British Columbia Ministry of
Forests, Lands and Natural Resource Operations

Operational Field Guide to the Establishment of Tansy Ragwort Biocontrol Agents in British Columbia

June 2013

Tyria jacobaeae

Longitarsus jacobaeae

Cochylis atricapitana

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

Uniform Resource Locators (URLs), addresses, and contact information contained in this document are current at the time of publication (September 2013).

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1. PURPOSE

This document summarizes information for the tansy ragwort (*Jacobaea vulgaris*, formerly *Senecio jacobaeae*) biocontrol agents *Botanophila seneciella* (a seed-feeding fly), *Cochylis atricapitana* (a root crown-feeding moth), *Longitarsus flavicornis* (a root-feeding beetle), *Longitarsus jacobaeae* (Italian and Swiss strains of root-feeding beetles), and *Tyria jacobaeae* (a defoliating moth). The agent *B. seneciella* is considered tertiary while the agents *C. atricapitana*, the Italian strain of *L. jacobaeae*, and *T. jacobaeae* are the focus of this document as they transition from primary to secondary. *L. flavicornis* and the Swiss strain of *L. jacobaeae* remain primary agents. Primary is a management term for biocontrol agents within the British Columbia Ministry of Forests, Lands and Natural Resource Operations (FLNRO) that are under development, the responsibility of the Range Branch and not yet an operational treatment tool. Secondary and tertiary agents are considered operational tools and range from limited in distribution to widespread or actively self-distributing, respectively. The information in this document is a combination of scientific facts and field observations. Intended as a 'field guide' for those unfamiliar with these agents the summary contains pertinent information for field propagation and establishment of the biocontrol agents as well as historical background of their introduction into British Columbia (B.C.).

2. INTRODUCTION

FLNRO's Invasive Plant Program's (IPP) purpose is to prevent potential, and control existing, invasive plant species to protect ecological, social, and economic values. The use of biological control is one method utilized in the endeavour of this purpose. 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.

Biocontrol Development is a component of the IPP and is the first step in the use of biological control. This responsibility is performed on behalf of the provincial ministries tasked with invasive species control and collectively comprise the Inter Ministry Invasive Species Working Group and include, but are not limited to: the Ministry of Agriculture (AGRI) - Plant and Animal Health Branch; Ministry of Environment (MoE) - Parks and Protected Areas Branch, and Ecosystems Protection and Sustainability Branch; Ministry of Forests, Lands and Natural Resource Operations (FLNRO)- Range Branch, and Resort Development Branch; Ministry of Transportation and Infrastructure (MoTI) - Engineering Branch; Ministry of Energy and Mines (MEM) - Mine Health, Safety and Permitting Branch; and the Ministry of Community, Sport and Cultural Development (CSCD) - Intergovernmental Relations and Planning Branch. Biocontrol Development is also performed as a cooperative venture between Agriculture and Agri-Food Canada (AAFC), Commonwealth Agricultural Bureau International (CABI-Europe) in Switzerland, as well as numerous other provincial and state agencies across western North America.

3. TANSY RAGWORT

Tansy ragwort (*Jacobaea vulgaris*), a member of the sunflower family (Asteracaeae) is a biennial or short-lived perennial. The mature plants stand on average 0.3 to 1.0 m tall and potentially up to 1.7 m in shaded areas. The stem and leaf stalks can be a purplish colour. The leaves on mature plants are "compound and varied, most deeply lobed, becoming smaller closer to the flowers" (Sheley and Petroff 1999). When the leaves are crushed they produce a foul smell. The flowers measure 1.6 cm across, are present from July to October, yellow and daisy-like with 10 to 16, but on average 13, ray flowers. A single plant can produce one to 15 clusters of flower heads and result in more than 150,000 seeds (Sheley and Petroff 1999; Powell et al. 1994). Seeds can persist for at least 4-5 years when buried up to 2 cm and at least 10-16 years when buried below 4 cm. Factors that promote germination are not readily available to seeds that rest in the soil below 1.5-2 cm. Accumulated litter and competing vegetation also suppress germination, therefore, seeds requires disturbance that removes the litter and vegetation and brings the seeds closer to the soil surface for them to germinate (McEvoy and Rudd 1993). However, in moist areas, tansy ragwort can perpetuate itself almost entirely from root buds which are most common on rosette roots. This lends to difficulty in chemical control when treated as a biennial instead of a plant with a persistent perennial root system (Harris and Schroeder undated 1989). Disturbance factors that promote tansy ragwort include, but are not limited to, grazing, mowing, clipping, tilling, logging and disruption of the soil surface by animals such as rabbits, gophers or marmots.

Figure 1 – Tansy ragwort rosette

Figure 2 - Tansy ragwort flowers

Tansy ragwort has been introduced into Australia, New Zealand, South Africa, Argentina, Brazil, the United States and Canada (Pemberton and Turner 1990). It is a problematic invasive plant in North America where it has invaded, primarily in disturbed areas like roadsides, unhealthy pastures or waste places, and generally in maritime-influenced regions with cool, high rainfall. In Canada it was first observed in the 1850’s and quickly spread (Weed Science Society of America 2012). It is reported to exist in the east in Labrador Newfoundland, Prince Edward Island, Nova Scotia, New Brunswick and Quebec as well as Ontario, while in the west it has invaded British Columbia. In the United States it is reported in the east in Maine, Massachusetts, New York, Pennsylvania, and New Jersey, as well as Michigan and Illinois while in the west it is in Washington, Oregon, and California as well as Idaho and Montana (Flora of North America 2012).

In Oregon, Hawkes (1980) reported the plant was moving into northeastern portions of the state that were characterized by 30-35 cm of annual rainfall, cold winters, warm, dry summers and sagebrush-Ponderosa pine and Ponderosa pine-Douglas-fir vegetation and by 1991 McEvoy and Cox described a range of tansy ragwort sites in Oregon from sea level to 1000 m with precipitation ranges from 100-250 cm. Sheley and Petroff (1999) later reported some plant communities in the U.S.A. to be fairly resistant to ragwort infestations, those dominated by sagebrush, desert and alkaline soils while large infestations have been found in habitats not expected to be invaded. Tansy ragwort was found in Montana, indicating the plant can establish and disperse into the intermountain zone and may spread further into new locations in northern U.S.A.

In its native habitat in Europe, tansy ragwort is found between latitudes 36^{o}N and 59^{o}N and west from Ireland to east in Siberia and in western Asia (Harris and Schroeder 1989; Weed Science Society of America 2012). The plant grows in elevations from sea level to 1600 m (Harris undated a).It is thought then that the invasive plant has great potential to spread in North America, however, there was speculation that spread to continental conditions may require an adapted genotype of the species (Harris and Schroeder 1989). It has been discovered that tansy ragwort in Europe has two chemotypes while in North America there has consistently only been one found to date. The different chemotypes have not been found related to specific inland or maritime climates. It is thought that a separate drought-adapted genotype has not been introduced in the B.C. interior. Conversely, since tansy ragwort reproduces sexually and contains large amounts of genetically variable material, it is possible this could result in evolution of the species to tolerate drier conditions (U. Schaffner, pers. comm. September 2012).

Within the areas that it has occupied in North America, tansy ragwort has had significant detrimental effects. The invasive plant was introduced into western Oregon in the late 1800's and within 50 years became the region's top noxious weed. The annual estimated losses due to this plant are up to $10 million (Weed Science Society of America 2012). This is in part due to the poisonous nature of the plant. Tansy ragwort contains pyrrolizidine alkaloids that remain present in the plant even when it is dried. These chemicals are not harmful until ingested. The liver turns them to pyrroles which attach to DNA, prevent cells from reproducing and over time leads to liver failure and death. A fatal dose which can range from 5-20% of body weight, may not be obvious for 1-18 months (Harris undated a). Cattle may accidentally feed on tansy ragwort when it grows among grasses or other plants they consume. When the tansy grows taller it is easier to avoid.

3.1 TANSY RAGWORT IN BRITISH COLUMBIA

In November 1977, tansy ragwort was only infesting the lower Fraser Valley and lower Vancouver Island (British Columbia Ministry of Agriculture 1977). In the fall of 1989, the B.C. Plant Protection Action Committee described the plant as continuing to spread on the lower mainland but not significantly on Vancouver Island. It also existed at this time in the B.C. interior in the Okanagan Valley and was considered to be expanding its range in B.C. (P. Harris and D. Schroeder, unpublished data, 1989, Biocontrol Subcommittee BCPPAC, B.C.).

The tansy ragwort site in the B.C. interior is located on the eastern slopes of the South Okanagan Valley approximately 30 km north of Penticton in an area described as Naramata or Chute Lake. The aspects of the slopes are west-facing and the plants exist at an elevation of 700 m in the Interior Douglas-fir BEC zone. (The Biogeoclimatic Ecosystem Classification (BEC) system is an ecological classification grouping similar landscapes called ecosystems into hierarchical classifications. The BEC in B.C. is defined as a particular plant community and its associated physiography, soil and climate that occupy a segment of the landscape (Meidinger and Pojar 1991). For more information on BEC, go to http://www.for.gov.bc.ca/hre/becweb/) In the U.S.A., Douglas-fir is considered a general indicator species for the potential habitat of tansy ragwort (Sheley and Petroff 1999). In 1994, the infested area was mapped and calculated to cover 1296.6 ha.

During the latter part of the 2000 decade, tansy ragwort in the lower Fraser Valley existed as small pockets and scattered plants and was considered under biological control in this area. However, in fall of 2011, it was noted that tansy ragwort was increasing on Vancouver Island. It has spread out from the Cedar/South Nanaimo area and has dense populations in the Inland Island highway median at Parksville, along the highway at Nanoose, between Port Alberni and Ucluelet, in the Sayward Valley and exists as far north as Port Hardy (E. Sellentin pers. comm. September 2011).

Figure 3 - Tansy ragwort near Nanaimo, Vancouver Island

In 2003, many large-scale forest fires burned in B.C. One such fire burned through part of the area infested with tansy ragwort in the Okanagan Valley and aided in the plant's continued spread. Tansy ragwort was still being actively treated by manual and chemical means in 2011 in the Okanagan Valley.

However, the plant has spread beyond the valley in this region and in 2010 it was also reported in Prince Rupert and in 2011 it was found on Haida Gwaii, in the Robson Valley and north of Prince George.

Figure 4 lists the number of tansy ragwort sites in B.C. to 2012 and their distribution across biogeoclimatic zones while Appendix A displays the sites in a map of the province.

Figure 4 - Distribution of tansy ragwort in provincial Biogeoclimatic zones to 2012

BEC	Number of Sites
BG	1
CDF	573
CMA	1
CWH	2852
ICH	16
IDF	493
MH	2
MS	307
PP	3
SBS	3
Total	4251

4. BIOLOGICAL CONTROL AGENTS FOR TANSY RAGWORT

In Canada and the U.S., biological control agents were sought to manage this invasive plant as a cost-effective alternative to chemical and mechanical treatments. The U.S.A. imported three biological control agents: the cinnabar defoliating moth *Tyria jacobaeae*; the root-feeding flea beetle *Longitarus jacobaeae*; and the seed-feeding fly *Botanophila seneciella* and found the best long-term control occurred when these agents were complemented with competitive vegetation (Sheley and Petroff 1999). An economic study of tansy ragwort in Oregon assessed the use of these three biological control agents to help mitigate the economic losses estimated in the millions of dollars due to (among others) decreased forage and cattle death from tansy ragwort poisonings and to decrease the costs necessary to control the invasive plant. The resulting report by Hans Radtke, An Economic Evaluation of Biological Control of Tansy Ragwort, discusses the success of this biological control program. In particular, data from "Table 6 Cost and Net Annual Benefits of Biological Control of Tansy Ragwort in 1974 Dollars" (Radtke 1993) has been plotted (Figure 5) to depict the overall economic benefits realized from the biological control of tansy ragwort by the seed fly, the flea beetle and the cinnabar moth. Coombs describes this cost benefit ratio as 15:1 or for every dollar that is spent a return of $15 is received (Oregon Department of Agriculture 2002).

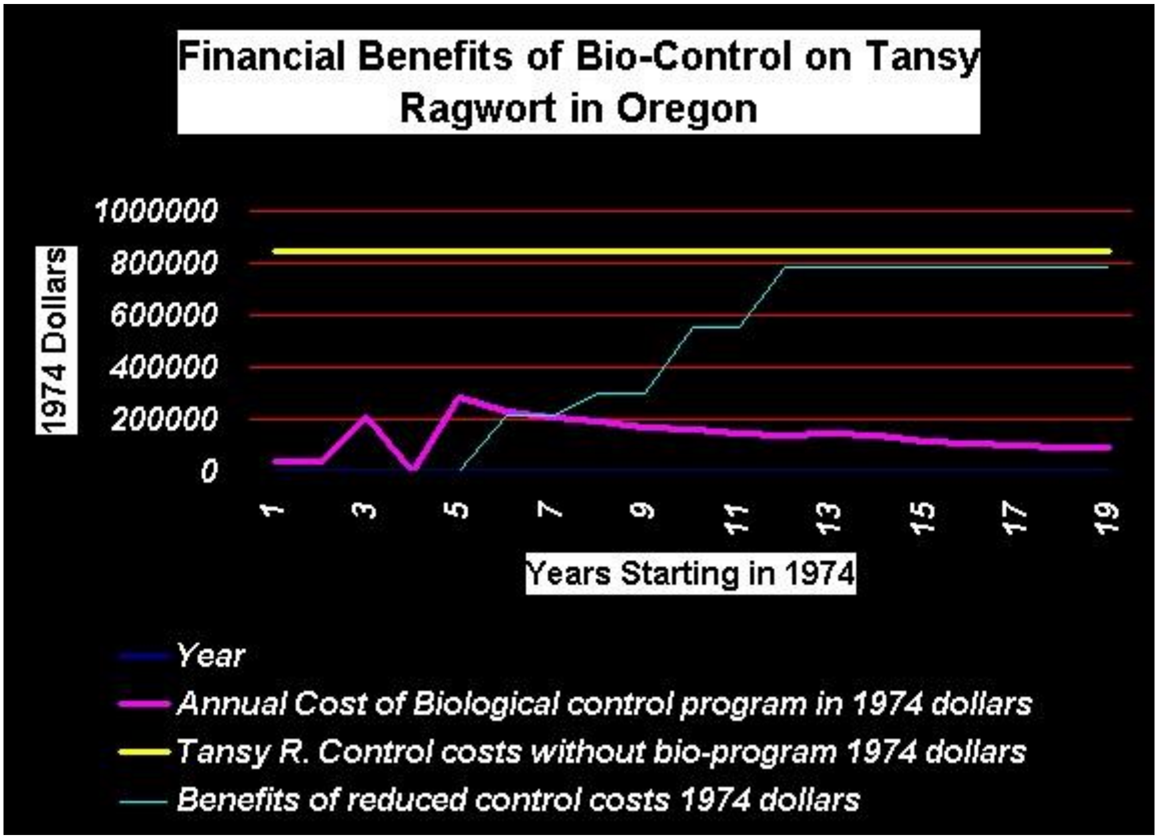

Figure 5 - Cost and Net annual benefits of biological control of tansy ragwort in 1974 dollars (Radtke 1993)

4.1 BIOLOGICAL CONTROL AGENTS FOR TANSY RAGWORT IN BRITISH COLUMBIA

Since the 1970's, several insect agents have been released in B.C. The dates included herein are the best available data from national historic records:

- *Tyria jacobaeae* (foliar-feeding moth) –1962;
- *Botanophila seneciella* (previously *Pegohylemyia or Hylemya seneciella* (Rees et al. 1996)) (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) – 1991;
- *Longitarsus gracilis* Kutschera (root-feeding flea beetle) – 2005; and
- *Longitarsus jacobaeae* Swiss strain (root-feeding flea beetle) - 2011.

4.2. HISTORY OF INTRODUCTIONS IN BRITISH COLUMBIA

When investigating potential biological control agents, it is important to note that damage to some parts of the plant is more harmful to the plant than others. For example, tansy ragwort has the ability to regenerate rapidly following defoliation when moisture is available.

The screening research for *Tyria jacobaeae*, the defoliating cinnabar moth was funded by New Zealand, the United States and Canada (Agriculture Canada) (Harris 2005). *T. jacobaeae*, was the first agent to be liberated against tansy ragwort in B.C. in 1962. Its numbers expanded in the lower mainland and defoliation of the plant in mid-summer was often extreme, removing leaves and flowers. However, the plant was able to regenerate later in the season with a new flush of green growth, but, if the moth's feeding was sufficient and timely, seed production would be greatly reduced.

Botanophila seneciella was introduced next at a single site in 1968 in the lower mainland. The agent was anticipated to be useful in feeding on remaining seed, particularly in higher elevation sites where establishment of *T. jacobaeae* might be unsuccessful. In habitat that was preferable for *T. jacobaeae*, it was thought the fly would survive in isolated plants that the moth did not prefer (Harris 2003a). The fly has been noted as widely established in southwestern B.C. but only found on 1% of the plants (Schroeder et al. 1989). Although beneficial to the complement of biocontrol agents on tansy ragwort, this agent was not believed to contribute a great deal as the target plant is not seed-limited, i.e. it can sustain itself with the production of root buds when the seedhead is damaged or following flowering (Harris undated d).

The screening research for the root-feeding flea beetle *Longitarsus jacobaeae* (Italian strain) was funded by New Zealand and the U.S.A (Harris and Crozier 2006). In 1971, *L. jacobaeae* (Italian strain) was introduced on the lower mainland. It was subsequently determined that an additional, very closely related flea-beetle species *Longitarsus flavicornis*, was included in one of the original releases in a mixed population that came via the U.S.A. (presumably from Italy) and was released in Nanaimo. There are no reliable external differences between the two flea beetles to tell them apart except *L. flavicornis* may appear a bit more reddish than the paler brown of *L. jacobaeae*. The differences between the two are discernible following dissection. *L. flavicornis* is an important biocontrol agent for the control of tansy ragwort in Australia (McLaren et al. 2000). It is estimated approximately 10% of the population released in Nanaimo was *L. flavicornis* (Harris undated d). Subsequent collections were made from the Nanaimo site and placed on the lower mainland, however, no *L. flavicornis* were recovered at these new sites and none have been found in Nanaimo in recent years. In Europe, *L. flavicornis* exists where the average winter temperature is above 0^{o}C, i.e. in southern England and south through western France and Spain to north Africa (Harris undated d).

By 1985, *B. seneciella* had not yet been found established and a second introduction was made. By 1989, *T. jacobaeae*, although established in the Lower Mainland, had declined in numbers significantly and was thought at that time to be ineffectual against tansy ragwort. Conversely, *L. jacobaeae* was well established near Nanaimo and Chilliwack and appeared to be having localized effects on its host, for example at two coastal sites, the larvae population had increased to a density of 13.1 and 5.0 per plant by 1981. In California, these larvae densities led to infestation collapses in the following few years (Harris and Schroeder 1989). However, *L. jacobaeae* was thought not to be dispersing fast enough to keep up with the spread of the plant nor was it able to attack tansy ragwort in higher elevation areas in the Okanagan Valley where winter started earlier in October as opposed to January on the coast (P. Harris and D. Schroeder, unpublished data, 1989, Biocontrol Subcommittee BCPPAC, B.C.; P. Harris pers. comm. March 1991). The decision was, therefore, made to pursue research for the summer breeding, root-feeding moth *Cochylis atricapitana* (P. Harris and D. Schroeder, unpublished data, 1989, Biocontrol Subcommittee BCPPAC, B.C.). An additional agent, *Ceutorhynchus atlanticus* was also proposed for screening research but this agent was never petitioned for release (Harris and Schroeder 1989).

The screening research for *C. atricapitana* was funded by Canada and Australia (Harris 2003b). *C. atricapitana* was subsequently released in B.C. in 1990 to a company named Bionomics which raised subsequent generations of the moths for releases in the lower mainland and on Vancouver Island in 1991.

Also in 1990, Agriculture and Agri-Food Canada reported *T. jacobaeae* to be playing a role in the reduction of tansy ragwort and *L. jacobaeae* to have nearly eliminated the plant in the Fraser Valley. *B. seneciella* was found and reported to decrease seed production by 10% and to be excellent at finding isolated plants (P. Harris unpublished data, 1991 Ag. Canada, Regina).

Agents released thus far had generally increased in sufficient numbers in south-coastal areas of B.C. to allow for their collection and transfer to the interior to attempt control of tansy ragwort at the Okanagan Valley site. Initial transfers included are shown in Figure 6.

Figure 6 - Initial transfer of tansy ragwort biocontrol agents into the Okanagan Valley

Agent	1992		1994		1997	
	Source	# Released	Source	# Released	Source	# Released
Tyria jacobaeae	Abbotsford	2000	Chilliwack	400		0
Longitarsus jacobaeae	Abbotsford	500	Nanaimo	1000	Chilliwack (600) & Nanaimo (900)	1500
Cochylis atricapitana		0	Nanaimo	100 infested rosettes		0

As of 1998, none of these agents released onto the bench on the east side of Okanagan Valley (elevation range 1094-1144 m) were found to be established. In particular, the Italian strain of *L. jacobaeae* was considered not adapted to the colder B.C. interior climate because the strain originated from southern Europe and, therefore, was not adapted to a short summer (CAB International 2001). The adults undergo a summer diapause and then begin breeding about October 1 in Canada (Harris undated d) and laying eggs too late in the season for survival where the growing degree days become shorter and temperatures cool too early. Plants in the Okanagan Valley are senesced by mid-October. Essentially the Italian strain of flea-beetle is not synchronized with the plants at higher elevations (CAB International 2001). However, *B. seneciella* was found dispersed in the Okanagan Valley and subsequent surveys of the fly revealed it to be also dispersed around the lower mainland and on Vancouver Island.

Due to the significant size and further potential for spread of tansy ragwort in the Okanagan Valley, the lack of success in getting the current complement of biological control agents to establish in this habitat and the need for an agent that inflicted the same type of damage as *L. jacobaeae* (Harris undated d) (*C. atricapitana* was expected to reduce tansy ragwort, but not solve it), discussions began to obtain an additional agent for B.C. The discussions focussed on a strain of *L. jacobaeae* from the Swiss Jura Mountains. The root-feeding flea-beetle was thought to be the most promising for controlling its host and the Swiss strain breeds earlier in the season. The Swiss strain *L. jacobaeae* inhabits areas in Europe with cool moist summers and early cold winters. The winter (Italian) and summer (Swiss) breeding biotypes of *L. jacobaeae* are widespread in Western Europe, interbreed and produce offspring with intermediate life cycles (Harris undated d). The Swiss strain had been approved for release In Canada in the 1970's but it did not establish when released. It had been permitted in 1993 for further imports to Canada, but, none were shipped, and it was also approved for import into the US in 2002. Additional screening was thought prudent given recent changes in phylogeny within the Asteraceae, including to the tribe Senecioneae, and a commitment to further investigate old (1970's) host specificity data (R. DeClerck-Floate, pers. comm., June 2010). Minimal screening would be required to address any untested native and plants of concern to B.C. and Canada. Screening research for this agent was initiated in 2005 by B.C.

Also in 2005, a shipment of 135 flea-beetles was obtained in May from Nova Scotia for release in the Okanagan Valley. It was thought this shipment contained *L. jacobaeae* (Italian strain) that may have adapted climatically in the cold maritime, following its previous introduction into Canada from Europe, to reproduce in the summer instead of the fall. Unfortunately, voucher specimens from the collection site were not sent to the Canadian Food Inspection Agency (CFIA) and the identification of the flea-beetles was not confirmed prior to their shipment and release. It was found subsequently that at least some of these flea-beetles were in fact *Longitarsus gracilis*. Host-specificity studies were planned for *L. gracilis* in conjunction with the studies on the Swiss strain of *L. jacobaeae* (to take advantage of the available test plants) to determine the consequences of this introduction and the potential to use this flea-beetle as a biological control agent. However, repeated attempts to collect more flea-beetles from the Nova Scotia site failed. Literature searches revealed this species to have a wider host range than its counterparts. It was decided to not redistribute this agent further. It was also determined through regular monitoring in the Okanagan Valley that *L. gracilis* was well established near a riparian zone and attempted removal from the province would require a broadcast application of general pesticide immediately adjacent to water, which did not take place.

In the meantime, attempts to have *T. jacobaeae* established in the provincial interior continued. In 2008, 1000 *T. jacobaeae* larvae were collected from Vancouver and Gabriola Islands and released into the Okanagan Valley. Monitoring of the release site has taken place each year from 2009 to 2012 and *T. jacobaeae* larvae and moths have been present each year. The plants have greatly dwindled on the site and the agent is dispersing. A second release (2273 larvae) was made in the Okanagan Valley in 2010, which has also established.

The Swiss strain of *L. jacobaeae* was again approved for import and the first shipment of 72 flea-beetles was released in May of 2011 in the Okanagan Valley. This flea-beetle has not been witnessed to survive through a winter, however, two subsequent shipments have been released at this same site in October 2011 and September 2012 with 702 and 1107 flea-beetles, respectively, and a third release of 898 flea-beetles was made nearby in June 2013. It is hopeful this agent will establish.

In 2012, the molecular analysis results of a 2011 collection of *Longitarsus* flea-beetles at the single release site of *L. flavicornis* (mixed with *L. jacobaeae* (Italian strain)) near Nanaimo revealed all the beetles to be *L. jacobaeae. L. flavicornis* is currently considered as not existing in B.C., however, further efforts are planned to collect and analyse further flea-beetles from this site.

Appendices B, C, D and E display the distribution of *T. jacobaeae*, *B. seneciella*, *L. jacobaeae*, and *C. atricapitana*, respectively, in the province to August 2012.

4.3 AGENT TIMING AND INTERACTION

Figure 7 - Timing of the life cycle stages of four tansy ragwort biocontol agents, their overlap and the recommended months for their handling

<table>
<tr><th rowspan="2">Biocontrol agent ↓</th><th rowspan="2">Activity of interest</th><th colspan="2">Jan</th><th colspan="2">Feb</th><th colspan="2">Mar</th><th colspan="2">Apr</th><th colspan="2">May</th><th colspan="2">Jun</th><th colspan="2">Jul</th><th colspan="2">Aug</th><th colspan="2">Sep</th><th colspan="2">Oct</th><th colspan="2">Nov</th><th colspan="2">Dec</th></tr>
<tr><th>1-15</th><th>16-31</th><th>1-15</th><th>16-28</th><th>1-15</th><th>16-31</th><th>1-15</th><th>16-30</th><th>1-15</th><th>16-31</th><th>1-15</th><th>16-30</th><th>1-15</th><th>16-31</th><th>1-15</th><th>16-31</th><th>1-15</th><th>16-30</th><th>1-15</th><th>16-31</th><th>1-15</th><th>16-30</th><th>1-15</th><th>16-31</th></tr>
<tr><td rowspan="4">Botanophila seneciella</td><td>Life cycle</td><td colspan="10">overwintering pupa</td><td>adult</td><td colspan="3">adult/egg/larva</td><td>larva</td><td colspan="3">larva/pupa</td><td colspan="6">overwintering pupa</td></tr>
<tr><td>monitor</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">adult</td><td colspan="4">larva</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>collect</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">adult</td><td colspan="4">larva</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Notes</td><td colspan="24">At high elevations, larva may emerge in July.</td></tr>
<tr><td rowspan="4">Cochylis atricapitana</td><td>Life cycle</td><td colspan="6">larva</td><td colspan="2">pupa</td><td colspan="2">adult</td><td colspan="2">larva</td><td colspan="2">Larva/pupa</td><td>adult</td><td colspan="2">adult/larva</td><td colspan="4">larva</td><td colspan="3">larva</td></tr>
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<tr><td>collect</td><td></td><td></td><td></td><td></td><td colspan="2">larva</td><td></td><td></td><td></td><td></td><td colspan="3">larva</td><td></td><td></td><td></td><td colspan="5">larva</td><td></td><td></td><td></td></tr>
<tr><td>Notes</td><td colspan="24">multiple larva/pupa found/plant root/crown. Excavate infested plants prior to larva vacating to pupate in the soil</td></tr>
<tr><td rowspan="4">Longitarsus jacobeaea (Italian)</td><td>Life cycle</td><td colspan="6">egg/larva</td><td colspan="2">pupa</td><td colspan="4">adult</td><td colspan="3">inactive adult</td><td colspan="3">adult</td><td colspan="6">adult/egg/larva</td></tr>
<tr><td>monitor</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">other</td><td colspan="5">adult</td><td></td><td></td></tr>
<tr><td>collect</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">adult</td><td></td><td></td></tr>
<tr><td>Notes</td><td colspan="24">Applicable to L. jacobaeae (Italian) strain only. Monitor OTHER refers to feeding evidence (Aug/Sep).</td></tr>
<tr><td rowspan="4">Tyria jacobaeae</td><td>Life cycle</td><td colspan="8">pupa</td><td colspan="2">adult</td><td colspan="2">adult/larva</td><td colspan="3">larva</td><td colspan="9">pupa</td></tr>
<tr><td>monitor</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">adult</td><td colspan="2">larva</td><td colspan="2">other</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>collect</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">larva</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Notes</td><td colspan="24">Monitor OTHER indicates the opportunity to monitor for presence only, extensive foliar feeding is typical of T. jacobaeae</td></tr>
</table>

4.4 AGENT HABITAT RANGE

Native (European) Distribution

Tansy ragwort has a widespread native range (see Section 3). The imported biological control agents used in B.C. come from a variety of locations within the host plant's range:

- *T. jacobaeae* is native from Europe to west central Asia, the original source of the agent was Switzerland (Harris 2005);
- *B. seneciella* was obtained through U.S.A sources of the fly through the 1960's which came from Paris, France. After May 1984, the proposed source for additional releases was Washington (P. Harris pers. comm. May 1984);
- *L. jacobaeae* (Italian strain) is native from the north Mediterranean to southern Scandinavia and from Ireland east to Siberia and Tibet, the original source of the agents was Italy (Harris and Crozier 2006);
- *L. flavicornis* is native to Italy, more specifically is the only species known from Milan, to southern England and south through western France and Spain to north Africa (Harris undated d);
- *C. atricapitana* is native from North Africa to southern Sweden and east to Poland and then to southern Russia. It is most common in coastal Western Europe. The original source was of Spanish moths via Australia in 1968 (Harris 2003b); and
- *L. jacobaeae* (Swiss strain) is likely native to north of the Alps from eastern France to Austria but may have a wider range as *L. jacobaeae* also is found throughout central, northern and eastern Europe. The source for B.C. is Switzerland (De Clerck-Floate et al. 2010).

Predicted North American Distribution

Biological control of tansy ragwort has done well in areas with moderate temperate and Mediterranean climates. *L. jacobaeae* has become well established and added to the control of its host in Oregon and elsewhere. There was concern with the original complement of agents to follow the invasive plant into colder climates. To view the distribution of treatment and dispersal sites of *T. jacobaeae, B. seneciella, L. jacobaeae* (Italian), and *C. atricapitana* in the province, see Appendices B, C, D and E respectively. If the Swiss strain of *L. jacobaeae* reflects its native range, these flea-beetles may be found at altitudes from 300 to greater than 1400 m and minimum temperatures of -25°C (De Clerck-Floate et al. 2010).

5. USING BIOLOGICAL CONTROL AGENTS FOR TREATMENT OF TANSY RAGWORT

Redistribution of agents is a critical part of a biocontrol program. It is important for invasive plant managers to determine whether resources should be allocated to redistributing any biocontrol agent or whether the agent may be effectively self-dispersing in a particular area. Referring to FLNR's text on the life cycle of individual biocontrol agent species found at http://www.for.gov.bc.ca/hra/Plants/downloads/AgentHandlingMatrix.pdf , to the IAPP Application found at http://www.for.gov.bc.ca/hra/Plants/application.htm and field monitoring for the presence of agents will assist in this determination.

To ensure efficient distribution throughout the biocontrol agents' potential provincial range, invasive plant managers should endeavour to recollect from established field sites and make releases into new sites. First, however, tansy ragwort infestations should be investigated for the presence of other agents not only to decrease competition for resources if the existing population is significant as can happen at intervals with *T. jacobaeae*, but, also to determine if a release of the agent is necessary. For general information regarding redistribution of biological control agents, please refer to Module 1.9 Biological Treatment & Monitoring of the IAP Reference Guide which is located at http://www.for.gov.bc.ca/hra/Publications/invasive_plants/IAPP_Reference_Guide/Module%201.9.pdf . For summarized layouts of each of the agent's life cycle stages, refer to http://www.for.gov.bc.ca/hra/Plants/biocontrol/bcmatrix.htm. For more detailed information on collecting, shipping and releasing methods and equipment, please refer to the document Biocontrol Agent Handling Techniques, for the collecting, shipping and releasing in B.C. which is located at http://www.for.gov.bc.ca/hra/Plants/downloads/HandlingTechniquesV2.pdf .

Treatment of tansy ragwort and subsequent monitoring of those activities in B.C., in particular on the lower mainland and on Vancouver and the Gulf Islands, is faced with the issue of extreme urbanization. Over the almost 50 years since treatment began, urban development has had a significant impact on the make-up of this landscape. Some sites where biological control agents have been released no longer exist and are replaced with homes, commercial buildings or roads, while other sites may have the tansy ragwort population increase or decrease from these same types of activities. This has led to difficulties in understanding micro-site habitat suitability of the various species. However, monitoring for the dispersal of the agents from their original point of release has been effective.

5.1 FIELD APPLICATION OF INDIVIDUAL TANSY RAGWORT BIOCONTROL AGENTS

For summarized descriptions on working in the field with each of the three agents transitioning to secondary, namely, *T. jacobaeae*, *L. jacobaeae* (Italian) and *C. atricapitana*, refer to the Appendices G, H, and I, respectively.

5.2 MONITORING DATA OF BRITISH COLUMBIA TANSY RAGWORT BIOCONTROL SITES

Six basic questions were investigated from IAPP data in October 2012 and biocontrol development records for each of the agents *T. jacobaeae, B. seneciella, L. jacobaeae* (Italian), and *C. atricapitana*.

1. Was there a preferred Biogeoclimatic (BEC) zone in which to release each species that led to establishment?
2. What were the BEC zones each species dispersed into?
3. What was the minimum number of agents released for each species that led to establishment?
4. Was there a preferred month to collect and release each species that led to establishment?
5. Was there a preferred field source to collect each species from that led to establishment?
6. Did the duration between collection and release of the agent affect its establishment?

It is important to understand the nature of monitoring when looking at the results of these questions and the data from which this information was summarized (located in Appendix F). Sites are monitored multiple times for several reasons:

- To determine establishment of the agent at a site. Finding agents at any given site, at any given time can be difficult and, therefore, negative monitoring results are generally thought of as unknown establishment. However, for the purposes of the tables within this document, unknown survival describes sites that have not been monitored;
- To investigate the timing of the life cycle of the agent in different habitats;
- To determine the correct time of the year to look for and collect the agent which can include purposely looking early or late within the window during which the agent is suspected to be visible, thus having a high likelihood that the result will be negative;
- To investigate specific details about the agent, such as what does the feeding damage look like on the plant and what affect it may have, where the agent may be located on the plant during different stages of its life cycle or time of the day or season, etc.;
- To determine if the population of the agent is building sufficiently to allow for collection; and
- To determine which sites are still in existence.

Additionally, there is a finite annual capacity to perform monitoring and dispersal work, which can result in all treatment sites not investigated regularly or at all and not all potential areas investigated for dispersal of the agent.

A negative monitoring occurrence, therefore, can be an artifact of the monitoring activity and not necessarily reflect the agent's presence, for example, that may be positive at a different time or in a different location. Also, some monitoring may be recorded as negative but could reflect site conditions such as no plants available due to attack by different agents or anthropogenic manipulation of the site.

Tyria jacobaeae

The minimum number of *T. jacobaeae* larvae collected and redistributed to a new site that resulted in establishment was 50 larvae (Appendix F). These agents were collected from a CWHdm BEC zone and released into this same BEC zone in July. Although the number of releases made in each of the BEC zones listed is not large (Figure 8), it appears that CWHdm is agreeable for survival of *T. jacobaeae* as is also reflected in the fact that the agent has dispersed further on its own into this BEC zone (Figure 9).

It is always preferable for the agents to be collected and redistributed within the same type of habitat. If the recipient site was 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. For example, IDFdm1 does not appear to be a preferred BEC zone (Figure 8), therefore, more larvae may help to ensure establishment. Early attempts (400 collected in 1992 and 1000 in 1994 both from CWHdm) to establish the agent into the IDF failed, but, later attempts (1000 collected in 2008 and 2273 in 2010 both from CDFmm) were successful. Success in the IDF could have been affected by the originating BEC zone, the handling of the larvae or the speed by which they were transferred and released into their new location (great care was taken to feed them abundantly and release them as fast as possible), or that the agent had acclimatized to B.C. Between Figures 8 and 9, it appears that all BEC zones the agent has been released into to date have allowed it to establish. For tansy ragwort sites in BEC zones different than those included below (see also Table 1, Appendix F)), it is recommended to collect the larvae from as similar BEC zones as possible and to handle them and release them as fast as can be managed.

There does not appear to be a preferred month for subsequent survival within the two months that the agent can be collected within (Figure 10). However, it is recommended to collect the larvae when they are of sufficient size. At any time, larvae will exist in varying sizes. The majority of the larvae should be greater than or equal to 20 mm long x 5 mm wide.

With respect to a preferred source of collection, most of the sites yield agents that readily establish at new sites, except for Sumas Mountain (33% survival). It cannot be determined if agents collected from this site are not healthy or whether subsequent handling of these agents resulted in poor condition and, therefore, poor survival, but, a contributing factor would have been the habitat of the release site as two of the failed sites were releases made in 1992 and 1994 in the IDFdm1 that did not establish (Figure 11).

The question was also asked if the length of time between collecting the caterpillars and releasing them could affect the success rate. These activities were done over a range of days (however, not all data is available) and cannot be discerned to be a cause for the agent to not establish at a site (Figure 12).

Figure 8 - *Tyria jacobaeae* survival per Biogeoclimatic zone

BEC	Survival Y	Survival N	Survival Unknown	Total No.
CDFmm	5 (71%)	2 (29%)		7 (100%)
CWHdm	4 (100%)			4
CWHxm1	7 (41%)	7 (41%)	3 (18%)	17
IDFdm1	1(33%)	2 (67%)		3
IDFxh	1 (100%)			1
Total	**18 (56%)**	**11 (34.5%)**	**3 (9.5%)**	**32**

Figure 9 - *Tyria jacobaeae* dispersal Biogeoclimatic zones

BEC	Total
CDFmm	17 (50%)
CWHdm	5 (15%)
CWHxm1	10 (29%)
IDFdm1	2 (6%)
Total	**34**

Figure 10 - *Tyria jacobaeae* survival per release month

Month	Survival Y	Survival N	Survival Unknown	Total No.
Unknown	6 (71%)	1 (14%)	1 (14%)	8
June	1 (50%)	1 (50%)		2
July	11 (50%)	9 (41%)	2 (9%)	22
Total	**18 (56%)**	**11 (34.5%)**	**3 (9.5%)**	**32**

Figure 11 - *Tyria jacobaeae* survival per source location

Source	Survival Y	Survival N	Survival Unknown	Total No.
Unknown	6 (86%)	1 (14%)		7
AAFC			1 (100%)	1
Bridal Falls	1 (100%)			1
Chilliwack	2 (50%)	2 (50%)		4
Haslam & Gabriola	1 (100%)			1
Haslam	2 (50%)		2 (50%)	4
Lazlo Lane, Cedar	1 (100%)			1
Nanaimo	1 (100%)			1
Sumas Mountain	4 (33%)	8 (67%)		12
Total	**18 (56%)**	**11 (34.5%)**	**3 (9.5%)**	**32**

Figure 12 - Days between collection and release of *Tyria jacobaeae*

Site	Location	No. Released	Collection Date	Treatment Date	Days Between	Established
101669	Chilliwack	1 (=unknown quantity)	Unknown	1900-01-02 (default date)	Unknown	Unknown
101658	King Rd. Abbotsford	3300+856	Unknown + Unknown	1962-01-01 & 1967-01-01	Unknown	Yes
101659	McKenzie Rd. Abbotsford	5000	Unknown	1963-01-01	Unknown	Yes
102375	Richardson Rd. Nanaimo	13,000+80+ 6200+2800	Unknown + Unknown + Unknown + Unknown	1964-01-01 & 1965-01-01 & 1966-01-01 & 1981-01-01	Unknown	Yes
101665	Cultus Lake Chilliwack	3500	Unknown	1972-01-01	Unknown	Yes
101666	Clearbrook Road Abbotsford	300	Unknown	1974-01-01	Unknown	No
101667	Cannor Road Chilliwack	300	Unknown	1981-01-01	Unknown	Yes
101670	Nicomen slough	500	Unknown	1989-07-10	Unknown	Yes
101671	25214-56th St. Langley	250	Unknown	1989-07-11	Unknown	No
101672	South side of 12B Rd. Langley	250	Unknown	1989-07-11	Unknown	No
102383	Keeping Rd. Abbotsford	250	Unknown	1989-07-11	Unknown	Yes
101674	Hudson Rd. Chemainus	125	Unknown	1989-07-26	Unknown	Yes
101675	Kevan Dr. Gabriola Island	300	Unknown	1989-07-27	Unknown	No
101676	Aldergrove	150	Unknown	1990-07-24	Unknown	No
101677	Huntington Rd. Langley	110	Unknown	1990-07-24	Unknown	No
101678	Ross Rd. Abbotsford	150	Unknown	1990-07-24	Unknown	No
101679	Starr Rd. Abbotsford	100	Unknown	1990-07-24	Unknown	Yes
101655	Powerline Naramata	1000	Unknown	1992-06-22	Unknown	No
101827	Chute Lake Rd. 2nd site powerline	400+1000	Unknown	1992-06-22 & 1994-07-14	Unknown	No
112297	Stamps Rd. Duncan	1 (= unknown quantity)	Unknown	1994-10-13	Unknown	Yes
101680	Glover Rd. & 216th St. Langley	200	1995-07-19	1995-07-19	0	Yes
101681	88th & 257th St. Langley	200	1995-07-19	1995-07-19	0	No
101682	River Rd. & Hudson Rd. Ladner	200	1995-07-19	1995-07-19	0	No
101683	88th Ave. &264th St.	200	1995-07-19	1995-07-19	0	Yes
101684	Old rock quarry north of Seabird Cafe Hwy 7	50	1996-07-26	1996-07-26	0	Yes
219933	Cedar-Huddington Road	100	Unk.	2006-06-13	Unknown	Yes
222684	Island highway	100	2006-07-19	2006-07-19	0	Yes
205096	Anderson Bay FSR Cortese	100	2006-07-19	2006-07-22	3	Unknown
241320	Anderson Bay FSR, Texada Island	100	2006-07-18	2006-07-22	4	Unknown
241321	Anderson Bay near airstrip,	200	2007-07-18	2006-07-22	4	Unknown

	Texada Island					
6820	Chute Lake Rd.	1000	2008-07-29	2008-07-31	2	Yes
210081	3.5 km off Lakeshore Rd. Okanagan Valley	2273	2010-07-14	2010-07-17	3	Yes

Botanophila seneciella

The earlier of the two releases of this agent was monitored in 2002. No agents were found, however, subsequent dispersal monitoring (Figure 13) has recorded the flies at thirty-one sites spread across the Lower Mainland, Vancouver Island, two Gulf Islands (Salt Spring and Gabriola) and into the interior in the Okanagan Valley (IDFdm1). Observations that have not been recorded in IAPP have noted this agent to exist at many tansy ragwort sites and not be restricted by a forest canopy. Of note, Markin (G. Markin, unpublished data, 1998, Montana) described the fly as well established and able to colonize the coniferous forest environment of the northern Rockies. In B.C., attack by the fly has resulted in a decrease in seed by approximately two-thirds of the capitula attacked for a total reduction of about 5%. However, since the plants are able to produce root buds and sustain themselves when the flowerhead is attacked or flowering is complete, the impact of the fly by itself is negligible (Harris undated d). Subsequently, Harris (P. Harris unpublished data, 1991 Ag. Canada, Regina) reported the fly to reduce the seed by 10% and was proving efficient at finding isolated plants. This latter characteristic, attacking isolated plants, is beneficial as *T. jacobaeae* does not avoid feeding on flowers containing *B. seneciella* but prefers dense infestations of tansy ragwort (Harris 2003a).

It is recommended to first monitor for dispersal of *B. seneciella* in new BEC zones that are in the proximity of the known infested areas as they may already be there. Thereafter, collect and redistribute this agent from as similar BEC zones as possible into the sites that are not intended for chemical control.

Figure 13 - *Botanophila seneciella* dispersal per Biogeoclimatic zone

BEC	Total Sites
CDFmm	9 (29%)
CWHdm	8 (26%)
CWHds1	1(3%)
CWHxm1	10 (32%)
IDFdm1	3 (10%)
Total	31

Longitarsus jacobaeae (Italian)

The minimum number of *L. jacobaeae* flea-beetles collected and redistributed to a new site that resulted in establishment was 150. These agents were collected from a CWHdm BEC zone and released into the CDFmm BEC zone in November. Although the number of releases made in each of the BEC zones listed is not large (Figure 14), it appears that CDFmm is agreeable for survival of *L. jacobaeae* as is reflected in the fact that the agent has dispersed further on its own into this BEC zone (Figure 15).

It is always preferable for the agents to be collected and redistributed within the same type of habitat. If the recipient site was 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. However, this has not proven successful in the IDF. Agent collection numbers have ranged from 500 to 1000, have come from BEC zones CDFmm, CWHdm and CWHxm1 and were collected in the months, April, September and October. Despite the variety of these factors, no release of this strain of flea-beetle has established in the IDF (Figure 16). All listed Coastal BEC zones have had *L. jacobaeae* (Italian) establish and disperse. Much of the area on the lower mainland contains *L. jacobaeae*.

There does not appear to be a preferred month to handle *L. jacobaeae* (Figure 17). The only months during which complete failure to establish has been recorded were at a single site with one release made in April and two releases made in October, all into the IDF. The failure to establish is likely due to the BEC zone released into, not the months the agents were handled.

All sources of *L. jacobaeae* have yielded a measure of success, except for the combined source of Sumas Mountain, Nanaimo and Vedder Canal, Chilliwack (Figure 18). However, again the failure to establish is likely due to the BEC zone the agents were released into (IDF) and not this combination of sources. These same sources have yielded successful establishment at other release sites.

Szucs et al (2011) have found the *L. jacobaeae* (Italian strain) is surviving, interbreeding and producing hybrids with the Swiss strain in cold winter climates of Montana. At this point in time, further studies are needed to understand whether the resulting traits of development time, fecundity, longevity, egg size and sex ratio are favourable and hence whether releases of both the Italian and Swiss strains of *L. jacobaeae* at the same sites should be done or avoided.

Figure 14 - *Longitarsus jacobaeae* survival per Biogeoclimatic zone

BEC	Survival Y	Survival N	Survival Unknown	Total No.
CDFmm	18 (100%)			18
CWHdm	14 (82%)	2 (12%)	1 (6%)	17
CWHxm1	19 (86%)	3 (14%)		22
IDFdm1		3 (100%)		3
Total	**51 (85%)**	**8 (13%)**	**1 (2%)**	**60**

Figure 15 - *Longitarsus jacobaeae* dispersal Biogeoclimatic zones

BEC	Total
CDFmm	10 (39%)
CWHdm	4 (15%)
CWHxm1	12 (46%)
Total	**26**

Figure 16 - *Longitarsus jacobaeae* survival per number released per Biogeoclimatic zone

Number Released	BEC	Est Y	Est N	Unk.
Unk.	CDFmm	1		
Up to 199	CDFmm	1		
200-299	CDFmm	2		
	CWHdm	4		
	CWHxm1	9		
300-399	CWHdm	3		
	CWHxm1	2		
400-499	CDFmm	1		
	CWHdm	2		
	CWHxm1	1		
500-599	CDFmm	2		
	CWHdm	2		
	CWHxm1	3	1	
600-699	CWHdm	1		
700-799	CDFmm	2		
	CWHdm	1		
	CWHxm1	4		
900	IDFdm1		1	
1000	CDFmm	7		
	CWHdm		1	
	CWHxm1	1	1	
	IDFdm1		2	
1200	CDFmm	1		
	CWHdm	1		
1500	CWHdm			1
2000	CDFmm	1		
	CWHdm	1		

Figure 17 - *Longitarsus jacobaeae* survival per release month

Month	Survival Y	Survival N	Survival Unknown	Total No.
Unknown	8 (100%)			8
August, November & October	1 (100%)			1
May	1 (100%)			1
September	2 (67%)	1 (33%)		3
October	29 (85%)	5 (15%)		34
October & April		1 (100%)		1
November	10 (83%)	1 (8.5%)	1 (8.5%)	12
Total	**51 (85%)**	**8 (13%)**	**1 (2%)**	**60**

Figure 18 - *Longitarsus jacobaeae* survival per source location

Source	Survival Y	Survival N	Survival Unknown	Total No.
Unknown	2 (100%)			2
Cassidy/Nanaimo		1 (100%)		1
Cedar/Nanaimo	2 (100%)			2
Chilliwack-Vedder Canal		1 (100%)		1
England & unknown	1 (100%)			1
Nanaimo	15 (88%)	1 (6%)	1 (6%)	17
Nanaimo/Oregon	1 (100%)			1
Peardonville	2 (100%)			2
Sumas Mountain	27 (87%)	4 (13%)		31
Sumas Mountain & Nanaimo & Vedder canal, Chilliwack		1 (100%)		1
UBC	1 (100%)			1
Total	**51 (85%)**	**8 (13%)**	**1 (2%)**	**60**

Cochylis atricapitana

C. atricapitana moths are difficult to collect as they are nocturnal (Powell et al. 1994). They have been observed in daylight hours, but, appear too fragile for collection purposes (S. Cesselli, pers. comm., Feb. 2013). Releases, therefore, have been made with larvae infested plants. The minimum number of *C. atricapitana* infested plants collected and redistributed to a new site that resulted in establishment was 50 (Appendix F). Except for the original releases raised in the Bionomics labs (2827, 398, 869 and 481 estimated larvae infesting plants) all subsequent collections made from the field in B.C. have been small in comparison. These subsequent releases were made with plants dug from sites established with the Bionomic releases; however, no plants were dissected at the time of collection to confirm the average number of *C. atricapitana* larvae infesting the roots. A few plants from these collection sites were sent to AAFC for dissection. It was confirmed that the roots did house *C. atricapitana* larvae along with *L. jacobaeae* larvae (D. Ralph, pers. comm., Mar. 2013). There have been eight releases of 50 infested plants, five of which have survived (Figure 19). There does not appear to be distinguishing factors from IAPP data to explain the successes or failures. The five established releases (made with 50 infested plants) were collected in May (4 releases) and October (1 release) while all the failed releases were collected in May. There are only two sources that supplied all eight of these releases (in fact, all the releases to 1996), the Sumas Mountain Road site and the Chemainus/Nanaimo site. The BEC zones of these sites are CWHdm and CDFmm, respectively. The established releases were placed into the CWHxm1 and the CWHdm, as were the failed releases.

The various months for handling the moth also show varying levels of success (Figure 20). Although the numbers for comparison are very small, October does appear to be a less successful month to collect larvae infested plants than in the spring.

Again, the sources of agents for collection have yielded varying success and one has shown no success, however, this site that failed to establish is in the IDFdm1 in the Okanagan Valley (Figure 21).

The Coastal BEC zones all have a variable success rate (Figure 22), but average 67% and higher and two have had dispersal sightings recorded for them (Figure 23). The IDF, on the other hand has had no success in having this agent establish.

The question was also asked if the length of time between harvesting the plants and transplanting them could affect the success rate. These activities were done quite quickly and do not appear to be a cause for the agent not establishing at a site (Figure 24).

Figure 19 - *Cochylis atricapitana* survival per release number

Number Released	Survival Y	Survival N	Survival Unknown	Total No.
50 plants	5 (62.5%)	3 (37.5%)		8
59-70 plants	1 (33%)	2 (67%)		3
100 plants		2 (100%)		2
150 plants	1 (100%)			1
398 moths+100 plants-481 moths	2 (100%)			2
869 moths	1 (100%)			1
2827 moths	1 (100%)			1
Total	**11 (61%)**	**7 (39%)**		**18**

Figure 20 - *Cochylis atricapitana* survival per release month

Month	Survival Y	Survival N	Survival Unknown	Total No.
April	3 (60%)	2 (40%)		5
April & October	1 (100%)			1
May	6 (67%)	3 (33%)		9
October	1 (33%)	2 (67%)		3
Total	**11 (61%)**	**7 (39%)**		**18**

Figure 21 - *Cochylis atricapitana* survival per source location

Source	Survival Y	Survival N	Survival Unknown	Total No.
Bionomics	3 (100%)			3
Bionomics & Abbotsford	1 (100%)			1
Fraser Valley		1 (100%)		1
Nanaimo	1 (33%)	2 (67%)		3
Sumas Mountain Rd.	6 (60%)	4 (40%)		10
Total	**11 (61%)**	**7 (39%)**		**18**

Figure 22 - *Cochylis atricapitana* survival per Biogeoclimatic zone

BEC	Survival Y	Survival N	Survival Unk.	Total No.
CDFmm	2 (67%)	1 (33%)		3
CWHdm	4 (67%)	2 (33%)		6
CWHxm1	5 (71%)	2 (29%)		7
IDFdm1		2 (100%)		2
Total	**11 (61%)**	**7 (39%)**		**18**

Figure 23 - *Cochylis atricapitana* dispersal Biogeoclimatic zones

BEC	Total
CWHdm	4 (44%)
CWHxm1	5 (56%)
Total	**9**

Figure 24 - Days between harvest and transplant of plants infested with *Cochylis atricapitana*

Site	Source	Location	BEC	No. Released	Date Collected	Date Released	Days Between	Established
102401	Bionomics	Private Abbotsford	CWHdm	2827 estimated larvae	Unknown	1991-04-02	Unknown	Yes
101829	Bionomics + Abbotsford	Sumas Mountain Rd. (private) Abbotsford	CWHdm	398 estimated larvae + 100 plants	Unknown+ Unknown	1991-04-05 +1994-10-06	Unknown	Yes
102383	Bionomics	Keeping Rd. (private) Abbotsford	CWHdm	869 estimated larvae	Unknown	1991-04-11	Unknown	Yes
101831	Bionomics	Chemainus/Nanaimo	CDFmm	481 estimated larvae	Unknown	1991-04-12	Unknown	Yes
101827	Nanaimo	Chute Lake Rd.	IDFdm1	70 plants	1994-04-25	1994-04-25	0	No
112295	Sumas Mountain Rd.	Dawson Rd. (private) Abbotsford	CWHdm	100 plants	1994-10-06	1994-10-06	0	No
101834	Nanaimo	Mudge Island	CDFmm	100 plants	1994-10-12	1994-10-13	1	No
101835	Sumas Mountain Rd.	Polar Avenue, Abbotsford	CWHxm1	50 plants	1995-05-17	1995-05-17	0	No
101836	Sumas Mountain Rd.	Cox Rd.	CWHdm	50 plants	1995-05-17	1995-05-17	0	Yes
101837	Sumas Mountain Rd.	Vedder Canal dyke	CWHxm1	50 plants	1995-05-17	1995-05-17	0	Yes
101838	Sumas Mountain Rd.	Old Yale Rd.	CWHxm1	50 plants	1995-05-17	1995-05-18	1	Yes
101839	Sumas Mountain Rd.	Private property	CWHdm	50 plants	1995-05-17	1995-05-18	1	No
101840	Sumas Mountain Rd.	Harris road (private) Abbotsford/Matsqui	CWHxm1	150 plants	1995-05-17	1995-05-18	1	Yes
101841	Sumas Mountain Rd.	Glenmore Rod. Abbotsford	CWHxm1	50 plants	1995-05-17	1995-05-18	1	No
101843	Sumas Mountain Rd.	McKee Rd (private) Abbotsford	CWHxm1	50 plants	1995-05-19	1995-05-19	0	Yes
102388	Sumas Mountain Rd.	Clayburn Abbotsford/Matsqui	CWHxm1	50 plants	1995-05-17	1995-05-18	1	Yes
102430	Nanaimo	Salt Spring (private)	CDFmm	60 plants	Unknown	1996-05-16	Unknown	Yes
6820	Fraser Valley	Chute Lake Rd.	IDFdm1	59 plants	2008-04-14 & 16	2008-04-17	3-1	No

6. SUMMARY

Tansy ragwort has been reported to be resurging in recent years, especially on Vancouver Island. Presumably this is due to the cool wet springs that much of the province has been experiencing but may also be due in part to local disturbance as both may lead to germination of buried seeds that the biocontrol agents cannot access. McEvoy and Cox (1991) mention the existence of an invulnerable stage in the plant's life cycle (in this case buried seed) can have significant effects on the "dynamics of biological insect control systems". In Oregon, they also measured the environmental conditions of precipitation, elevation, land use, and year of *L. jacobaeae* releases (while also having releases of *T. jacobaeae* and B. *seneciella*) and found they did not influence the speed of, nor level of success of, the biocontrol agents in controlling tansy ragwort. It is expected the biological control agents will increase in numbers in their natural predator-prey cycle with their host plant once it is available. Monitoring of previously controlled sites followed by disturbance or significant rainfall may reveal localized plant resurgence and potential action required such as re-introduction of locally extirpated agents due to lack of food.

Multiple agents are always recommended for control of tansy ragwort. To date, the most significant effect on tansy ragwort in B.C. has been as a result of *T. jacobaeae* and *L. jacobaeae* (Italian). Continued dispersal monitoring of these two agents, along with *B. seneciella and C. atricapitana*, particularly along the fringes of where they are currently known to exist is recommended to improve understanding and prepare for movement of the agents in the future as tansy ragwort spreads. See Appendices G, H and I for specific information on the description, effects and handling of *T. jacobaeae*, *L. jacobaeae* (Italian strain) and *C. atricapitana*, respectively as they transition to secondary, operational biocontrol agents. McEvoy and Cox (1991) showed that biological control insects are able to keep tansy ragwort at low population levels. They demonstrated that the agents caused heavy mortality of smaller, younger plants and a sharp decline in the reproduction of large mature plants in the infestations. Subsequent monitoring and collection of quantified plant survey data is recommended to show success of biocontrol.

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______. undated c. *Longitarsus jacobaeae* (Waterhouse) and *L. flavicornis* Stephens. root beetles, tansy ragwort *Senecio jacobaeae* L. Ag Canada Res. Stn.

______. undated d. Release of the summer-breeding biotype of *Longitarus jacobaeae* against tansy ragwort (*Senecio jacobaeae*) in Canada. Ag Canada Res. Stn. Lethbridge.

______. undated e. *Tyria jacobaeae* (Cinnabar moth), Defoliator, Tansy ragwort *Senecio jacobaeae* (L.). Ag. Canada Res. Stn.

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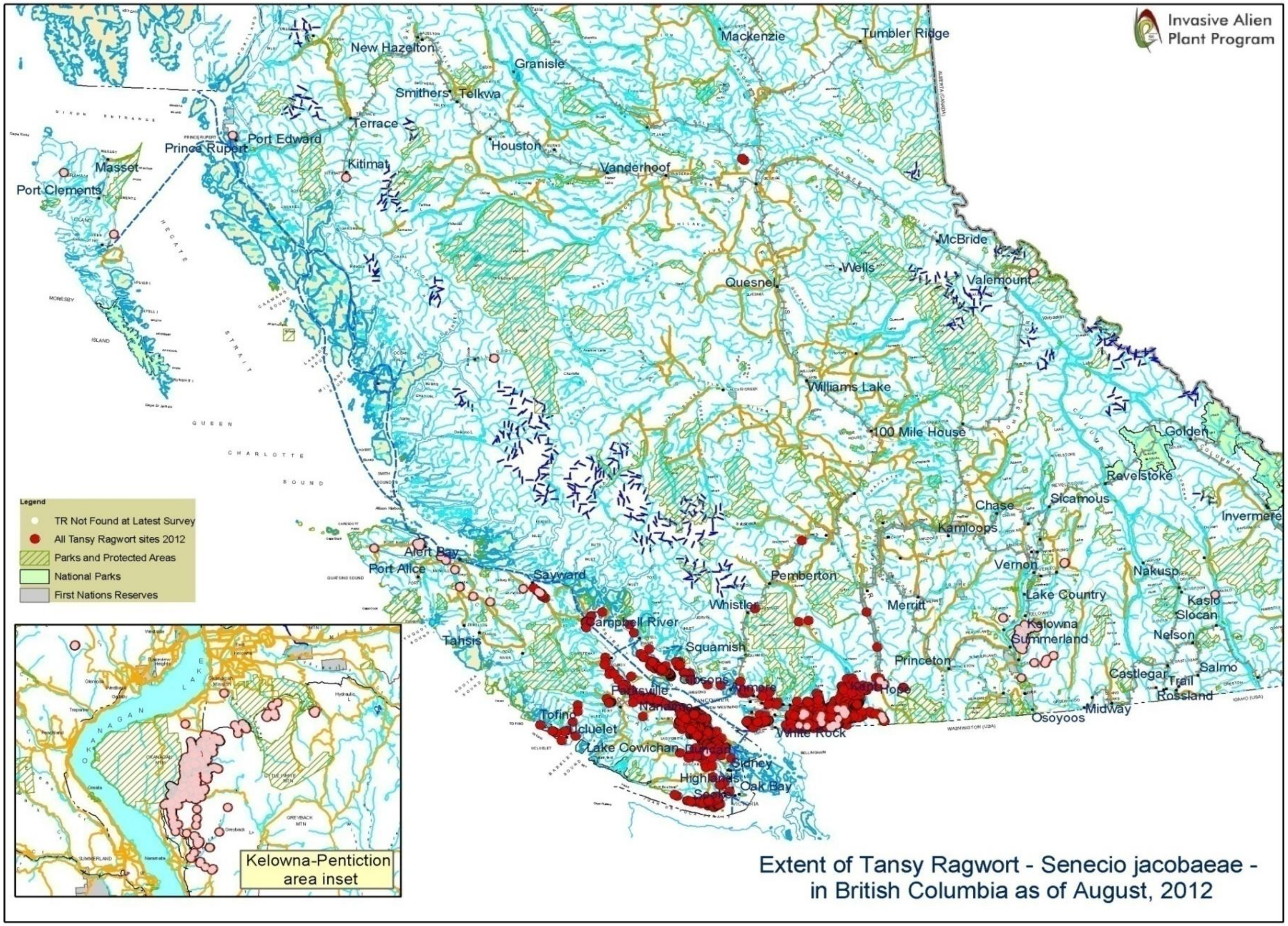
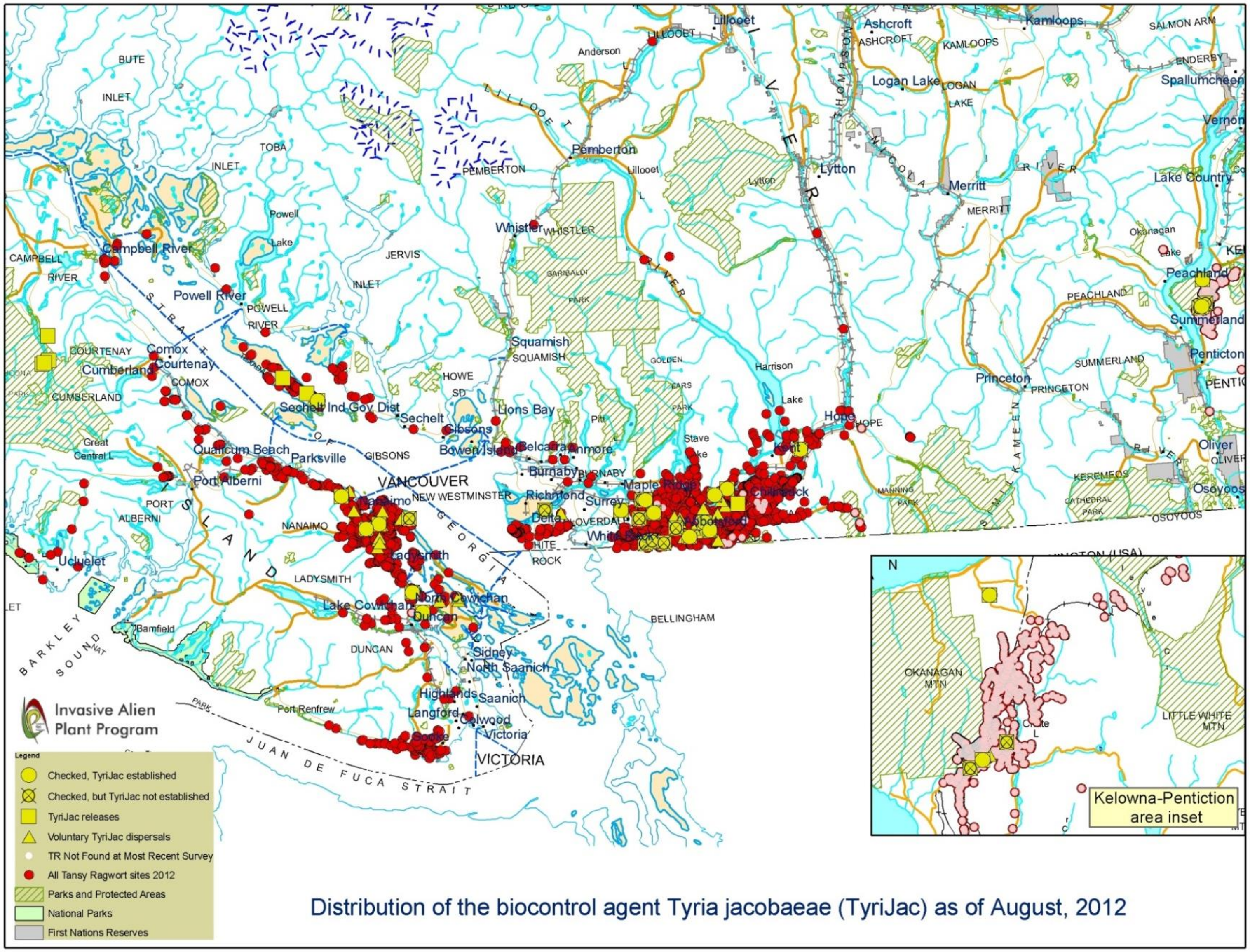
APPENDIX A. Extent of Tansy ragwort in British Columbia

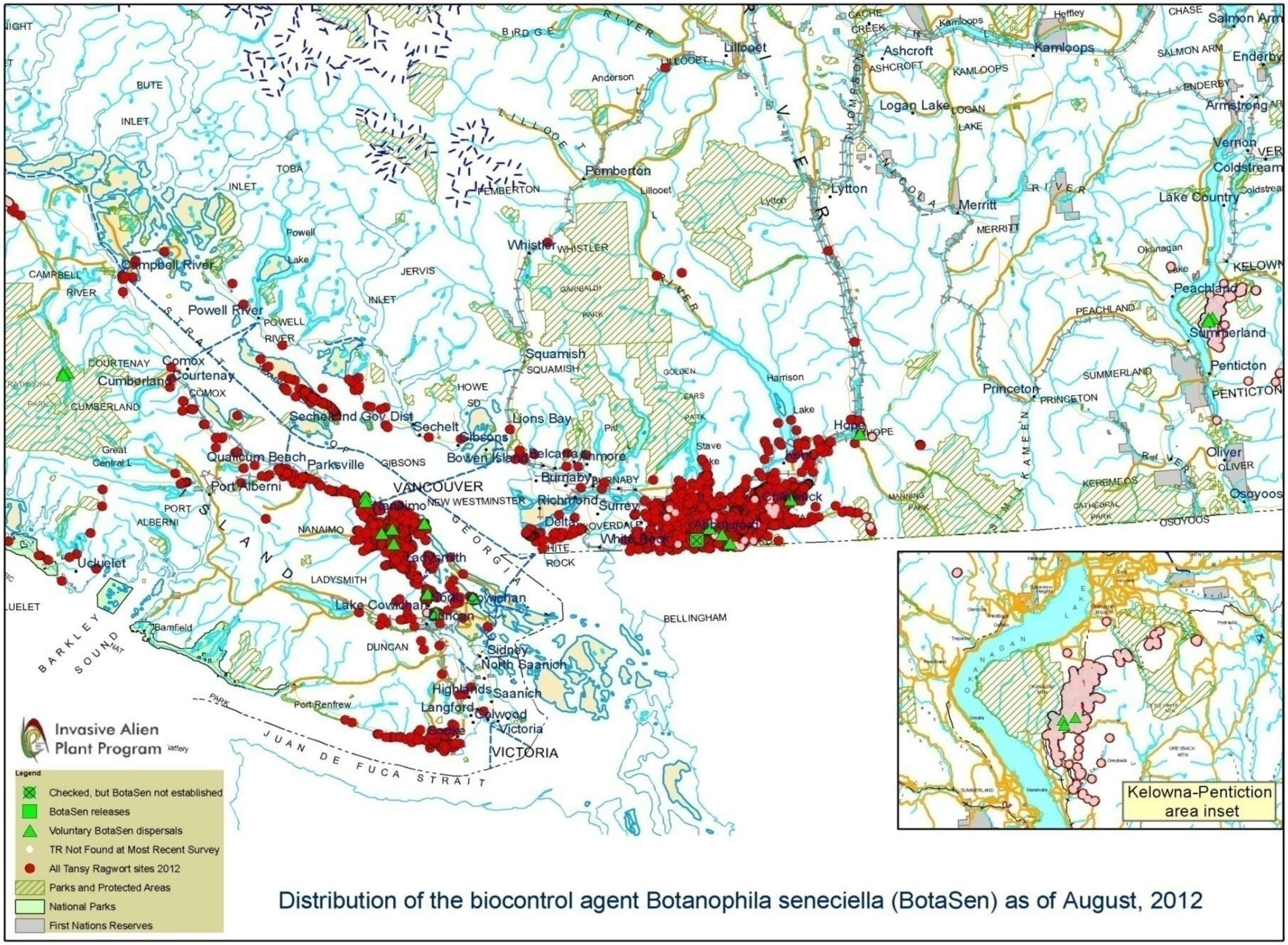


APPENDIX B. Distribution of *Tyria jacobaeae* in British Columbia



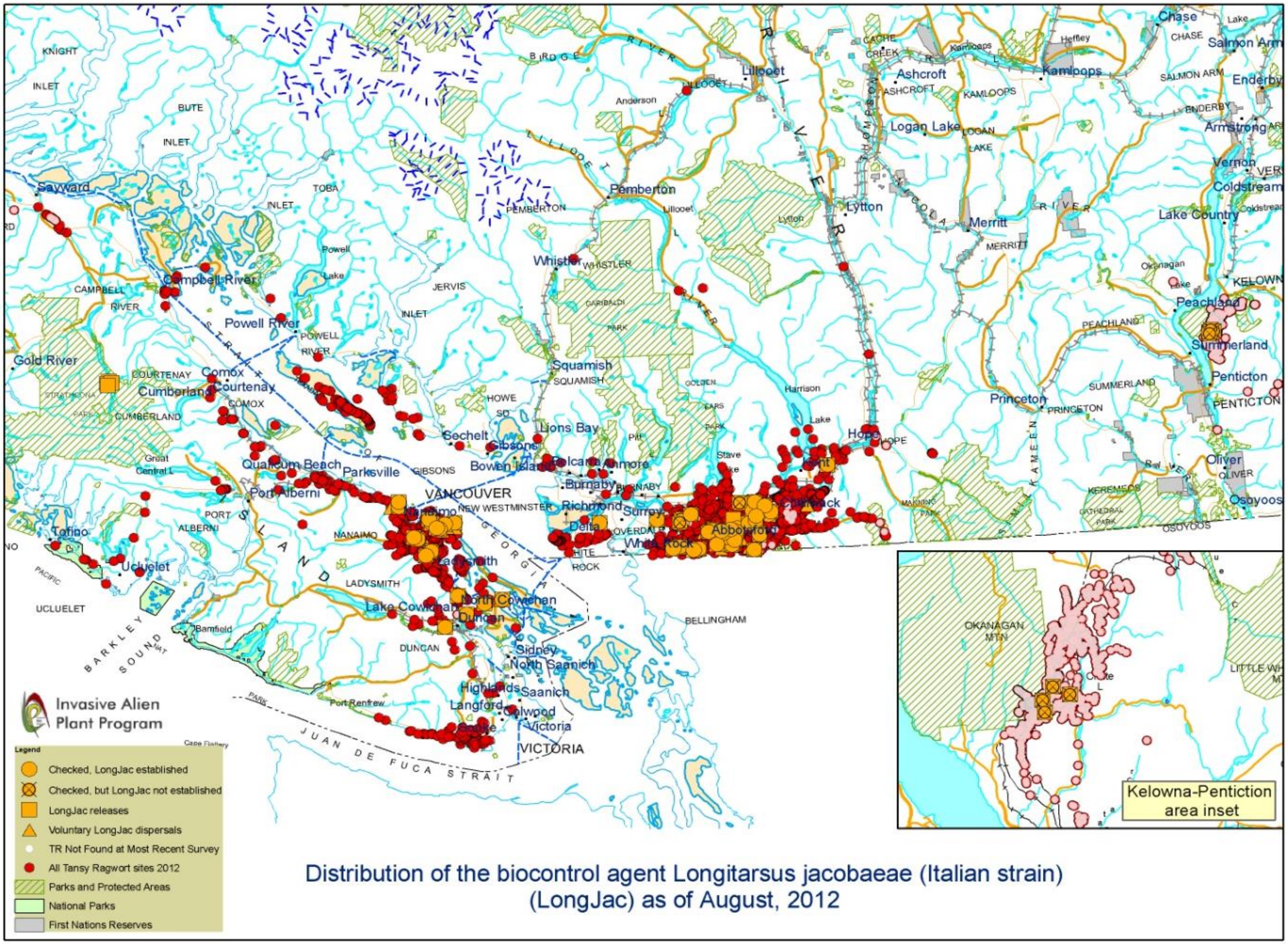
Distribution of the biocontrol agent Tyria jacobaeae (TyriJac) as of August, 2012

APPENDIX C. Distribution of *Botanophila seneciella* in British Columbia

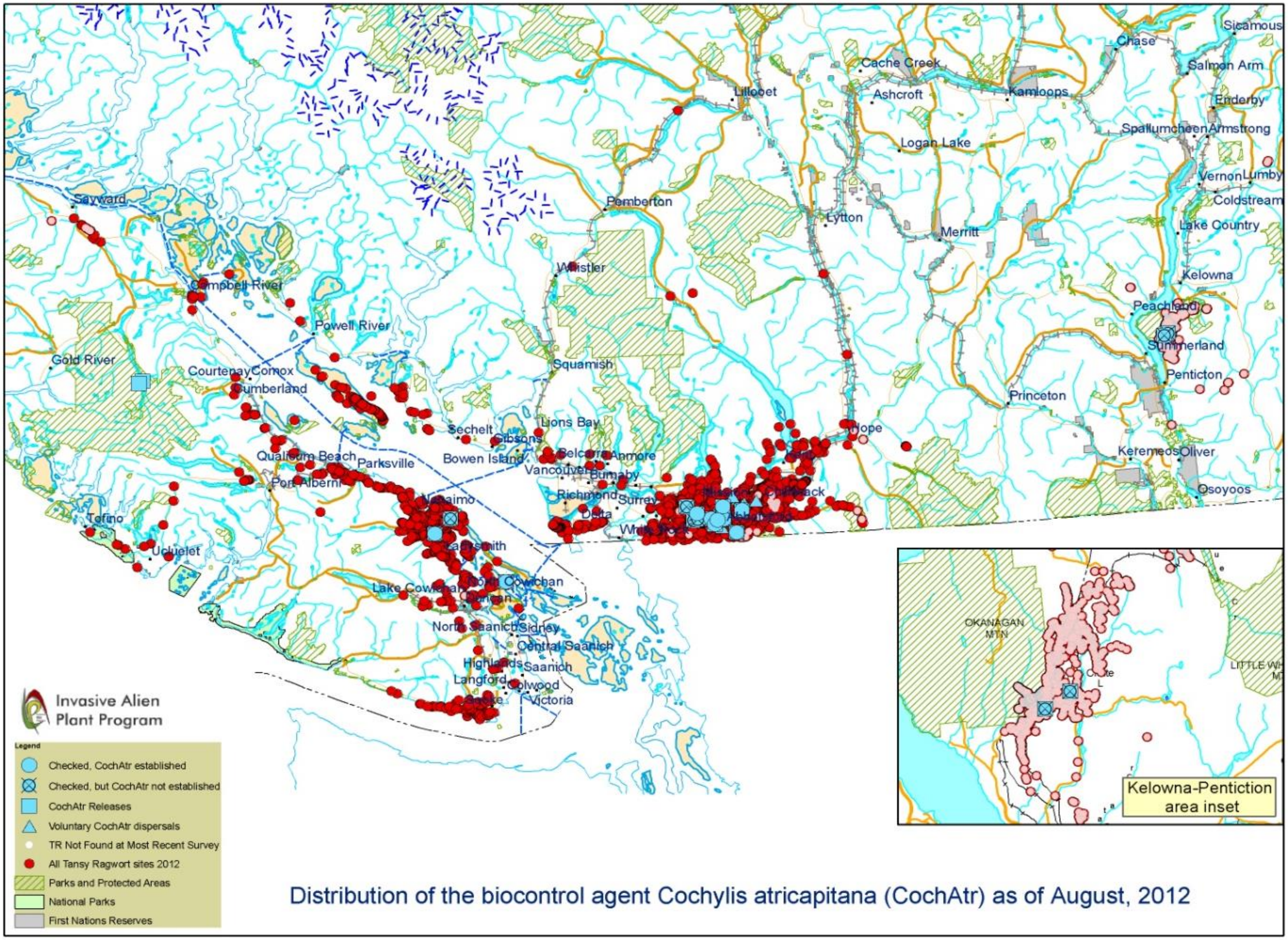


Distribution of the biocontrol agent Botanophila seneciella (BotaSen) as of August, 2012

APPENDIX D. Distribution of *Longitarsus jacobaeae* in British Columbia



APPENDIX E. Distribution of *Cochylis atricapitana* in British Columbia



APPENDIX F. Tansy ragwort biocontrol agent Invasive Alien Plant Program (IAPP) application monitoring data
(British Columbia Ministry of Forests Lands and Natural Resource Operations, 2012)

Table 1 - *Tyria jacobaeae* release monitoring

Site	Treatment Date	Source	Location	No. Released	BEC	1968	1969	1970	1972	1974	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2007	2008	2009	2010	2011
101669	1900-01-02 (default date)	AAFC	Chilliwack	1 (=unknown quantity)	CWHxm1																								
101658	1962-01-01 & 1967-01-01		King Rd. Abbotsford	3300+856	CWHxm1		Y														Y	Y						N	
101659	1963-01-01		McKenzie Rd. Abbotsford	5000	CWHxm1		Y														N	N							
102375	1964-01-01 & 1965-01-01 & 1966-01-01 & 1981-01-01		Richardson Rd. Nanaimo	13,000+80+ 6200+2800	CDFmm	N		Y														N		N				Y	
101665	1972-01-01		Cultus Lake Chilliwack	3500	CWHxm1				Y	Y												N						Y	
101666	1974-01-01		Clearbrook Road Abbotsford	300	CWHxm1																N	N							
101667	1981-01-01		Cannor Road Chilliwack	300	CWHdm																N	Y							
101670	1989-07-10	Sumas Mountain	Nicomen slough	500	CWHdm																	Y							
101671	1989-07-11	Sumas Mountain	25214-56th St. Langley	250	CWHxm1																	N							
101672	1989-07-11	Sumas Mountain	South side of 12B Rd. Langley	250	CWHxm1																	N							
102383	1989-07-11	Sumas Mountain	Keeping Rd. Abbotsford	250	CWHdm																	Y							
101674	1989-07-26	Sumas Mountain	Hudson Rd. Chemainus	125	CDFmm																	Y		N	N			Y	
101675	1989-07-27	Sumas Mountain	Kevan Dr. Gabriola Island	300	CDFmm																	N		N					
101676	1990-07-24	Sumas Mountain	Aldergrove	150	CWHxm1																	N							
101677	1990-07-24	Sumas Mountain	Huntington Rd. Langley	110	CWHxm1																	N							

101678	1990-07-24	Sumas Mountain	Ross Rd. Abbotsford	150	CWHxm1																N							
101679	1990-07-24	Sumas Mountain	Starr Rd. Abbotsford	100	CWHxm1																Y						N	
101655	1992-06-22	Sumas Mountain	Powerline Naramata	1000	IDFdm1								N			N	N	N	N			N	N					
101827	1992-06-22 & 1994-07-14	Sumas Mountain & Sumas Mountain	Chute Lake Rd. 2nd site powerline	400+1000	IDFdm1								N		N	N	N	N	N			N	N					
112297	1994-01-01		Stamps Rd. Duncan	1 (= unknown quantity)	CDFmm																Y							
101680	1995-07-19	Chilliwack	Glover Rd. & 216th St. Langley	200	CWHxm1															Y	Y							
101681	1995-07-19	Chilliwack	88th & 257th St. Langley	200	CWHxm1																N							
101682	1995-07-19	Chilliwack	River Rd. & Hudson Rd. Ladner	200	CDFmm															N	N							
101683	1995-07-19	Chilliwack	88th Ave. &264th St.	200	CWHxm1																Y							
101684	1996-07-26	Bridal Falls	Old rock quarry north of Seabird Cafe Hwy 7	50	CWHdm																Y							
219933	2006-06-13	Lazlo Lane, Cedar	Cedar-Huddington Road	100	CDFmm																						Y	
222684	2006-07-19	Haslam Lake Rd.	Island highway	100	CDFmm																			Y			Y	
205096	2006-07-22	Haslam Rd., Nanaimo	Anderson Bay FSR, Cortese	100	CWHxm1																						Y	
241320	2006-07-22	Haslam Rd.	Anderson Bay FSR, Texada Island	100	CWHxm1																							
241321	2006-07-22	Haslam Rd.	Anderson Bay near airstrip, Texada Island	200	CWHxm1																							
6820	2008-07-31	Haslam Rd. and South Road, Gabriola Island	Chute Lake Rd.	1000	IDFdm1																					Y	Y	Y
210081	2010-07-17	Nanaimo	3.5 km off Lakeshore Rd. Okanagan Valley	2273	IDFxh																							Y

Table 2 - *Tyria jacobaeae* dispersal monitoring

Site ID	Dispersal Date	Location	BEC
101831	2007-08-22	Junction of Haslam and Adshead Roads in Cedar district. Between Chemainus and Nanaimo.	CDFmm
101831	2003-08-03	Junction of Haslam and Adshead Roads in Cedar district. Between Chemainus and Nanaimo.	CDFmm
102417	2010-07-15	Cedar Road at bridge, Nanaimo	CDFmm
102421	2003-09-10	500 m down Cedar Road (south) from Island Hwy, Nanaimo-Cedar District.	CDFmm
102429	2010-07-14	Stamps Road, Duncan.	CDFmm
102430	2005-08-23	Salt Spring Island. At the end of Mansel Road, off Robinson Road. At hydro line on Rain Forest Road. Go to first stop sign in the estates and straight at the next stop sign. NOTE: Take "No public access road" to office to obtain permission to access the area.	CDFmm
102431	2010-07-16	Collins Road, Saltspring Island.	CDFmm
112294	2010-10-19	Hwy 91, Delta, east side of hwy 0.5 km south of 72nd Avenue intersection.	CDFmm
219687	2006-07-18	Hilbert Rd., Cassidy-Yellow Pt.	CDFmm
219918	2006-06-13	Cedar - Lazo Lane	CDFmm
233468	2011-08-19		CDFmm
233482	2012-07-14		CDFmm
235724	2007-08-01	Nanaimo, King Road (parallel to Nanaimo Parkway) on private property; new owner acitively involved in IP control	CDFmm
246907	2010-07-14	South of Cassidy Airport, off Simpson Road in Industrial area.	CDFmm
246920	2008-07-30	South Road, Gabriola Island. Forest opening - most conifers have been removed - alder is replacing.	CDFmm
246921	2008-07-30	South Road, Gabriola Island. Between ### South Road and Crestwood Road.	CDFmm
246922	2008-07-29	Haslam Road, private field with cattle grazing. UTM's are approximate, selected the location off IAPP map display.	CDFmm
270152	2003-08-19	SSI, Mansell Road/Nose Point Road.	CDFmm
270153	2010-07-14	Adshead Road, near Cedar.	CDFmm
101836	2003-08-23	Cox Road and gravel pit road intersection.	CWHdm
102392	2003-09-03	Industrial Way and Hwy 1 (TCH), Exit #109, Chilliwack.	CWHdm
102398	2003-09-22	Nicomen Slough, North side of Hwy #7.	CWHdm
102401	2003-09-02	[...] Property, Abbotsford.	CWHdm
244296	2007-07-25	DCK - Lougheed Hwy, near Hodgson Rd.	CWHdm
101838	2002-06-03	Between Old Yale Road and railway line on rail way rights of way (just above old cabin).	CWHxm1
101838	2003-08-27	Between Old Yale Road and railway line on rail way rights of way (just above old cabin).	CWHxm1
101840	2003-09-02	Abbotsford/Matsqui, Property beside XXXXX, Harris Road.	CWHxm1
102377	2003-10-02	100 m west of Riverside Road, Abbotsford.	CWHxm1

102384	2003-08-14	North Parallel Road, Abbotsford.	CWHxm1
102389	2003-10-02	Gladwin Road, Abbotsford (Matsqui).	CWHxm1
102390	2003-10-02	Near Gladwin Road, Abbotsford, Matsqui.	CWHxm1
102393	2003-10-02	XXXXX Quadling Road. XXXXX XXXXXX Farms, Abbotsford/Chilliwack	CWHxm1
102408	2003-08-15	Clayburn Road and Bell Road, Abbotsford (Matsqui).	CWHxm1
102425	2002-06-06	Glover Road, Langley	CWHxm1

Table 3 - B*otanophila seneciella* release monitoring

Site	Treatment Date	Source	Location	No. Released	BEC	1992	1993	1994	1995	1998	1999	2000	2001	2002	2003	2004	2005	2007	2008	2009	2010	2011
102372	1968-01-01		PEARDONVILLE, ECHO RD. GRAVEL PIT, ABBOTSFORD	1	CWHxm1									N								
102383	1985-11-07		Farm, Keeping Road, Abbotsford	1	CWHdm																	

Table 4 - *Botanophila seneciella* dispersal monitoring

Site ID	Inspection Date	Location	BEC
6820	2007-09-19	Chute Lake Road.	IDFdm1
101655	2001-10-29	Powerline, R.O.W. Naramata, Chute Lake Road. Naramata watershed.	IDFdm1
101665	2010-07-12	Cultus Lake. Between Maple Falls and Iverson. Chilliwack.	CWHxm1
101670	1991-09-30	Nicomen Slough. North side of Hwy #7 near pumphouse.	CWHdm
101674	2010-07-14	Hudson Road, Chemainus.	CDFmm
101675	2005-08-24	Kevan Drive, Gabriola Island.	CDFmm
101827	2000-09-28	Chute Lake road, Naramata. Powerline R.O.W. Second site on powerline access road, near mud bogging area.	IDFdm1
101831	2007-08-22	Junction of Haslam and Adshead Roads in Cedar district. Between Chemainus and Nanaimo.	CDFmm
101837	1990-08-10	Vedder Canal dyke, west side, lower road, just north of the #2 Road entrance.	CWHxm1
101838	2010-07-12	Between Old Yale Road and railway line on rail way rights of way (just above old cabin).	CWHxm1
101843	2010-07-13	McKee Road, across from clubhouse at golf course, Abbotsford.	CWHxm1
102375	2005-08-23	Richardson Road, Nanaimo.	CDFmm
102385	1990-08-10	XXXX Farm, Dawson Road, Abbotsford.	CWHdm

102386	1990-08-19	Dawson and Willet Roads, Abbotsford.	CWHdm
102388	1990-08-10	At [...] Clayburn, between Bell and Wright Streets, Abbotsford (Matsqui).	CWHxm1
102410	1990-08-10	Keeping and Sumas Mountain Road, Abbotsford (Sumas Mountain)	CWHdm
102417	2010-07-15	Cedar Road at bridge, Nanaimo	CDFmm
102418	2010-07-15	XXXXX Farm, Akenhead Road, Nanaimo.	CDFmm
102421	2010-07-15	500 m down Cedar Road (south) from Island Hwy, Nanaimo-Cedar District.	CDFmm
102429	2010-07-14	Stamps Road, Duncan.	CDFmm
102430	2005-08-23	Salt Spring Island. At the end of Mansel Road, off Robinson Road. At hydro line on Rain Forest Road. Go to first stop sign in the estates and straight at the next stop sign. NOTE: Take "No public access road" to office to obtain permission to access the area.	CDFmm
237363	1992-09-29	West side of Lickman Rd. at corner of Yale Rd.	CWHxm1
246194	1990-08-10	Lower Sumas Mountain Road, Abbotsford. FVRD site #s: 77,641.	CWHxm1
246629	1990-08-10	Downes rd. East of Mt Lehman on S side of rd.	CWHxm1
246999	2011-07-22	Hack Brown. East of Nixon.	CWHdm
248156	1990-08-10	Lefeuvre north of Huntington. East side of road.	CWHxm1
264135	1990-08-19	Chilliwack, Columbia Valley at Iverson Rd. and Columbia Valley Rd.	CWHdm
271494	1990-08-10	Hackbrown	CWHdm
276147	2011-07-18	RCO, DCK, Hope. Most northern entrance/exit into Hope from the Coquihalla Hwy.	CWHds1
279920	1991-09-30	Keeping E Sumas mountain	CWHdm
280812	1990-08-10	Vedder Mountain Road	CWHxm1

Table 5 - *Longitarsus jacobaeae* (Italian strain) release monitoring

Site ID	Treatment Date	Source	Location	No. Released	Zone	1900	1979	1984	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2007	2008	2009	2010	2011
102380	1900-01-02		Along dike on frontage road.	300	CWHxm1												Y								
102372	1971-01-01 &1972-01-01 &1974-01-01	UBC	Echo Road, near airport, gravel pit site, Abbotsford.	400 + 593 + 200	CWHxm1												Y	N						N	
102375	1974-01-01 & 1976-01-01	England & unknown	Richardson Road, Nanaimo.	92 + 1000	CDFmm			Y										Y		Y				Y	Y

102377	1978-01-01	Peardonville	100 m west of Riverside Road, Abbotsford.	200	CWHxm1	Y											Y						Y	
102378	1978-01-01	Peardonville	1/2 km west of Cannor Road and CNR crossing.	500	CWHdm												Y							
102379	1983-01-01		Between Minto and Evans Road, Nanaimo.	1 (unknown)	CDFmm											Y	Y							
102381	1984-01-01	Nanaimo	Peardonville-Huntington Road, west of Bradner Road, Abbotsford.	350	CWHxm1											Y	Y						Y	
102382	1984-01-01	Nanaimo/Oregon	50 m west of Watcom Road and Parallel Road, Abbotsford.	1000	CWHxm1											Y	N						N	
102384	1986-10-30	Sumas Mountain	North Parallel Road, Abbotsford.	200	CWHxm1												Y						N	
102385	1986-10-30	Nanaimo	XXXX Farm, Dawson Road, Abbotsford.	450	CWHdm												Y							
102386	1986-10-30	Sumas Mountain	Dawson and Willet Roads, Abbotsford.	250	CWHdm											Y	Y						N	
102387	1986-10-30	Nanaimo	Wright Street and Bateman Avenue, Abbotsford (Matsqui).	250	CWHdm											Y	Y						N	
102388	1986-10-30	Nanaimo	At [...] Clayburn, between Bell and Wright Streets, Abbotsford (Matsqui).	200	CWHxm1											N	Y							
102389	1986-10-30	Nanaimo	Gladwin Road, Abbotsford (Matsqui).	200	CWHxm1											N	Y							
102390	1986-10-30	Nanaimo	Near Gladwin Road, Abbotsford, Matsqui.	200	CWHxm1										N		Y							
102391	1986-10-30	Nanaimo	Glenmore Road, 300 m north of Downes Road, Matsqui, Abbotsford.	250	CWHxm1										N		Y						Y	
102392	1986-10-30	Sumas Mountain	Industrial Way and Hwy 1 (TCH), Exit #109, Chilliwack.	200	CWHdm											Y	Y						Y	
102393	1986-10-30	Sumas Mountain	XXXXX Quadling Road. XXXXX XXXXXX Farms, Abbotsford/Chilliwack	400	CWHxm1												Y							

102394	1986-10-30	Sumas Mountain	Iverson Road, between Lunzmann and Henderson Roads, Cultus Lake, Chilliwack.	650	CWHdm												Y						N	
102395	1986-10-30	Sumas Mountain	Columbia Valley Road, 300 north of Henderson Road, Cultus Lake, Chilliwack.	250	CWHxm1												Y						N	
102396	1986-10-30	Sumas Mountain	Duncan, Vimy Hall area off Gibbins Road.	400	CDFmm												Y							
102398	1988-11-14	Sumas Mountain	Nicomen Slough, North side of Hwy #7.	300	CWHdm											Y	Y							
101674	1988-11-18	Sumas Mt.	Hudson Road, Chemainus.	250	CDFmm												Y						Y	
102400	1988-11-18	Sumas Mountain	Haslam property on Adshead Road, Nanaimo.	250	CDFmm												Y							
102401	1989-11-08	Sumas Mountain	[...] Property, Abbotsford.	400	CWHdm												Y							
102402	1989-11-08	Sumas Mountain	Nicomen, north side of Hwy 7.	1200	CWHdm	Y											Y						Y	
102403	1989-11-17	Sumas Mountain	North Road, Gabriola Island.	1200	CDFmm												Y							
102404	1990-10-17	Sumas Mountain	Nicomen Island Research site.	1000	CWHdm												N							
102405	1990-10-17	Sumas Mountain	South end of powerline across Sumas Mountain, Abbotsford.	2000	CWHdm												Y							
102406	1990-10-17	Sumas Mountain	Glenmore Road, 1 km south of Downes Road, Abbotsford.	1000	CWHxm1												N							
102383	1986-08-07 & 1988-11-14 & 1990-10-18	Sumas Mountain & Sumas Mountain & Sumas Mountain	[...] Farm, Keeping Road, Abbotsford.	100 + 200 + 250	CWHdm	Y										Y	Y							
102407	1990-10-18	Sumas Mountain	XXXX properties, Clayburn, Abbotsford.	750	CWHxm1												Y							
102408	1990-10-18	Sumas Mountain	Clayburn Road and Bell Road, Abbotsford (Matsqui).	750	CWHxm1												Y						Y	Y
102410	1990-10-18	Sumas Mountain	Keeping and Sumas Mountain Road, Abbotsford (Sumas Mountain)	500	CWHdm												Y							

102411	1990-10-19	Sumas Mountain	Frontage road, west of Lickman, Chilliwack.	750	CWHdm													N						Y	
102412	1990-10-19	Sumas Mountain	1.4 km north of Keith Wilson bridge, Vedder Canal, Chilliwack.	250	CWHxm1													Y						Y	
102413	1990-10-19	Sumas Mountain	0.7 km west of Robinson Road on Majuba Road, Chilliwack, (Yarrow).	750	CWHxm1													Y						Y	
102414	1990-10-19	Sumas Mountain	Luckakuck Road, Chilliwack	750	CWHxm1													N						Y	
102415	1990-10-23	Sumas Mountain	27424-12B Street, Langley (Aldergrove).	250	CWHxm1													Y						N	
102416	1990-10-23	Sumas Mountain	Bradner Road, 0.2 km north of Marsh-McCormick, Abbotsford.	300	CWHdm													Y						N	
102417	1990-10-24	Sumas Mountain	Cedar Road at bridge, Nanaimo	500	CDFmm													Y						Y	
102418	1990-10-24	Sumas Mountain	XXXXX Farm, Akenhead Road, Nanaimo.	500	CDFmm													Y						N	
102419	1990-10-24	Sumas Mountain	South Road, Gabriola Island.	750	CDFmm													Y							
102420	1990-10-24	Sumas Mountain	850 m from North Road on Degnen Road, Gabriola Island.	750	CDFmm													Y							
102421	1992-11-25	Sumas Mountain	500 m down Cedar Road (south) from Island Hwy, Nanaimo-Cedar District.	150	CDFmm													Y						N	
102422	1993-11-10	Nanaimo	XXXX-264th Street, Langley.	500	CWHxm1													N							
102423	1993-11-10	Nanaimo	[...]Upper Sumas Mountain Road, Abbotsford.	1500	CWHdm																				
102424	1993-11-10	Nanaimo	XXXX- XXXth Street, Aldergrove, (Langley)	500	CWHxm1													Y							
102425	1993-11-10	Nanaimo	Glover Road, Langley	500	CWHxm1	N												Y						Y	
102426	1994-10-13	Nanaimo	South Road, Gabriola Island.	1000	CDFmm													Y							
102427	1994-10-13	Nanaimo	Mudge Island, North side.	1000	CDFmm													Y							
102428	1994-10-13	Nanaimo	XXX Weathers Way. XXXX XXXX property, Mudge Island.	1000	CDFmm													Y							

102429	1994-10-13	Nanaimo	Stamps Road, Duncan.	1000	CDFmm												N						Y	
102430	1996-05-16	Nanaimo	Salt Spring Island. At the end of Mansel Road, off Robinson Road. At hydro line on Rain Forest Road. Go to first stop sign in the estates and straight at the next stop sign. NOTE: Take "No public access road" to office to obtain permission to access the area.	1000	CDFmm												Y						Y	
102431	1996-09-21	Nanaimo	Collins Road, Saltspring Island.	1000	CDFmm												Y						Y	
101684	1996-09-24	Cedar, Nanaimo	3.6 km north of Seabird Cafe on Hwy #7. Old rock quarry.	300	CWHdm												Y						Y	
101655	1992-10-20 & 1994-04-25 & 1997-10-24	Sumas Mountain & Nanaimo & Vedder canal, Chilliwack	Powerline, R.O.W. Naramata, Chute Lake Road. Naramata watershed.	500 + 1000+ 600	IDFdm1			N	N			N	N	N	N			N	N					
101827	1997-10-24	Cassidy, Nanaimo	Chute Lake road, Naramata. Powerline R.O.W. Second site on powerline access road, near mud bogging area.	900	IDFdm1							N	N	N	N			N	N					
6820	2001-09-20	Chilliwack-Vedder Canal	Chute Lake Road.	1000	IDFdm1														N	N		N		
112294	2001-11-08	Cedar/Nanaimo	Hwy 91, Delta, east side of hwy 0.5 km south of 72nd Avenue intersection.	2000	CDFmm												Y						Y	

Table 6 - *Longitarsus jacobaeae* (Italian strain) dispersal monitoring

Site ID	Inspection Date	Location	BEC
101831	2003-08-08	Junction of Haslam and Adshead Roads in Cedar district. Between Chemainus and Nanaimo.	CDFmm
101675	2003-09-11	Kevan Drive, Gabriola Island.	CDFmm
112297	2003-08-21	Stamps Road, Duncan	CDFmm
246920	2008-07-30	South Road, Gabriola Island. Forest opening - most conifers have been removed - alder is replacing.	CDFmm
246921	2008-07-30	South Road, Gabriola Island. Between ### South Road and Crestwood Road.	CDFmm
246922	2008-07-29	Haslam Road, private field with cattle grazing. UTM's are approximate, selected the location off IAPP map display.	CDFmm
103998	2008-10-28	North side of Mudge Island.	CDFmm
222684	2010-07-14	Island Highway	CDFmm

101831	2010-07-14	Junction of Haslam and Adshead Roads in Cedar district. Between Chemainus and Nanaimo.	CDFmm
270153	2010-07-14	Adshead Road, near Cedar.	CDFmm
246999	2011-07-19	Hack Brown. East of Nixon.	CWHdm
112295	1994-10-06	XXXXX Dawson Road, off Upper Sumas Mountain Road, Abbotsford.	CWHdm
101836	2008-04-16	Cox Road and gravel pit road intersection.	CWHdm
275973	2010-10-18	RCO/DCK, Hwy 7, Nicomen Slough area. North Nicomen Road.	CWHdm
101835	2003-10-02	Between [...] and [...] Polar Avenue, Abbotsford.	CWHxm1
101840	2003-08-26	Abbotsford/Matsqui, Property beside XXXXX, Harris Road.	CWHxm1
101665	2003-09-03	Cultus Lake. Between Maple Falls and Iverson. Chilliwack.	CWHxm1
101678	2003-10-02	South of Peardonville on Ross Road, Abbotsford.	CWHxm1
101672	2003-09-07	South side of 12B Road, Langley.	CWHxm1
101680	2003-09-07	Glover Road and 216th Street. West of railway, Langley	CWHxm1
101658	2003-10-02	Between McKenzie and Riverside Roads on King Road, Abbotsford.	CWHxm1
101838	2010-07-12	Between Old Yale Road and railway line on rail way rights of way (just above old cabin).	CWHxm1
271670	2010-10-20	industrial way west of lickman rd on the north side of the road	CWHxm1
276543	2010-10-19	RCO, DCK, Langley. Glover Road. Rail line edge - between rail and fenceline (private). No plants found on the road edge.	CWHxm1
248116	2010-10-19	Vye east of MacKenzie on the south side.	CWHxm1
101841	1995-08-18	Next to [...] Glenmore Road. Abbotsford.	CWHxm1

Table 7 - *Cochylis atricapitana* release monitoring

Site	Treatment Date	Source	Location	No. Released	BEC	1992	1993	1994	1995	1998	1999	2000	2001	2002	2003	2004	2005	2007	2008	2009	2010	2011
102401	1991-04-02	Bionomic	Private Abbotsford	2827 larvae	CWHdm	Y									Y							
101829	1991-04-05 +1994-10-06	Bionomic+ Abbotsford	Sumas Mountain Rd. (private) Abbotsford	398 larvae + 100 plants	CWHdm									Y	N							
102383	1991-04-11	Bionomic	Keeping Rd. (private) Abbotsford	869 larvae	CWHdm	Y									Y			Y				
101831	1991-04-12	Bionomic	Chemainus/Nanaimo	481 larvae	CDFmm		Y								Y		N	n			N	
101827	1994-04-25	Nanaimo	Chute Lake Rd.	70 plants	IDF dm1			N	N	N	N	N	N			N	N					
112295	1994-10-06	Sumas Mountain Rd.	Dawson Rd. (private) Abbotsford	100 plants	CWHdm										N						N	
101834	1994-10-13	Nanaimo (Cedar area)	Mudge Island	100 plants	CDFmm										N							
101835	1995-05-17	Sumas Mountain Rd.	Polar Avenue, Abbotsford	50 plants	CWHxm 1										N						N	
101836	1995-05-17	Sumas Mountain Rd.	*Cox Rd.*	50 plants	CWHdm										Y			Y	Y			

101837	1995-05-17	Sumas Mountain Rd.	Vedder Canal dyke	50 plants	CWHxm 1								N	Y				Y			
101838	1995-05-18	Sumas Mountain Rd.	Old Yale Rd.	50 plants	CWHxm 1								N	Y				N		Y	
101839	1995-05-18	Sumas Mountain Rd.	Private property	50 plants	CWHdm												N			N	
101840	1995-05-18	Sumas Mountain Rd.	Harris road (private) Abbotsford/Matsqui	150 plants	CWHxm 1									Y						N	
101841	1995-05-18	Sumas Mountain Rd.	Glenmore Rod. Abbotsford	50 plants	CWHxm 1									N						N	
101843	1995-05-19	Sumas Mountain Rd.	McKee Rd (private) Abbotsford	50 plants	CWHxm 1									N						Y	
102388	1995-05-18	Sumas Mountain Rd.	Clayburn Abbotsford/Matsqui	50 plants	CWHxm 1									Y			N	N			
102430	1996-05-16	Nanaimo	Salt Spring (private)	60 plants	CDFmm									Y		Y				N	
6820	2008-04-17	Fraser Valley	Chute Lake Rd.	59 plants	IDF dm1														N	N	N

Table 8 - *Cochylis atricapitana* dispersal monitoring

Site	Dispersal Date	Location	BEC
102414	2010-10-18	Luckakuck Rd. Chilliwack	CWH
101667	2003-09-03	Cannor Rd x CNR Chilliwack	CWH dm
102378	2003-09-03	½ km west Cannor Rd x CNR Chilliwack	CWH dm
102392	2003-09-03	Industrial Way & Hwy 1 exit #109 Chilliwack	CWH dm
102387	2003-10-02	Wright St. & Bateman Ave. Matsqui	CWH dm
102408	2003-08-15	Clayburn Rd. x Bell Rd. Matsqui	CWH xm1
102384	2003-09-02	North Parallel Rd. Abbotsford	CWH xm1
102412	2003-09-03	1.4 km north of Keith Wilson bridge Vedder Canal Chilliwack	CWH xm1

APPENDIX G. *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 26). 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 25). The **pupae** are dark reddish-brown and 20 to 25 mm long (Rees et al. 1996) (Figure 27).

Figure 25 - *Tyria jacobaeae* larvae on tansy ragwort

Figure 26 - *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 27 - *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 28). 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. jacobaeae* is not present). In these cases it may be necessary to re-introduce *T. jacobaeae* when the plant density builds again.

Figure 28 - Defoliated stalk of tansy ragwort

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
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

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 29) 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 29 - 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

Figure 30 - *Tyria jacobaeae* feeding "residue" on tansy ragwort plant (feces and molts)

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 by *L. jacobaeae*. Plants can appear blackened as the larvae discard their molted skins and deposit feces on the plants (Figure 30). Take care not to walk on larvae travelling between plants.

Monitor for **adults** as per the Handling Cycle table above. 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 31).

Figure 31 - 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 32 –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 33 – 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.

APPENDIX H. *Longitarsus jacobaeae* (Italian strain)

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

Longitarsus jacobaeae (Italian strain) are root-feeding flea beetles of tansy ragwort (Figure 34). The **adult** males are 2-4 mm long while the females are 1 mm larger than the males. Initially golden-tan, they change to golden-brown when mature and finally to dark brown when old. They have enlarged rear legs that enable them to leap great distances. The **eggs** are oval and measure 0.66 x 0.3 mm. They are initially yellow and darken over time (Harris and Crozier 2006). The hatching **larvae** are white, slender, comma-shaped and 6 mm x 1mm. Its head capsule is dark brown and its thoracic shield and anal plate are brown (Powell et al. 1994; Harris and Crozier 2006) (Figure 35). The **pupae** are white and 2-4 mm long (Rees et al. 1996).

Figure34 - *Longitarsus jacobaeae* (Italian strain) adult (Powell et al. 1994)

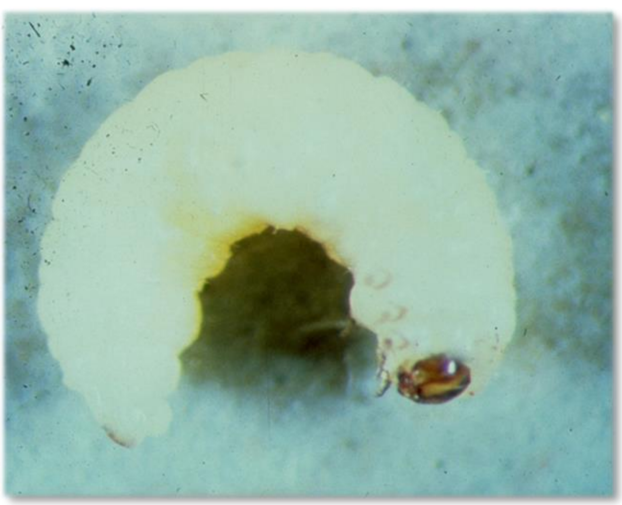


Figure 35 - *Longitarsus jacobaeae* (Italian strain) larvae (Powell et al. 1994)

Life Cycle

The **adults** generally emerge in early spring to early summer (May to June), feed for a short time and aestivate until late summer or early fall (September), however spring emergence can be delayed (Powell et al. 1994; P. Harris pers. comm. June 1994. When they appear later in the season they feed intensely. The shortened days activate sexual changes in both males and females, for example, the flight muscles are absorbed when oviposition begins (Harris undated d). In areas where continuous long days occur, 99% of beetles die before ovipositing. Oviposition is delayed until October when ideal habitat will offer 3.5 months of suitable weather. Sites which are too cool will inhibit oviposition (Harris and Crozier 2006). Mating and oviposition continues until sub-zero temperatures arrive, however, if freezing temperatures do not occur, the adults may continue to feed for an additional year (Powell et al. 1994). The flea beetle has historically not been able to control tansy ragwort in Nova Scotia, New Brunswick, Prince Edward Island, B.C. interior and higher elevation sites in Oregon since it starts breeding around the first of October in Canada which allows less than a month compared to the approximate three months on the B.C. lower mainland and 6 months in some areas of Oregon (Harris undated d). However, Italian strain flea-beetles have more recently been found at inland U.S.A. sites at Mt. Hood, Oregon and Lincoln County, Montana where the mean annual temperatures are 5.6 and 4.5^{o}C and mean winter temperatures are -0.76 and -5.13^{o}C, respectively (Szucs et al. 2011). Each female will lay between 500 to 1000 **eggs** which are deposited individually at the root crown or base of a leaf petiole or in the soil near the roots. The incubation period takes 2-16 weeks (Harris and Crozier 2006). The eggs are vulnerable to desiccation in dry conditions, so long, moist autumns are necessary. Eggs that are laid early will hatch in approximately 30 days, yet those that are laid late can remain until spring (Harris undated c). **Larvae** take 8-14 weeks to mature and generally feed on the cork-like outer layers of the root crown and lateral roots. If their numbers are high, they will bore into the root crown and mine the petioles of lower leaves (Harris and Crozier 2006). Long grooved formations within the roots are the result of feeding on the outer layers. Mature larvae typically overwinter in plant roots and will move to the soil to pupate the following June, doing so up to 5 cm from the plant (Wilkinson 1986).

Effect on Tansy ragwort

Many consider *L. jacobaeae* to be the most effective biocontrol agent for reducing tansy ragwort stand densities, including in low density infestations and near the coast (Italian strain) (Sheley and Petroff 1999). The flea beetles' population has been shown to rapidly increase and crash in response to their host plant's increase following disturbance and rapid decline following the bioagent's attack. *L. jacobaeae* has a strong ability to search out and colonize tansy ragwort infestations. The flea beetle is also able to attack many of the plant's parts, stages and in various seasons, conditions (tolerates some shade and soil moisture) and plant densities (McEvoy and Rudd 1993). **Adult** ragged shot-hole feeding (5mm diameter holes) typically causes little impact to the plant however, in large quantities, heavy adult feeding can kill rosettes in the fall and winter months (Harris undated c ; P. Harris, A.T.S Wilkinson and J. H. Myers, unpublished data, undated, Canada; King County 2004). Washington State University (2013) notes that adult feeding restricts photosynthesis and the plant's ability to store nutrients. **Larvae** preferentially feed on and can kill small rosettes (Harris and Crozier 2006). Density of larvae found at early B.C. release sites was 5-13 larvae/rosette on 95% of the rosettes sampled which led to significant reductions in tansy ragwort biomass (CABI 1988). Root feeding impacts the plant's stored energy reserves necessary to survive the winter. Some reports say the larvae feeding during the winter on rosette roots can cause the rosettes to die when they begin to bolt the following spring while others claim the combined efforts of **adult and larvae** feeding can kill plants by the time they would typically be producing new vegetative shoots and buds (King County 2004; Washington State University 2013). In general, it has been noted that the effectiveness of biocontrol may take up to six years before a significant change in plant density can be observed, for example, 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 (King County 2004; Thompson and Harris 1986). However, McEvoy and Rudd (1993) demonstrated that *L. jacobaeae* rapidly reduced tansy ragwort's ability to survive which led to a sharp decline in plant abundance in a five year field study. *L. jacobaeae* feeding can indirectly affect seed production; however, this is more efficient when coupled with *B. seneciella* or *T. jacobaeae* (in particular) feeding. Buried seed is not affected and the plant population may resurge if the number of flea-beetles decreases as a result of lack of food. *L. jacobaeae* can survive on few plants (unlike *T. jacobaeae*) and remain in an infestation, their numbers rising again when the flea beetle adeptly finds new plants as the plant population increases (Harris and Crozier 2006; Corvallis Oregon newsletter 1988). However, if the flea-beetle population is no longer present due to lack of food, the agent may need to be re-introduced into the area.

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
Longitarsus jacobeaea (IT)	Life cycle	egg/larva						pupa		adult				inactive adult			adult			adult/egg/larva					
	monitor																other		adult						
	collect																		adult						
	Notes	Applicable to *L. jacobaeae* (Italian) strain only. Monitor OTHER refers to feeding evidence (Aug/Sep).																							

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

Agent Behaviour

The **adults** are more easily observed when tansy ragwort plants are growing in areas with less plant competition or where the competing vegetation is grazed. Adults are rarely found on the upper half of bolted plants, but instead are frequently observed on the upper and lower leaf surfaces of large rosette or basil leaves during the spring and summer months. After initially feeding, the adults aestivate for the remainder of the summer (Powell et al. 1994). They become most active in the fall when the autumn rains begin (Sheley and Petroff 1999) and breeding commences. Adults choose oviposition locations prior to commencing egg laying (Harris undated d). During the breeding and ovipositing periods, the adults can frequently be found on the soil surface near plants. In mild climates, adults can hibernate during winter months. The agent can also spend the winter months as **eggs**. Typically, **larvae** overwinter and they spend this time in plant roots but will overwinter in the soil. Larvae can be found feeding down leaf petioles into the root crown and continuing to move into the root and mine the interior and exterior root parts (King County 2004; Washington State University 2013). In crowded or waterlogged conditions, the larvae will feed on root crowns and within the petioles of lower leaves (Harris and Crozier 2006).

Dispersal Behaviour

Adult flea-beetles distribute themselves by walking (Powell et al. 1994). Females stop dispersing once they become reproductive in the fall as studies from New Zealand have shown that the flight muscles of *L. jacobaeae* are absorbed when oviposition begins (Harris undated d).

Collecting

L. jacobaeae are collected for redistribution as **adults**. As the adult flea beetles aestivate during the summer months, they appear more abundant and are less prone to disperse as they mate and oviposit in the fall. The optimal handling months occur between late September and late November. It has been found that it is more difficult to monitor for and collect adults in thick, competing vegetation. Check for feeding evidence to determine their presence. The shot holes will be visible mainly on the lower leaves. Collect the flea beetles by aspirating them from the plants with hand-held aspirators or large units carried on the back. With this method, collection can take place any time of day. Once an area has been passed over, wait approximately 30 minutes and re-visit the area again as those flea-beetles that fled the disturbance will readily return to the plants. When aspirating the flea-beetles with large backpack aspirators, plant and other debris also gets sucked up. Place all contents into a large plastic bag to allow the flea-beetles to emerge from the debris. Separate the flea-beetles from the debris, which may contain a variety of unwanted invasive plant seeds and predators such as spiders, by using a hand-held aspirator. Transfer the flea-beetles to containers for transport. If large numbers of flea-beetles are placed into a container, add fluffed up tissue to create surface area upon which the beetles can cling and disperse themselves from one another to prevent constant contact and disturbance from other jumping flea-beetles.

Releasing

Releases that resulted in establishment of *L. jacobaeae* Italian strain in B.C. have ranged in number from 100 to 2000. It is recommended to release a minimum of 150 flea beetles (preferably more) to a new site with the same habitat and approximately 1000-2000 to a different habitat. In Montana U.S.A., 100 to 500 are recommended (Rees et al. 1996). In any case, 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 is advisable to use larger numbers to transfer to compensate for the stress on the population as much as possible. 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). Releasing *L. jacobaeae* and *T. jacobaeae* together is considered the most effective biocontrol agent combination. Observe the preferred site characteristics described below for recommendations of where to release the flea-beetles, however, note that on one hand a study in Oregon investigating the four environmental conditions of precipitation, elevation, land use and year of flea beetle releases found that the success of controlling tansy ragwort was independent of the variation in these conditions (McEvoy and Cox 1991), while on the other, these conditions may or may not have more influence in B.C.'s habitats.

Monitoring

Monitor by observing **adults** and their ragged shot-hole feeding (Figure 36) within the leaf surface (distinct from the large quantities bitten off from the edges of the leaf by *T. jacobaeae* larvae more commonly found on the upper plant) during early spring, in late summer and into late fall. Both *L. jacobaeae* and *C. atricapitana* **larvae** create brown-coloured root crowns which can be seen when basal leaves are pulled away from the root crown. When plants are excavated prior to the spring pupation period, slender white-coloured larvae or feeding damage can be observed on or in plant roots. This feeding evidence and early instar larvae can also easily be confused with *C. atricapitana*. It is advised to differentiate between these larvae species later in the season (end of July) when *C. atricapitana* can be distinguished as Lepidoptera and late-developing *L. jacobaeae* larvae may be feeding on the outside of the roots (P. Harris pers. comm. June 1994; P. Harris pers. comm. Aug. 2002). Flea beetle larvae have three pairs of true legs on the thoracic segments while 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 (P. Harris pers. comm. Aug. 2002). *L. jacobaeae* and *C. atricapitana* can co-exist as they typically feed in different locations on the root (Harris 2003b). *L. jacobaeae* create long grooved formations on the roots as the result of feeding and can be easily seen when the outer layer is scraped away (Figure 37) (Cesselli pers. comm. 2013). Look for the larvae at the root crown and in the petioles of the lower leaves if the soil is very moist.

Figure36 - Adult shot-hole feeding evidence

Figure 37 - Feeding scars exposed on root after scraping off outer root layer

Preferred Site Characteristics

Site Size

Potential release sites should be no less than 250 m^2. Sites should have a corridor of plants in suitable habitat to allow the agent to self-disperse as the main infestation declines or a plan should be in place to actively re-distribute the biocontrol agent.

Plant Density

Plant density should be at least 4 plants/m^2. As adult flea beetles walk between plants, dense infestations are preferred, however, *L. jacobaeae* will colonize and establish in lower density tansy ragwort infestations than *T. jacobaeae* (McEvoy and Rudd 1993). Also, all release sites should have well established plants where a significant portion of the plants are healthy rosettes that larvae can feed on throughout the winter and ensure the sustainability of the infestation. McEvoy and Cox (1991) found smaller, younger plants in the infestations carried the highest numbers of *L. jacobaeae* larvae. Sites require sufficient plants and security to endure for the length of time required for *L. jacobaeae* to build to a well-established population, generally four years (Wilkinson 1986).

Ground Cover

L. jacobaeae have been found on sites with both ground cover and bare soils, therefore, showing no preference.

Competing Vegetation

Adults and evidence have been found in areas with significant competing vegetation including shrubs, forbs and grasses, which help to out-compete weakened tansy ragwort plants, however, the agent has also been found in stands with no competing vegetation, therefore no preference is shown.

Shade

L. jacobaeae prefers sunny locations, but, adult flea beetles have been found on plants growing in small isolated infestations within closing canopy. The flea-beetle does not tolerate heavy shade, however, it has been noted to populate plants growing in shade (Rees et al. 1996; McEvoy and Rudd 1993).

Slope

L. jacobaeae is found on flat and a variety of slopes in B.C., therefore, showing no preference. However, in Atlantic Canada, south facing slopes with good drainage are recommended (Stewart and Sampson 2009).

Aspect

L. jacobaeae shows no preference for a particular aspect as they are found on varying aspects and on flat ground.

Elevation

To date, *L. jacobaeae* has established at elevations in B.C. as low as 5 m and as high as 285 m. King County (2004) predicted preferred elevations were below 731 m while Harris and Crozier (2006) indicated the flea beetle would not go over 400 m.

Temperature

L. jacobaeae breeding/oviposition is inhibited when sites are too cool (Harris and Crozier 2006). Italian strain flea-beetles have recently been found at inland U.S.A. sites in Oregon and Montana with mean annual temperatures of 5.6 and 4.5^{o}C and mean winter temperatures of -0.76 and -5.13^{o}C, respectively (Szucs et al. 2011).

Moisture Regime

L. jacobaeae eggs can desiccate in dry conditions, so mild, rainy autumns/winters are necessary (Harris undated d), however areas that are flooded are not desirable. On Vancouver Island in the Nanaimo, Cedar and Duncan areas and on the lower mainland from Hwy 91 near Delta east to Bridal Falls, the flea-beetle is established in areas with significant precipitation throughout the winter, spring and fall months. The flea beetle has been reported as suitable for sites in the Pacific Northwest coast (McLaren et al. 2000). McEvoy and Cox (1991) determined that precipitation in Oregon does not decrease the combined ability of *L. jacobaeae* and *T. jacobaeae* to control tansy ragwort infestations.

Soil Moisture

The flea beetles are frequently found on lower slopes, valley bottoms and plains in hygric and subhygric areas 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, however, this may also reflect that the eggs do not survive in dry soil (Harris and Crozier 2006) and the agent does not establish in spring flood sites. Although pupae of *T. jacobaeae* have been reported to absorb water and perish when the soil is too moist and well-drained sites are best for *L. jacobaeae* establishment, this species can tolerate moist sites better than *T. jacobaeae* (Wilkinson 1986). Larvae can endure spring flooding by feeding on the root crown and leaf petioles in mild climates (Powell et al. 1994).

Soil Texture and Compactness

L. jacobaeae require well-drained soils. They are frequently found on coarse soils along roadsides and on silt-loam soils common in the Fraser Valley, lower mainland, and agricultural properties. 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).

Salinity

Some indication has been found that salinity in the top A horizon of soil may affect success of the closely related flea beetle *L. flavicornis* (Potter et al. 2004). It is recommended saline soils are avoided when releasing *L. jacobaeae*.

Snow Cover

L. jacobaeae has established on Vancouver Island near Nanaimo, Cedar and Duncan areas and on the lower mainland from Hwy 91 near Delta east to Bridal Falls where snowfall may be absent or wet and heavy.

Disturbance

Unlike other biocontrol agents of tansy ragwort, *L. jacobaeae* appears to tolerate some disturbance. It is found at roadside sites that are mowed and in fields that are grazed by livestock. King County (2004) noted that regular mowing may prolong the life of the plant as a short-lived perennial and increase the longevity of a site by keeping the plants in an artificial rosette stage and preventing bolting. However, the closely related flea beetle *L. flavicornis* has had difficulty establishing at some sites in Tasmania, Australia. The working of the wet soil by cattle hooves is suspected of causing high larval mortality at some of these sites (McLaren et al. 2000).

Biogeoclimatic Ecosystem Classification Zones

L. 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 flea beetle 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 38 - Established releases

BEC	Release[a]	Dispersal[b]
CDFmm	18/18 (100%)	10/10 (100%)
CWHdm	15/17 (88%)	4/4 (100%)
CWHds1		0/2 (0%)
CWHxm1	20/22 (90%)	12/12 (100%)
IDFdm1	0/2 (0%)	

[a] # sites with establishment/ # release sites

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

General Location in Province

L. jacobaeae has been widely released in the Fraser Valley, in the lower mainland and on Vancouver and Gulf Islands. The most easterly release was made near Seabird Island in 1996. It established and is self-dispersing westward to within 21 km of the Fraser Valley tansy ragwort infestations. It has dispersed as far east as Agassiz (Bridal Falls) but no evidence has been found at any of the tansy ragwort infestations established in the immediate Hope area (the furthest east of the coastal infestations). It is established and dispersing on Vancouver Island and various Gulf Islands in the general areas of the releases including Nanaimo, Cedar, Cassidy, Duncan, and, Gabriola, Salt Spring, and Mudge Islands.

Figure 39 - *Longitarsus jacobaeae* release made on November 18, 1988 on Vancouver Island

Summer 1990

Fall 1997

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 *L. jacobaeae* numbers in subsequent years as they move through their predator-prey cycle. Cool wet springs in Oregon have not decreased the flea-beetle populations as they are reported to still be active (Oregon Wheat 2011). A resurgence of the plant in areas where it was formerly controlled by the flea beetle may result in an increase in the local *L. jacobaeae* population, giving rise to a source for collection and redistribution elsewhere. 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 flea-beetle to ensure efforts are not wasted. It is recommended to collect and release *L. jacobaeae* (Italian) into gaps found in its distribution, primarily on Vancouver Island, on any of the Gulf Islands, the Sunshine Coast, and on the lower mainland towards Squamish. More specifically, collections that arise from CWHds 1 sites may be best suited for release eastward towards the Hope area and northwest towards Squamish while collections taken from within the CWHmm zones may be better suited to release sites located up the Sunshine Coast and northern Vancouver Island. As no collections from coastal B.C. have resulted in establishment in the interior to date, it was not thought they would survive at higher elevation, cold winter sites, however, Italian strain flea-beetles have recently been found at inland, cooler U.S.A. sites in Oregon and Montana. It is not currently recommended to attempt further releases of the Italian strain into the Okanagan Valley as a pure Swiss strain *L. jacobaeae* release has been made in this location and although these two strains can hybridize and survive in a natural setting, the resulting traits of development time, fecundity, longevity, egg size and sex ratio are not yet known (Szucs et al. 2011). Further studies are needed to determine if their hybridization should be promoted or avoided. For this same reason, it is currently not recommended to distribute this strain to the Haida Gwai tansy ragwort infestations. Greater success may be found with the Swiss strain if it establishes in B.C.

APPENDIX I. *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 40). 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 41). **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 40 - *Cochylis atricapitana* adult (Powell et al. 1994)

Figure 41 - 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 42 - Cochylis atricapitana larvae and feeding damage

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

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 43 - 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 44 - 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.