plant density should be at least 2 plants/m^2. All release sites should have a mix of first year rosettes, mature rosettes and bolting plants to allow for multiple generations to oviposit and to prevent the moth from taking flight to find suitable plants. When several biocontrol agent species are released on the same site, the site size and the plant density should be increased.

Ground Cover
In B.C., evidence of larvae feeding has been found most commonly on rosettes growing in areas with little ground cover.

Competing Vegetation
In B.C., neither adults nor evidence of larvae have been found on tansy ragwort plants growing within thick, competing vegetation. However, at these sites, larvae have been found on rosettes established on the margins of the thick competing vegetation, therefore, heavy plant competition does not appear favourable.

Shade
In B.C., neither adults nor evidence of larvae have been found on rosettes growing in open or closed canopy, therefore, shade does not appear favourable.

Slope
In B.C., adult and larvae have been found on artificial slopes, natural slopes and flat areas therefore, slope does not appear to affect establishment.

Aspect
Adults and larvae do not appear to have a preference for a particular aspect.

Elevation
In B.C., the moth has been able to establish at elevations as low as 11 m and as high as 250 m. Powell et al. (1994) notes *C. atricapitana* to be more effective in controlling tansy ragwort at higher elevations.

Temperature
No temperature preferences have been identified to date in B.C. Although Harris (2003) mentions the moth as useful for areas with early winters, it has not yet survived attempts to establish it in the southern interior where temperatures are more extreme than the moderate habitats of the lower mainland and islands.

Moisture Regime
No moisture regime preferences have been identified to date in B.C., however, the moth has not yet survived attempts to establish it in the southern interior where it is drier throughout the summer and much of the moisture comes as snow, unlike the lower mainland and islands where precipitation is significant throughout the winter, spring and fall. Schroeder et al. (1989) describes the moth as most effective in warmer and drier parts of the tansy ragwort range while Kimber (2013) lists *C. atricapitana* as being commonly distributed around the coast in the British Isles.

Soil Moisture Regime
Established releases and positive dispersal locations 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. These features may be more a reflection of where the plant grows. From observations, the moths appear to prefer habitats with bare ground and well drained soils. *C. atricapitana* **larvae** that

pupate in water-logged soil may be negatively affected from absorption of too much moisture as are *T. jacobaeae*. Schroeder et al. (1989) says the moth avoids moist sites.

Soil Texture and Compactness

C. atricapitana appears to prefer coarse well-drained soils. However, plants growing in the silt-loam soils in the Fraser Valley were not inspected as they were within private land, typically within crops. Additionally, research has found that dense soil with low porosity can affect survival of soil inhabiting larvae in general by restricting their movement (Potter et al. 2004). Kimber (2013) describes the moth as being common on chalky ground in the British Isles.

Snow Cover

C. atricapitana has established on Vancouver Island near Nanaimo and in the Fraser Valley around Abbotsford and Chilliwack where the snowfall is not consistent, but is wet and heavy when it does occur.

Disturbance

Although the larvae have been found on plants that have been previously mowed, the moth would be less successful at sites that are mowed when flowers are present as the flowers and upper stem and leaves are required for the first larval generation. Excavation also would not only disturb the plants and agents feeding on them in the summer, but winter excavation would disturb pupae development. Additionally, wind, natural or that caused by heavy traffic, may negatively affect the fragile moth. It has established at a windy site in B.C. but the majority of sites have windbreaks of some kind. *C. atricapitana* may be affected by parasites and predators. In Australia, parasitic tachinid fly larvae were seen attacking the moth larvae and spiders and birds have been seen feeding on the adult moths (McLaren et al. 2000).

Biogeoclimatic Ecosystem Classification Zones

C. atricapitana 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, however the moth is reported as able to adapt to all habitats supporting tansy ragwort (Powell et al. 1994). 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 4 - Established releases

BEC	Release[a]	Dispersal[b]
CDFmm	2/3 (66%)	
CWHdm	4/6 (67%)	4/5 (80%)
CWHds1		0/1 (0%)
CWHxm1	5/7 (71%)	5/5 (100%)
IDFdm1	0/2 (0%)	

[a] # sites with establishment/ # release sites

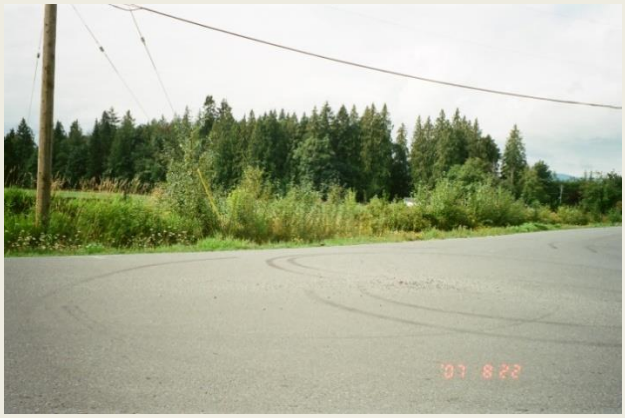
[b] # sites with *C. atricapitana*/sites monitored

General Location in Province

C. atricapitana has been released and found established in three general areas of the province including in the Fraser Valley, on Vancouver Island, and on several coastal islands. Dispersal sampling in the Fraser Valley has shown it to disperse up to seven and a half kilometers from the nearest release. General established release and dispersal areas include Abbotsford, Chilliwack, Nanaimo, Cedar, and Mudge and Salt Spring Islands.

Figure 5- Establishment locations

Cox Road, Abbotsford



Junction of Adshead and Haslam Cear Roads

Recommendations

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 *C. atricapitana* numbers in subsequent years 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. Re-introduction may be required if the tansy ragwort infestation resurges from buried seed. *C. atricapitana* may be the best option to address sites where *L. jacobaeae* (Italian) may not be effective when freezing temperatures come before breeding, ovipositing, and larvae hatching and feeding can be completed. This biocontrol agent can be released in field-collected infested plants, successfully reared in a laboratory situation or left to self-disperse.

Cochylis atricapitana (Tansy ragwort root crown feeding moth) – Operational Field Guide

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		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
		1-15	16-31	1-15	16-28	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-31
Cochylis atricapitana	Life cycle	larva						pupa		adult		larva		Larva/pupa		adult	adult/larva		larva				larva		
	monitor					larva						larva						larva							
	collect					larva						larva						larva							
	Notes	multiple larva/pupa found/plant root/crown. Excavate infested plants prior to larva vacating to pupate in the soil																							

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