British Columbia Ministry of
Forests, Lands and Natural Resource Operations

Appendix H *(Longitarsus jacobaeae)* to the Operational Field Guide to the Establishment of Tansy Ragwort biocontrol agents in British Columbia

Susan Turner (P.Ag.), Sandy Cesselli

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Longitarsus jacobaeae

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

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Prepared by

Susan Turner (P.Ag)
Biocontrol Specialist
Invasive Plant Program
Ministry of Forests, Lands and Natural Resource Operations
441 Columbia Street
Kamloops, B.C. V2C 2T3

Sandy Cesselli
Biocontrol Technician
Invasive Plant Program
Ministry of Forests, Lands and Natural Resource Operations
441 Columbia Street
Kamloops, B.C. V2C 2T3

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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

Figure1 - *Longitarsus jacobaeae* (Italian strain) adult (Powell et al. 1994)

Longitarsus jacobaeae (Italian strain) are root-feeding flea beetles of tansy ragwort (Figure 1). 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 2). The **pupae** are white and 2-4 mm long (Rees et al. 1996).

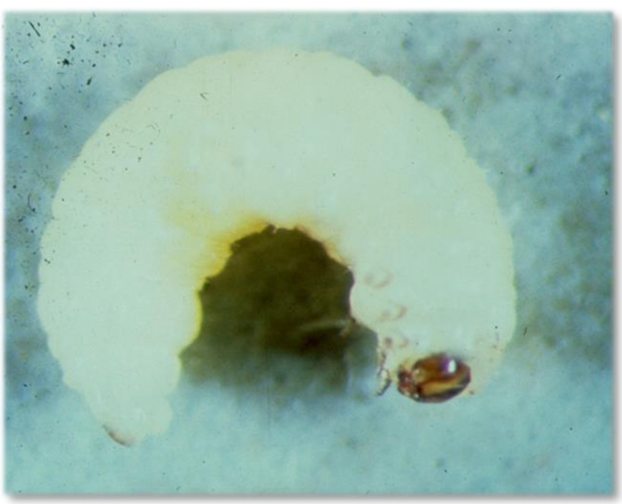

Figure 2 - *Longitarsus jacobaeae* (Italian strain) larvae (Powell et al. 1994)

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.

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 3) 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 4) (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.

Figure3 - Adult shot-hole feeding evidence

Figure 4 - 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°C and mean winter temperatures of -0.76 and -5.13°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 5 - 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 6 - *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.

Handling Cycle

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

Biocontrol agent ↓	Activity of interest	Jan 1-15	Jan 16-31	Feb 1-15	Feb 16-28	Mar 1-15	Mar 16-31	Apr 1-15	Apr 16-30	May 1-15	May 16-31	Jun 1-15	Jun 16-30	Jul 1-15	Jul 16-31	Aug 1-15	Aug 16-31	Sep 1-15	Sep 16-30	Oct 1-15	Oct 16-31	Nov 1-15	Nov 16-30	Dec 1-15	Dec 16-31
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