OPERATIONAL FIELD GUIDE

TO THE PROPAGATION AND ESTABLISHMENT OF THE BIOCONTROL AGENT *MOGULONES CRUCIGER*

(HOUND'S-TONGUE ROOT-FEEDING WEEVIL)

May 2004

Information contained in this Field Guide is comprised of fact and field observations as of September 2003. Site specific experiences may vary.

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Forest Practices Branch
Range and Integrated Resources Section
Invasive Plant Biocontrol Program
British Columbia Ministry of Forests

PREPARED BY:

SUSAN TURNER
INVASIVE PLANT BIOCONTROL PROGRAM
FOREST PRACTICES BRANCH
MINISTRY OF FORESTS

EDITED BY:

DR. ROSE DECLERCK-FLOATE
RESEARCH SCIENTIST
WEED BIOCONTROL
AGRICULTURE AND AGRI-FOOD CANADA

DWAINE BROOKE
INVASIVE PLANT BIOCONTROL PROGRAM
FOREST PRACTICES BRANCH
MINISTRY OF FORESTS

INFORMATION CONTRIBUTED BY:

MARSHA DEWOLF
INVASIVE PLANT BIOCONTROL PROGRAM
FOREST PRACTICES BRANCH
MINISTRY OF FORESTS

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1. PURPOSE

This document summarizes information for the hound's-tongue biological control agent *Mogulones cruciger* while it was classified as 'primary' and the responsibility of the Forest Practices Branch. The information is a combination of scientific facts and observations. Intended as a 'field guide' for those unfamiliar with *M. cruciger*, the summary contains pertinent information for field propagation and establishment of the biocontrol agent in British Columbia.

2. INTRODUCTION

The goal of the BC Ministry of Forests' Alien Invasive Plant (Weed Control) Program is to reduce target invasive plant populations to ecologically and economically acceptable levels and to prevent their encroachment into new areas. The biological control portion of the program includes biocontrol agent screening, propagation, release, collection and monitoring.

Implicit in the use of biocontrol methods is the acknowledgment that invasive plant eradication is not a goal. Rather, biological control agent species and host invasive plant species exist in predator-prey relationships with the invasive plants held at acceptable population levels and the insect populations self-sustaining.

The biocontrol program is cooperative among the Ministry of Forests, Ministry of Agriculture, Food and Fisheries (MOAFF), Agriculture and Agri-Food Canada (AAFC), Centre for Agriculture and Bioscience International Institute for Biological Control (CAB IIBC) in Switzerland, and several U.S federal and state agencies and universities.

Hound's-tongue (*Cynoglossum officinale*) is a biennial or short-lived perennial of European origin, supposedly from the mountains of Eastern Europe and Western Asia (Freese 1987). This invasive plant is thought to have arrived in North America as a contaminant in cereal seed in the 1800s (De Clerck-Floate and Schwarzlaender 2002). The first herbarium specimen collected of this plant in Canada dates back to 1859 in Ontario and it was first reported as "common and a weed around Montreal (Macoun 1884)" (Schwarzlaender 1996). It occurs across Canada with serious infestations in Southern Ontario and B.C. with the earliest herbarium record of hound's-tongue in B.C. from Keremeos in 1992 (Upadhyaya and Cranston 1991). As of 1993 it had not been found in Prince Edward Island or Newfoundland (Jordan et al. 1993).

Hound's-tongue seeds are surrounded by a barbed envelope or burr and therefore cling to the fur, hair and wool of animals (Figure 1). Each plant can produce over 600 burrs (Harris 1989). The burrs are an irritant that can lead to mechanical damage as well as economic loss in livestock due to decreased sale prices, handling costs to remove the burrs prior to market and "a decline in the reputation of the rancher" (Upadhyaya and Cranston 1991) (Figure 2). The plants themselves are toxic and have a distinct odour when fresh so are generally avoided by grazing animals. However, if the dried invasive plant is mixed into hay, cattle and horses are at serious risk to poisoning. Like other invasive plants, hound's-tongue grows in place of desired wildlife and livestock forage, decreases recreational land values and affects B.C.'s biodiversity when it forms dense monocultures. For more information on hound's-tongue, see Appendix A.

Figure 1 Barbed burr surrounding hound's-tongue seeds (Cranston et al. 1996)

Figure 2 Hound's-tongue burrs on cow

In 1986, over 2000 ha of B.C. were infested with hound's-tongue (Cranston and Pethybridge 1986). Efforts to control the invasive plant with chemical and mechanical means have been undertaken but have not proven economical. For example, "use of picloram, the chemical of choice, is often not feasible because of cost and impact on non-target forages or tree species" (De Clerck-Floate and Schwarzlaender 2002). Additionally, cutting stalks reduces seed set but does not prevent it and any unripened seeds left may still be viable to germinate the following spring. Hound's-tongue infests pastures, open forests and road edges and is spread by human activity, particularly logging, and by the movement of animals, both wild and domestic. Cattle have been noted to be the main dispersers of seed to new sites (De Clerck-Floate and Schwarzlaender 2002). Tracking the spread of hound's-tongue, considering these vectors, and then attempting to control it with chemical and mechanical means over varying terrain has

proven difficult and costly. With the use of a biocontrol agent hound's-tongue would be followed by the agent to its new, scattered locations and controlled.

Due to the nature of hound's-tongue to produce seeds only once and then die, it was determined that biological control agents that fed on the rosettes (either on the roots or leaves) and potentially prevented flowering were desired (Freese 1987). Screening for *M. cruciger* (formerly *Ceutorhynchus cruciger*) began in 1988. Approval was received to introduce the weevils into Canada in 1997 and the weevils were released in B.C. that same year. However, new concerns came to light in the U.S.A. over the safety of some native Boraginaceae species that had not been included on the original test plant list which was accepted at the beginning of the project by the regulatory agencies. Of particular concern were some native species with endangered status in the U.S.A. Subsequent tests performed by De Clerck-Floate and Schwarzlaender in laboratory conditions and open field sites and investigations of the weevil's behavior in natural conditions in B.C. were conducted. It has been documented that *M. cruciger* can complete full development on species within closely-related genera in the Boraginaceae, but, it prefers hound's-tongue as its host. The results of the new studies showed that *M. cruciger* can complete development on nine of the 22 native North American Boraginaceae investigated. These nine species are from four genera within the tribe Eritrichieae, but, all experienced less attack than the intended host, hound's-tongue, particularly under open field conditions within the rangeland of B.C. Of particular emphasis within these studies were the U.S.A. endangered species of *Cryptantha* (*C. crassipes* is listed as endangered in the U.S.A.) and *Plagiobothrys* (two species in this genus are listed as endangered in the U.S.A.). The same results as above were noted for six of 12 species of *Cryptantha* but no or incomplete development was found on the tested *Plagiobothrys* species (De Clerck-Floate and Schwarzlaender 2002).

3. *MOGULONES CRUCIGER*

Coleoptera: Curculionidae
Common name: Hound's-tongue root-feeding weevil

BIOLOGY

GENERATIONS PER YEAR: one

ADULT STAGE: Weevils are about 2-3 mm in diameter, round and dull brown (De Clerck-Floate 1998) with a pattern on their elytra (anterior wings that protect the functional wings) resembling a white cross (Figure 3). *M. cruciger* adults may live up to two years and have two, possibly even three, oviposition periods during this time. Adult weevils emerging in the spring have either overwintered as adults hibernating in the soil or as eggs or larvae that developed through the autumn, winter and spring as temperatures allowed. Adult weevils that

hibernate during the winter emerge in the spring prior to weevils that overwinter as eggs or larvae as these latter need first to complete their development. In B.C. the first emerging weevils have been observed as early as March and the second flush has been observed in significant numbers in May. They continue to emerge to a certain degree throughout the summer during which the developmental stages of the varying generations overlap. However, approximately 22% of the weevils were observed to not emerge directly after pupation in a field study in Hungary but instead remained in the roots until the following spring (Schwarzlaender 1997). Schwarzlaender (1997) also reports that the sex ratio of emerging weevils is almost equivalent. The weevils, both males and females occurring on the same plants, feed on hound's-tongue leaves during a "prematuration period" (Jordan et al. 1993). Adult feeding results in oval-shaped holes in the leaves, but, feeding also occurs on all aerial plant parts and continues until hibernation in the autumn. There is a noticeable reduction in feeding with high summer temperatures when the adults hide in the leaf litter (Schwarzlaender 1997). Adult feeding has been observed to significantly impact the plants in B.C.

Two weeks to 34 days after emergence, (average 21 days), mating begins (Schwarzlaender 1996), however, females that emerged following spring pupation took longer to mature and begin copulation, up to 75 days. Copulation between the adult and the F1 generation does occur (Schwarzlaender 1997). Oviposition then begins. Females can oviposit in the autumn, hibernate and continue the following spring. In Hungary, the number of eggs laid per female in the spring was 18 times higher than that laid in autumn (Schwarzlaender 1997). In B.C., the peak of oviposition appears to be in May. In Europe, females were observed to prefer bolting plants over rosettes and large plants over small ones for oviposition (Schwarzlaender 1997), however, in B.C. females oviposit into both vegetative rosettes and reproductive plants (De Clerck-Floate pers comm. 2004). The females chew holes into the stems or leaves, in particular into the petioles, approximately 0.5 mm in diameter deep and 1 mm in length into which they lay the eggs. The holes are then covered over and preserved with frass. Oviposition sites appear as "small dark green spots on the plant surfaces" (Jordan et al. 1993). The green spots look and feel like hard, raised blisters. Near the end of the oviposition period, if the plant stems are no longer suitable for oviposition, the females will lay their eggs directly into the root to ensure the first instar larvae survive (Freese 1989). The adults then return to hiding in the soil or under rosette leaves where they will remain for the summer. Some feeding activity may occur on the rosette leaves during this time (Jordan et al. 1993).

Figure 3 ***Mogulones cruciger*** **adult**

EGG STAGE: Eggs are "whitish yellow" in colour and "of cylindric oval shape" "measuring 0.9 mm in length and 0.6 mm in width" (Jordan et al. 1993). Under proper temperature conditions, eggs begin to develop immediately following oviposition. Jordan et al. (1993) reports egg development is delayed by low temperatures and was witnessed to cease below 6^{o}C in laboratory conditions, but, when temperatures occur at 25^{o}C, on average development of the eggs takes 7 days. Schwarzlaender (1997) reports under greenhouse conditions, eggs take 15 days to complete development.

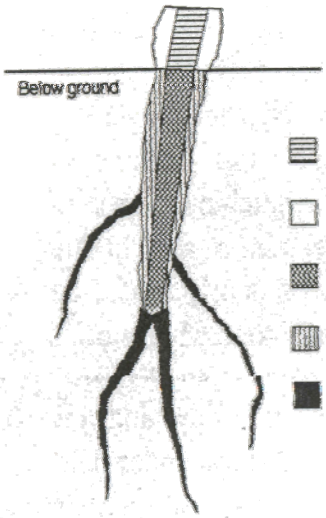
LARVAL STAGE: Larvae are "whitish" and "have a light brown head capsule" (Jordan et al. 1993). Mature larvae appear fatter in the middle and often curl into a comma shape. The larvae develop through 3 instar stages which take approximately 30 to 35 days to complete under natural conditions (Jordan et al. 1993). On average, in the initial two weeks the first instar larvae feed downward from basal leaf parts where the eggs were deposited. They are mostly found in the root crown. The second instar larvae then move further down in the next two weeks. They feed mostly on inner root tissue or the root cortex. The third instar or mature larvae move still further down. They feed mainly on inner root tissue or the root cortex of the taproot or in secondary roots, which often destroys the entire tissue. As described, the different instars feed in different locations in the root (Jordan et al. 1993) (Figure 4). Competition for root resources does occur, particularly when multiple larvae are present on a root (De Clerck-Floate, pers comm. 2004). Larvae that hatch from eggs laid in the spring develop faster than larvae hatching from eggs laid in the autumn due to higher soil

temperatures. Soil temperatures affect the development of larvae whose threshold is "nearly 4°C" (Jordan et al. 1993). The overlap frequency of eggs and larval stages found spring and summer from root dissections in Switzerland are shown in Figure 5. When mature larvae are ready to pupate they leave the roots and move into the soil (Jordan et al. 1993).

PUPAL STAGE: Within a single day, larvae spin oval cocoons of silk 7 x 5 mm in size, the outside of which is covered with soil. *M. cruciger* develop for 24 to 26 days in the summer. Pupation is complete approximately 10 days after the cocoon is spun. However, once the new adults "shed their pupal skin", they stay "another ten days inside their cocoons to harden" (Jordan et al. 1993). Pupation of F1 larvae occurs in late June to July in Europe. The temperature threshold for pupation is 8°C (Jordan et al. 1993).

F1 ADULTS: F1 adults emerge from mid-June to mid-October in Switzerland where 90% emerge by July 20th. They feed, mate and may oviposit in mid-September to mid-October. Only a few eggs are laid at this time. These weevils overwinter, mate and oviposit the following spring. Finally these long-lived weevils may interbreed with the new F1 generation and oviposit again the following autumn. Female weevils may lay 200 eggs during their life span (Jordan et al. 1993). The overlapping generations of the *M. cruciger* life cycle can be seen in Figure 6.

DISPERSAL METHOD: The adult weevil walks and flies to reach its mate and host plants.



Feeding site	L1	L2	L3
Root crown (centre)	52.9	26.0	18.4
Root crown (outer part)	35.4	35.4	14.6
Tap root (centre)	4.4	11.3	37.3
Tap root (outer parts)	5.9	21.3	14.8
Secondary rootlets	1.4	6.0	14.9

Figure 4 "Feeding sites of immature" *M. cruciger* "instars; proportion (%) of each larval instar found at different sites (n=642 larvae; 193 roots)" (Jordan et al. 1993)

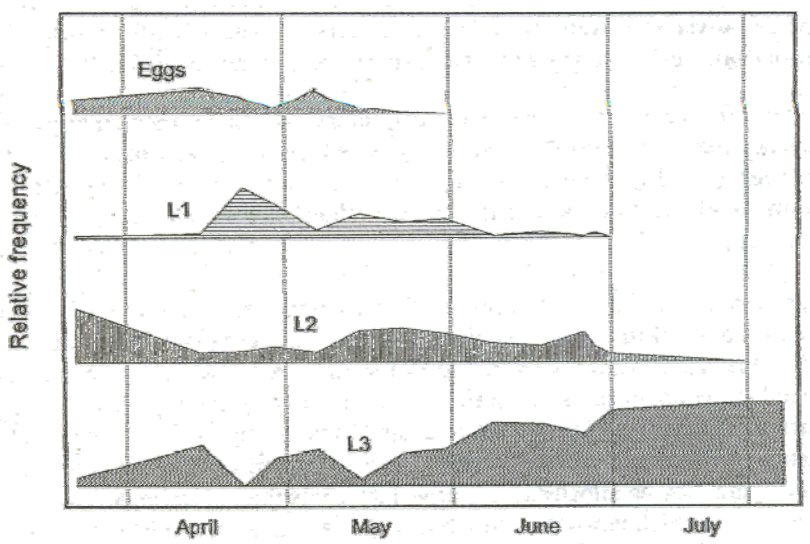


Figure 5 "Relative frequency of immature stages of" *M. cruciger* "during spring and summer" (Jordan et al. 1993)

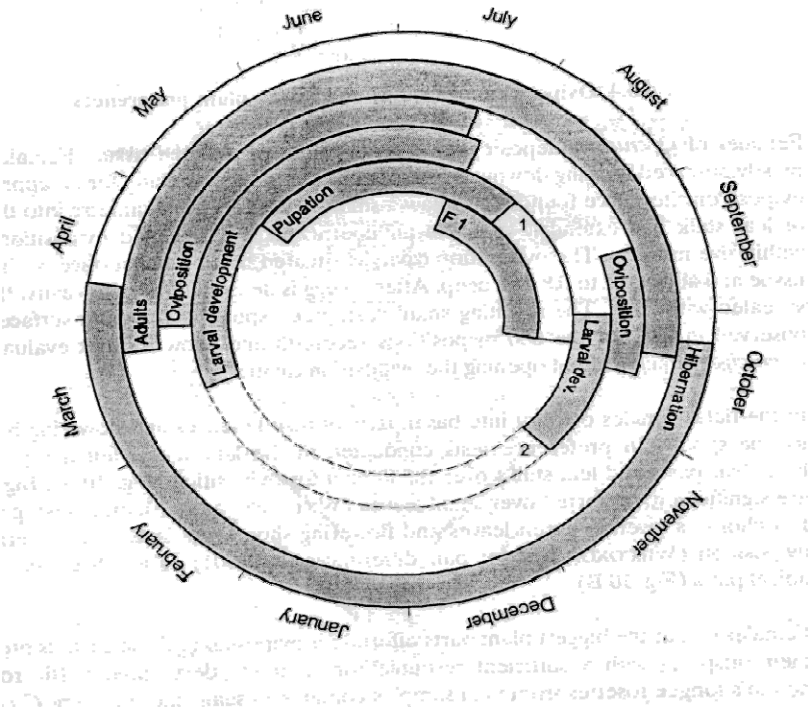


Figure 6 "Life cycle of" *M. cruciger* "(1): Prolonged diapause in adult stage; (2) larvae in winter quiescence" (Jordan et al. 1993)

RANGE

Native (European) Distribution

M. cruciger is common throughout Europe and occurs in Algeria and Morocco (Jordan et al. 1993). Weevil populations used for screening, and later importation into Canada, were located in Austria, Hungary and Yugoslavia.

M. cruciger is found in a variety of habitats in its countries of origin. It extends "from moist to mesic forest habitats as well as to dry gravel pits" (Jordan et al. 1993).

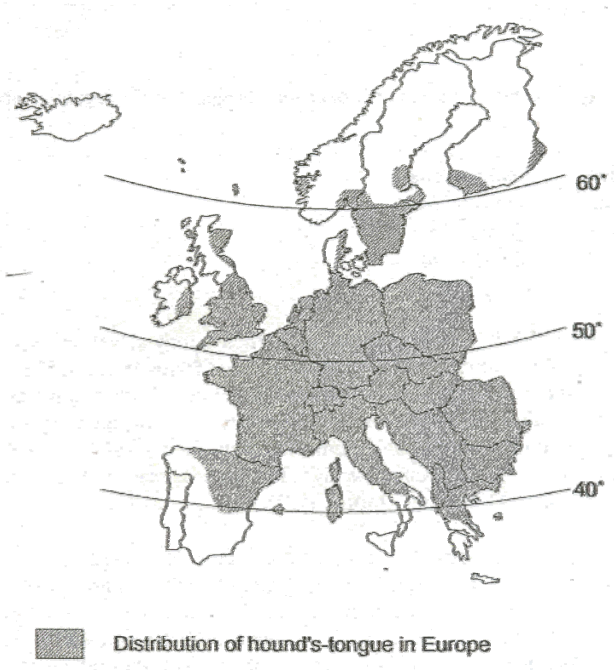


Figure 7 "Distribution of hound's-tongue in Europe" (Jordan et al. 1993)

Predicted North American Distribution

Potential "distribution in Canada will be limited by the distribution of hound's-tongue (Jordan et al. 1993). In Canada, as of 1988, the distribution of hound's-tongue includes all provinces except Prince Edward Island and Newfoundland and it is most abundant in Ontario and British Columbia (Upadhyaya et al. 1988).

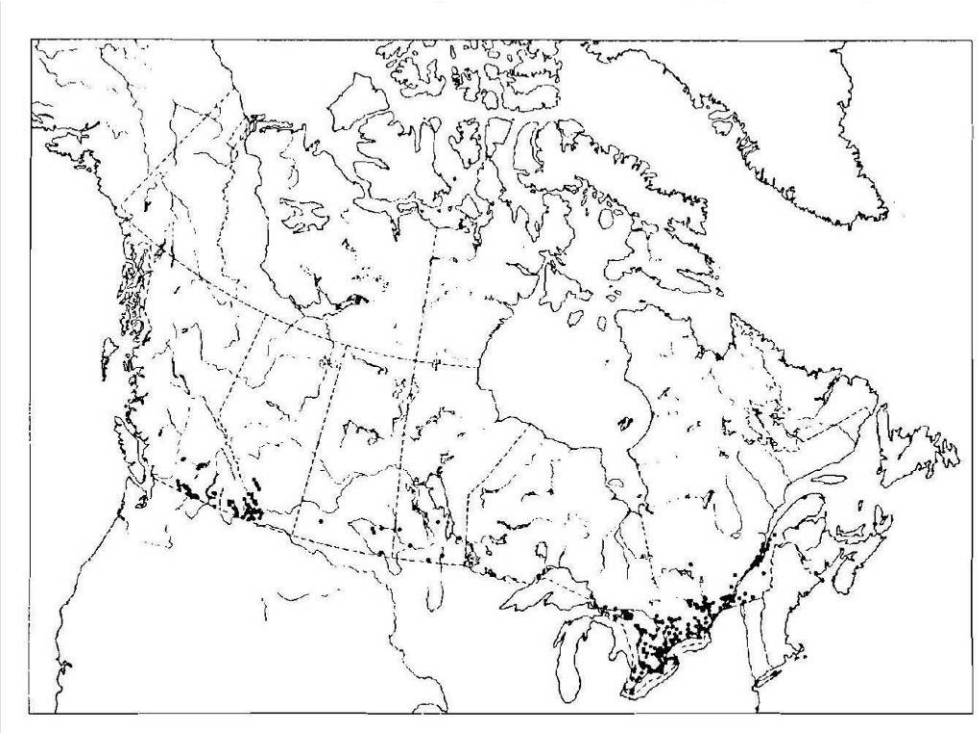


Figure 8 Distribution of hound's-tongue in Canada (Upadhyaya et al. 1988)

B.C. HABITAT

As predicted, *M. cruciger* have established on hound's-tongue throughout its distribution in B.C. The habitats range from the Bunchgrass very dry warm (BGxw2) through Ponderosa pine very dry hot (PPxh2), Interior Douglas-fir very dry hot to moist warm (IDFxh1 to IDFmw2), Interior Cedar-Hemlock very dry warm (ICHxw) and to the Montane-Spruce dry mild (MSdm) biogeoclimatic (BEC) zones (see Appendix A for a definition of BEC zones). The majority of weevils have been placed in the IDF and ICH. These biogeoclimatic zones not only have the greatest concentration of hound'-tongue in the province but sites of lower elevation that are drier and warmer have been kept free to date for the future distribution of *Longitarsus quadriguttatus*. *L. quadriguttatus* is a root-feeding flea beetle whose habitat range is in the warmer, drier spectrum of hound's-tongue's range.

M. cruciger do not appear to be affected by elevation within their host's range as they have been found at elevations ranging from 407 m to 1512 m. Slope and aspect also do not appear to be a factor in *M. cruciger* establishment. Sites with varying slopes and aspects have all established. Proximity to water and varying soil moisture and texture seem to not affect *M. cruciger* survival. This hardy weevil tolerates little/no heavy snow cover. For example, a site

at Apex Mountain (IDF dk2; 1512 m; 47 % slope; 182^{o} aspect) near Penticton has just as healthy a *M. cruciger* population as a site in Barnhartvale (Kamloops) (PP xh2; 550 m; 15% slope; 360^{o} aspect) (Figures 9 and 10, respectively). Apex Mountain (site of a down-hill ski resort) receives far more snow that Barnhartvale.

The presence or absence of varying ground cover, debris or competing vegetation is not a factor in *M. cruciger* establishment. For a general list of vegetation found at hound's-tongue sites in the former Kamloops Region portion of the Southern Interior Forest Region see Appendix A.

The only factor that, to date, has bearing on the survival of *M. cruciger* on hound's-tongue in B.C. is the presence or absence of the target plant.

Figure 9 Apex Mountain release site near Penticton

Figure 10 Barnhartvale, suburb of Kamloops, release site

4. HISTORY OF INTRODUCTION

Screening of *M. cruciger* occurred between 1988 and 1996. The weevil was approved for release in April 1997 and the first releases into B.C. were made later that same spring to the Ministry of Forests Propagation Facility (MOFPF) in Kamloops and to field sites around B.C.

The following table summarizes collection and redistribution data.

Source	1997	1998	1999	2000	2001	2002
Received from CABI or AAFC	1023	2984	5686[a]			
Reared & Collected from MOFPF		576	3148	15191	15491	6081
Released to MOFPF	102	160				
Released to Field	921	3400	8834	15022	15251[b]	6081

[a] 5091 *M. cruciger* were released in B.C. for a study conducted by Dr. De Clerck-Floate from AAFC.
[b] 240 weevils expired while waiting in captivity for field sites to be free of snow and to produce plant material.

Figure 11 Collection and release summary of *Mogulones cruciger* in B.C.

5. REDISTRIBUTION

Redistribution of agents is a critical part of the biocontrol program. To ensure distribution throughout *M. cruciger's* potential provincial range, personnel must be able to recollect from field releases and make releases into new sites.

FIELD COLLECTION

Where to collect

Weather conditions have some effect on locating the weevils. Warm temperatures in early spring increase weevil activity and bring them out of the soil and up onto the plants. When several warm to hot days occur in a row, many weevils are visible. Conversely, during cloudy or cool days, the weevils are found in the soil and crevices around the root crown rather than up on the plants. The weevils tend to not like the continual hot summer temperatures, during which they hide in vegetation or in the soil.

The following are suggested Collection Site Criteria*:

- Sites should be 2 to 3 years old as weevil populations devastate their hosts and cause hound's-tongue infestations to crash following this time span. If sites are large, they may last longer and be collectable in year four, for example, the Harper Lake gas pipeline site.
- Sites should be between 500 and 1700 m^2 in size. If the infestation is destined to be a collection site, a minimum size would be 1000 m^2 as the weevils will decimate a smaller

site and move elsewhere within 2 to 3 years**.** Studies by Dr. De Clerck-Floate have shown collapses of 400 m^2 sites in 2 years using 300 and 400 weevils (Wikeem et al. 2002).

- The minimum estimated hound's-tongue density should be greater than 5 plants per $metre^2$. *M. cruciger* require a lot of plant material to sustain a population for several years at a site. Also, *M. cruciger* collection is time-consuming so dense patches are needed to make this activity efficient.
- Sites should have a variety of plant stages present in order to sustain the infestation. Female weevils initially choose the largest plants in a hound's-tongue population to lay their eggs upon. These plants are typically those that will bolt and become reproductive. However, the weevils are quite capable of ovipositing and developing on plants that remain vegetative rosettes (De Clerck-Floate, pers comm. 2004). Typically, spring collection occurs when most of the plants are still in the rosette stage and the weevils are most active.
- Sites will appear collectable from the obvious number of feeding holes in the leaves; especially the leaf petioles (Figure 12 and 13). The petiole damage is a consistent indicator of the weevils' presence as other insects may cause similar feeding damage to *M. cruciger* on the leaf blades (De Clerck-Floate, pers comm. 2004). Also, the plants will not be robust following significant weevil feeding. The rosettes will often appear chlorotic, twisted and stunted.
- Topographies of successful sites have varied. All sites where hound's-tongue has been capable of growing have been able to accumulate enough heat units for *M. cruciger* development.
- Sloped sites are more difficult to collect from as the equipment tips over readily, making collection more time-consuming.
- All soil types where hound's-tongue is found.
- Although not found to be an issue to date, sites receiving cold air drainage may be poor choices, especially if they are relatively flat, allowing cold air to pool.
- Preferably on Crown land with easy access within 100 km of Regional or District Offices.
- Sites should be easily traversed for collection.
- It takes approximately two hours to complete collection on one site. Generally, only two sites are collected from in a single day unless they are quite close together to minimize travel.

*These criteria also need to be kept in mind when establishing future collection sites (current release sites) to ensure a future population of *M. cruciger* in the field. See discussion under Field Release.

Figure 12 Petiole damage

Figure 13 Petiole damage with blisters

Currently, a list of possible collections sites in the Southern Interior Forest Region include:

1. DKA-MOCR-99-002 McGillivery Lake FS Road, plant density decreasing substantially in 2002;
2. DME-MOCR-98-006 Pike Mtn. FS area, road edge release;
3. DME-MOCR-98-001 Otter Creek Rd., plant density decreasing in 2002;
4. DME-MOCR-00-010 West China Creek Rd., in 2002, weevils not yet in large numbers;
5. DSA-MOCR-98-001 Off Harper Lake Rd. gas line lower site;
6. DSA-MOCR-98-002 Off Harper Lake Rd., cattle guard area, small site;
7. DSA-MOCR-98-003 Off Harper Lake Rd., gas line upper release;
8. DSA-MOCR-99-001 Harper Lake, rough road access;
9. DSA-MOCR-99-002 Chase Creek Rd., small site;
10. DSA-MOCR-00-005 Skimikin FS rec site;
11. DVE-MOCR-99-001 Oyama; in 2002, weevils had not yet expanded into large potential area of site
12. DBO 00156 Boothman Boothman; easy access, flat terrain;
13. DBO 01001 Morrissey Morrissey; easy access, moderate terrain;
14. DCB 99140 Eager Hills Cranbrook NE Hwy#3; small site, slope, close to town; and
15. DCB 01008 Rampart Lease .2km on Mayook Station road; easy access, flat terrain, larger site.

How to collect

A variety of collection methods were attempted to gather *M. cruciger* from field sites. Field collection of *M. cruciger* involves aspirating adult weevils from a hound's-tongue infestation.

Visually locating and hand-picking or tipping weevils from the plants is possible but proved difficult and time-consuming. Many plants are still rosettes when collection occurs in the spring but either as rosettes or bolted plants they are lush and somewhat more fragile and susceptible to breaking than other invasive plant species. The goal may not be to maintain the plants and site for collection, but, the weevils may fall off the broken plants before they can be caught. The nature of *M. cruciger* to quickly form a ball and drop from view when movement is noticed is the biggest deterrent to tipping or handpicking this agent. The dark brown and white colouration of the insect creates a mottled effect that is very hard to pick out once the weevil has fallen from the plant and is lying motionless on the soil. If the insect has rolled into the tight leaf axils, they are difficult to extract without harming them unless aspirating with strong suction.

Due to the lush, breakable nature of the host plant, sweep netting was not found to be an efficient collection method.

Aspirating with modified hand-held vacuums was attempted, however, the suction was not strong enough to retrieve the weevils from the leaf axils or amongst the top layer of debris/soil. Dr. Bourchier suggested the use of a modified leaf blower and, following further adaptations, the unit was field tested (Bourchier pers comm. 1998). When compared to the hand-held vacuum aspirators, the leaf blowers proved to be 2.45 times more efficient in collecting weevils. *M. cruciger* weevils are aspirated (vacuumed) from hound's-tongue plants using modified leaf blowers (Figure 14).

First, old stalks are clipped and moved to the side so the working area is free of obstacles but the site still retains the seed source. The nozzle is maneuvered quickly over the upper and lower sides of the leaves, between leaves surrounding any buds, into the leaf axils, around the root crown and outward from the root crown over the soil to the drip line of the leaves (Figure 15). Aspirate outward from the release stake until the feeding holes on the leaves can no longer be found (Figure 16). Be sure to keep the catchment container from tipping over as the debris will clog the hoses.

Figure 14 Modified leaf blower used to aspirate weevils

Figure 15 Aspirating hound's-tongue root crown

Figure 16 Aspirating hound's-tongue site

Aspirating continues, covering several plants until approximately 5 to 8 cm of debris has accumulated in the catchment container (Figure 17). At this point the debris within the container begins to swirl vigorously around the container and can clog the hoses.

Figure 17 Modified leaf blower with catchment container attached

The collected debris can then be decreased in volume by running it gently through a series of soil sieves. Although not necessary, this step allows for much of the nutlets, plant parts, other insects and debris to be left at the collection site. Sifting these contents at the site can also help to decrease predation on the weevils by not storing them with spiders and other predators. Three sieves (#3, 6 and 10) are used with the reservoir tray at the bottom. Leaves and twigs get caught and are discarded from the #3 sieve with 6.7 mm holes. Pebbles, nutlets, burrs and large clumps of soil are caught and discarded from the #6 sieve with 3.3 mm holes. The weevils fall through and are caught in the #10 sieve with 2.00 mm holes while fine dirt and smaller insects fall through and are discarded in the reservoir tray below (Figure 18). A few small weevils may fall through the holes of #10 into the reservoir tray but it is not efficient to try to retrieve these. (Although not efficient, use of a sieve with 1.40 mm holes would catch these occasional weevils.)

Sieve #3

Sieve #6

Sieve #10

Reservoir tray

Figure 18 Sequence of collection debris in soil sieves

When it is warm and the weevils active, leaving the catchment container uncovered or constantly opening the lid of the container is not effective as the weevils will fly back out. It

is more efficient, particularly when operating with two people, to use an intermediate container that has a lid. Debris can be placed into this container and while one person continues to collect, the other person can sieve the debris. Tap the sides of the intermediate container to knock the weevils from the walls so they do not readily fly out when the lid is opened. It is best to fill the first sieve (#3) only half full each time as it is more efficient with less material. However, #3 can be filled twice before subsequent sieves have their material removed.

The weevils are further separated from debris by placing the contents from the #10 sieve each time into the bottom of a bucket that is scored/scratched around the inside from the bottom to 15 to 20 cm up the sides (where the funnel will rest). When collection is complete, place an inverted, scored funnel about 10 cm above the debris (Figure 19) and rest hound's-tongue leaves, gathered from the site, atop the funnel (Figure 20). Add a lid, with a mesh screen in the center, on top (Figure 21).

Figure 19 Scored funnel

Figure 20 Hound's-tongue leaves placed on top of funnel, respectively

Figure 21 Bucket with weevils, funnel, hound's-tongue leaves and mesh lid in place

The weevils will separate themselves from the debris by crawling up the bucket walls toward light and feed on the leaves. This step allows for significant efficiency in field collecting *M.*

cruciger. It is also important to ensure the weevils are not contained and transported within soil inadvertently collected at a site as it is thought to desiccate them and to clog their spiracles (Eva Pavlik, pers comm. 2003). Other containers and methods of allowing the weevils to move to a light source may be used, but, it is essential to ensure the weevils can gain traction on the surface they must climb toward the light. The lower portion of the bucket and the inside of the funnel must be scored/scratched to enable the weevils to climb the sides. The bucket is taken back to the office or home and placed in a warm area (~20^{o}C). Either put the bucket next to a window for natural light cycles or, preferably, put a light over the bucket to assimilate daylight. Some spiders make it to this stage so do not leave the weevils in the bucket too long, mid-afternoon the following day is best. Aspirate the weevils from the top of the container and from within the curled leaves using modified hand-held vacuums (Figure 22)**.** The number of weevils can be confirmed at this time. On average during spring trials, 78% of the weevils rose from the debris and climbed to the top of the funnel. Live weevils were still found in the debris along with dead ones that had been collected from the soil. If left longer, more weevils may rise from the bottom of the bucket, but, fresh hound's-tongue leaves should be added and consideration would need to be given to length of time the weevils will remain alive in the bucket and what is efficient for the collector. Sifting through the debris may be preferred (discerning between dead weevils and live weevils playing dead) or having a local 'hound's-tongue dump site' where left-over material (including some accidentally collected seed) can be discarded along with any missed *M. cruciger* weevils.

Figure 22 Hand-held vacuum modified to aspirate

Once removed from the bucket, the weevils are placed into 1 litre containers with a mesh opening in the lid. Mesh screens on the storage lids are critical to allow ventilation and to

prevent a build up of condensation that can drown the insects. Hound's-tongue is placed in the containers to provide feed. Do not use too much plant material as it is lush and produces a lot of condensation. If there is moisture in the containers, care should be taken as the weevils can either drown in small amounts of water or their elytra (wing covers) can be damaged when they get stuck to the wall of the containers. One large or two small leaves should be sufficient. Remove any early flower heads before placing hound's-tongue into containers. Containers are kept cool and out of direct sunlight. If the weevils are to be kept for any length of time before releasing, they should be stored in quantities of 100/container. The weevils will need to be transferred to clean containers every two days and supplied fresh hound's-tongue for foraging.

Additional Considerations

Sites can be visited more than once for collection. A bit of time is needed for the plants to recover from aspirating. If possible, leave the site for two weeks for recovery.

Collection in the rain should not be attempted as the hairy nature of hound's-tongue leaves retains a lot of moisture and the hoses of the aspirating units would continually get clogged with mud. Tipping the insects off the plants onto paper towel (or first onto your hand) to remove moisture as suggested for some other agents is also not applicable since the insects generally are collected in the spring when the plants are still rosettes, only allowing the leaves to be shaken while the agents are frequently found in the leaf axils and on the soil. Allow plants to dry before aspirating, however, the soil can be slightly moist. In this case, regularly check for clogged hoses. Tap the ends frequently to remove any build-up and feed sticks into the hose if necessary to check the passage and dislodge dirt.

M. cruciger can be sexed to get equal numbers of males and females for shipment by looking for characteristics similar to those used for sexing *Cyphocleonus achates*. However, a strong hand lens or a microscope and a method of slowing the weevils down, such as putting them in a cooler or refrigerator, to investigate the shape of their abdomens is needed. This is neither practical for field work nor necessary for *M. cruciger*, as mentioned previously, as the sex ratio of emerging weevils is almost equivalent.

M. cruciger may also be collected using the same technique in late August to September. The resulting collection will consist of two generations of weevils as the F1 generation will be emerging. However, spring collection is recommended as explained in the following section.

When to collect

Time of Year

First weevils to emerge in the spring are the overwintering adults from the soil. In the tents at the MOFPF (located in the BGxh2 at 346 m) weevils can be seen in the second and third weeks of March. Weevils may show up earlier if the winter breaks early and temperatures climb. If temperatures climb slowly, the emergence of weevils is spread over a longer period of time. The dependence of emergence and hence collection on the accumulation of enough heat units has not been observed or investigated. Next, the larvae, hatched from eggs laid in the summer or fall of the previous year, need to complete their development in the roots and then pupate in the soil prior to emergence. The collection period is, therefore, between mid April to the end of May with peak collection generally occurring at the beginning to mid May.

In a study by Dr. Rose De Clerck-Floate looking at the impact and dispersal of biological control agents for hound's-tongue and spotted knapweed in B.C., collections taking place between May 9 to 12, 2000, found the majority of agents "immediately around the crown of the plants in the leaf litter and duff but some weevils were occasionally found on the leaves and petioles" (Wikeem et al.. 2001). Fewer adults generally are observed at field sites starting mid to late May. This may be the oviposition period when the females lay their eggs directly into the root to ensure the first instar larvae survive. Individual sites require monitoring to determine differences in the weevils' cycle due to varying habitats. Collections should subside prior to the weevils' disappearance in the spring to ensure the collection site continues its population and the females transported to new locations still have eggs needing to be oviposited to start a new colony.

M. cruciger hide in the soil prior to the bolting of plants and are not generally seen in June and July. When *M. cruciger* were collected in June using a modified leaf-blower, the resulting weevils did not rise from the bucket to feed on hound's-tongue leaves. Instead, they were found dead in the bottom of the bucket the next day. It is possible they all may have been weevils at the end of their life span or perhaps the abrupt change in their cycle caused too much stress. For whatever reason, it was not found to be a successful time for collection.

M. cruciger re-emerge in August along with the F1 generation that continues to appear into September. The weevils will feed and sometimes mate and oviposit until cold temperatures drive them into the soil for the winter.

When collection was attempted in September, only 26% of the weevils rose to feed on hound's-tongue leaves on top of the funnel. Some of these weevils later died, but overall, only 39% of the weevils were alive, much less than the numbers collected in the spring.

Collection is best done in the spring due to the generations and activities of the weevils. The spring is the main oviposition period. The weevils are up feeding and developing their ovaries and then congregating to mate. They are more easily found in the spring as opposed to the late summer when they generally disperse. Also in late summer, some of the potential collected weevils would be finishing their life span and would not contribute to a new site.

Time of Day

M. cruciger weevils are very temperature tolerant. They are active when most biological control agents are dormant. However, warmer temperatures do draw the weevils up onto the plants, making them more visible but also more active and apt to fly. Therefore, collection can take place from early morning through to late afternoon.

Additional considerations

The CAB IIBC September 30, 1994 Quarterly Report on Weeds notes that continual yearly collection of weevils from a site will cause a significant decline in their numbers and refraining from collecting for a year or more may be necessary to allow the population to recover. For most agents, depending on operational goals, it may be worthwhile to rotate collection sites from year to year to sustain their insect populations. However, since *M. cruciger* have such a devastating affect on hound's-tongue, the infestations would have to be very large to still exist once left for a year or more. It may be best to collect until it becomes no longer economical or time-efficient and then leave the site to the weevils.

SHIPPING

Collected insects are shipped to new release sites in 1 litre bulk food containers. When readied for field delivery, weevil numbers in containers may be combined to make quantities of 200/container. See the discussion under Insect Release for the number of weevils to release. The shipping containers are well ventilated and contain sufficient hound's-tongue to feed the weevils during transport. If flower heads exist they should be removed and left at the site but generally should not be an issue as they should not be forming at the time of shipping. Containers are packaged into carefully sealed boxes to avoid insect escape during shipment. Cold packs are wrapped first in plastic bags to contain the majority of condensation and then in newspaper or paper toweling to prevent further condensation from building up inside the containers and damaging or drowning the insects. The cold packs are used to keep the weevils cool and reduce their activity if they are traveling any distance. The agents are shipped quickly via courier or bus to release locations.

FIELD RELEASE

Potential release sites

A potential release site needs to meet certain criteria to ensure success and longevity. It must meet Ministry needs from a program and logistical standpoint, i.e. travel distance, land tenure, accessibility. It must also be conducive to agent survival and establishment.

Below are suggested release site criteria and considerations. They are based on observations of past sites that have been successful.

Criteria

- Release sites should be large enough to support a viable insect population with potential for natural dispersal.
- Hound's-tongue infestations have a potential to crash. Sites with all bolting plants should be avoided. Infestations containing a variety of stages of growth (i.e. variety of plant sizes in early spring) are necessary to maintain a host population.
- Females will initially require the large roots of mature plants to oviposit (i.e., to help get the population established and increasing). Sites must contain rosettes that are either bolting or will bolt within the season (biomass dependent).
- A variety of soils have proven suitable for *M. cruciger*.
- Sites with other vegetation present, even moss, have been reported as suitable for *M. cruciger*.
- The average estimated hound's-tongue density should be greater than 5 plants per metre^2.
- Shade does not seem to be a factor in establishment.
- Topographies of successful sites have varied. All have been able to accumulate heat units.

Considerations

- Plentiful rodent activity, such as ground squirrels or pocket gophers, is preferred as the soil is constantly disturbed providing ideal beds for hound's-tongue germination. The activity prolongs the life of the site.
- Releases at any elevation should be attempted. The highest recorded elevation where establishment has been successful is 1512 m in the Southern Interior Forest Region.
- Sites of any biogeoclimatic zone are potential for *M. cruciger* release.
- Sites that are easy to traverse are preferred.

The following are suggested steps to take when making a site selection:

1. Plan release site locations prior to requesting agents. Release sites should be pre-selected the fall or spring prior to release of agents. This avoids 'drop and dash' releases and promotes overall invasive plant management planning.
2. Determine tenure and stability of land management. Preferably a site will be located on Crown Land with MOF mandated as the steward and have a cooperative tenure holder. Other suitable locations may be land under the jurisdiction of other agencies with the goals of controlling invasive plants and establishing/maintaining working relationships. Release sites might be located in or close to relevant municipalities with the goal of future cost-effective collection sites. An example is a municipal water reservoir that is long term and most activity, particularly herbicide spraying, is prohibited.
3. Make sure the site will not be disturbed after release. Crown control of the site is preferred with future management known. Discuss future development plans for the site wherever it is located.
4. Check previous release records and maps to ensure no prior release of the agent has been made at a potential site. An unofficial rule is that a distance of 1 km constitutes a separate release.
5. Monitor plants at potential site to ensure the agent is not already present through natural dispersal.
6. Check the immediate vicinity of the proposed release site for bird colonies, ant hills and wasp nests to minimize predation.

Insect release

Before any weevils can be released there is preparatory work that needs to be completed at the site. Make sure that all paperwork, photos, site maps, measurements, etc. are completed before opening any lids, otherwise people will be treading on insects.

The optimum number of weevils for release is dependent on the size of the hound's-tongue infestation. Releases of 200, 400, 600 and 800 have been used at previous MOF sites. Many sites have been devastated to equivalent degrees within short periods of time with increasing numbers for release. Dr. De Clerck-Floate's study used releases of 100, 200, 300 and 400 weevils. Releases of both 300 and 400 were found to basically eliminate infestations of approximately 400 m^2 with a plant density of more than 5 plants/m^2 only after two years. Additionally, Dr. De Clerck-Floate's study found the numbers of weevils on the site "increased linearly" "from populations of 100 to 400 insects per treatment" (Wikeem et al. 2001). Once the weevils depleted their food supply they readily dispersed. For efficient use of insects and man-power, it was determined the optimal number of weevils for release was 300 on infestations of comparable size (i.e. 400 m^2). Releases of 200 through 600 should be considered for smaller and larger infestations. The decision for optimum numbers to release will be in part dependent on the number of weevils available to collect.

The following are suggested steps to take when making an insect release:

1. Mark the release site with a semi-permanent stake to assist relocation efforts for follow-up agent establishment and invasive plant impact monitoring.
2. Fill out the 'Biological Control Release Record' (see Appendix C) that is shipped with the weevils accurately and completely. Information on the forms is fundamental to further analysis of the program. One completed copy of the Release Record is kept in the District office and one is returned to the MOF Regional office. The forms are then collated to create a provincial database.
3. Create accurate site maps complete with permanent tie points. This is essential for future monitoring of the release site.
4. Take photographs. They have proven to be useful tools to both relocate the release site and to provide an ocular comparison of the site over time. A suggested method and form (EM-9) is outlined in the Procedures for environmental monitoring in range and wildlife habitat management manual (Prov. of B.C. 1990).
5. Gently release the weevils (once the paper work is completed) at one location by the stake. They will disperse themselves from this initial release point. It is more difficult for insects to propagate if they are spread over a large area.

Additional considerations

Initial releases for the season should be made in similar latitudes (or altitudes) or further south (or lower altitudes) than collection sites to ensure temperatures are conducive to agent establishment. As northern release sites warm, they can receive insects. Once northerly temperatures begin to drop, releases should be directed south again to provide for the longest possible establishment season.

If more than one collection site is available, it is preferable to redistribute weevils into habitats similar to those they are acclimatized to.

Although re-release is a consideration for most agents, it is likely not an issue with *M. cruciger* since all sites monitored to date have proven to be established. However, if necessary, before re-releasing at a site the Region plan needs to be reviewed, i.e. can agents be spared for re-release at a site that may or may not be conducive to the agents' survival when they could be placed at a new site?

6. MONITORING

Monitoring of field sites can be carried out to determine:

1. Whether the agent has established at the release site;
2. The density of agents per plant or area;
3. How far the agent has spread from the release point;
4. The agent's preferred habitat and current range;
5. Areas that are unsuitable to the agent;
6. Any effects the agent has had on the invasive plant population;
7. Potential collection sites;
8. If collecting from the site has had any effects on plant or agent populations; and
9. Agent life cycle information i.e. emergence dates, effects of weather.

Depending on the type of information being sought the monitoring technique will vary. However, once the type of information is identified, the monitoring techniques should be consistent for all sites to be able to compare the resulting information. Reconnaissance methods can be used to assess parameters such as site suitability, presence or absence of agents, dates of emergence etc. A suggested monitoring form ('Release Site Monitoring Form') detailing information to collect at each site can be found in Appendix C. Many details listed on this form can be found on the original release form. Some will not change over time and need not be duplicated if the information is already recorded, while other details, particularly the plant's dispersal description, may change.

A more rigorous method is needed for quantifiable information on insect and plant populations. It is suggested that this type of monitoring be planned at selected sites as dictated by the constraints of program planning, time and budget.

A suggested transect method is as follows:

1. Find the release stake or from the description on the release form, the closest position to the release stake. Mark a starting point.
2. Determine four directions from the starting point for running the transects. If cardinal directions cannot be used, determine 4 non-cardinal right angles. Pace out 25 m in each direction.
3. Pace out three parallel transects at least 2 metres apart: two 33 m long and one 34 m long if the site does not allow for this transect design.
4. Pace out two 50 m parallel lines lying side by side or staggered (as can be accommodated by the site). The intent is to monitor a uniform number of plants randomly, if the site does not allow for either of the above transect designs.
5. Visually check for adults on or around the root crown of plants every meter when monitoring in the spring or late summer. Count and record the number of weevils.

6. Or, monitor using the same method but dig up a plant every meter and check the inside of the root for larvae in late June to the second, possibly the third week of July. The larvae should be large enough to see and yet not have left the root to pupate in the soil. Count and record the number of larvae.

A suggested form for this method (Biocontrol Agent Monitoring Form) is found in Appendix C.

AGENTS

Sites can be monitored for the presence of adults from as early as the middle of March in low elevation sites but more commonly in mid April. *M. cruciger* adults will be visibly active until the end of May, prior to plant bolt (or mid June at high elevation sites) and then visible again in August and September. The weevils tend to congregate more in the spring and so are easier to find than in late summer and fall. Adult weevils can be found in the soil and in crevices around the root crown, in rosette centers and on the leaves. The weevils can be found on both the upper and lower surfaces of the leaves. When observed at side angles or if the weevils are on their backs, their abdomen and rostrum may resemble hound's-tongue burrs with their radicles.

It has been observed at a low elevation site (the MOFPF) in early May (i.e. more advanced than high elevation sites), coinciding with the main flush of dandelion blooms, that many weevils were clinging to rosette roots while not as many were seen up on the plants. It was assumed these were females preparing to oviposit into the root and could, therefore, mark the end of the collection period at this low elevation site (see When to Collect section for further explanation). This could be the reason for weevils not being as visible at sites come mid to end of May.

M. cruciger could also not be visible at times as they may have dispersed. This can occur if they decreased their food supply. However, dispersal has also been observed when the plant population is still substantial. *M. cruciger* may experience population pressure. The weevils are able to travel long distances to find new host plants. On average the weevil was found to travel half a km per year in search of new hound's-tongue patches (De Clerck-Floate pers comm. 2004).

Presence of *M. cruciger* can also be monitored for the distinct feeding and oviposition damage by adults on leaf petioles in the spring. In late summer mature hound's-tongue plants will have perished. In the autumn, the weevil "deposits its eggs exclusively into rosette leaves of its host plant" (Jordan et al. 1993). The feeding holes are about 2-5 mm^2 with very smooth and regular edges (Figures 12 and 13). Quantities of oviposition or feeding damage at sites can be used to compare weevil population sizes. In Dr. De Clerck-Floate's dispersal studies, random plants were chosen and for each plant 10 leaves were selected and the percentage of these with petiole damage was determined (De Clerck-Floate pers comm. 2004).

Feeding damage on the leaves can be used to determine weevil presence. Feeding holes appear as small, uniform holes within the leaves, not along the edges (Figure 23). In Dr. De Clerck-Floate's study, the "incidence" of feeding damage "was linearly related to the number of insects initially released" (Wikeem et al. 2001). The incidence of frass on the plants can indicate adult presence but it is not plentiful unless the weevil population is high. If the frass is still black and moist, the weevils are still present.

Figure 23 Hound's-tongue plant with *M. cruciger* leaf feeding damage

Monitor for the presence of larvae and or frass in roots from mid June until the end of July. For two year old release sites, the incidence of larval attack has been observed to be "directly related to the initial number of weevils released" (Wikeem et al. 2001). Hound's-tongue roots can sustain multiple larval attacks. Heavily attacked roots can become hollow and paper thin (Figure 24).

Figure 24 Hound's-tongue roots with multiple larval attacks

PLANTS

A method needs to be developed for measuring responses of the host invasive plant population. Useful parameters to monitor would be: height, density, biomass production, seed production, cover, and frequency.

During screening, it was found that hound's-tongue plants that experienced attack by *M. cruciger* were smaller than those not attacked (e.g. 61% smaller) (Jordan et al. 1993). Leaf length was one of the methods used as an indication of plant size. A study also found that 56% of "attacked rosettes were killed by winter feeding larvae" (Jordan et al. 1993). It was found that the number of larvae feeding was not necessarily a factor but more importantly where the larvae fed. If "sensitive plant parts e.g. vegetative cone, vascular bundles or leaf buds" were attacked, even a single larva could kill a plant (Jordan et al. 1993). Additionally, a reduced root crown size due to larvae and adult feeding could prevent flowering. A further study showed "a 30% lower reproduction effort (low number of seeds and lower seed weight) of plants attacked by" *M. cruciger* "than of unattacked plants" (Jordan et al. 1993).

In field observations, heavily attacked plants appear stunted, wilted and chlorotic.

DISPERSAL

Dispersal information is best presented in map form.

7. SUMMARY

M. cruciger is one of two biological control agents present in B.C. to control hound's-tongue. Hound's-tongue has significantly decreased at many sites where the weevil has been released as shown in Figures 25 and 26 below. *M. cruciger* is a significant factor in the long term management of hound's-tongue in the province.

Figures 25 Hound's-tongue before *M. cruciger* attack (1997) at Chase Creek

Figures 25 Hound's-tongue after *M. cruciger* attack (2001) at Chase Creek

APPENDICES

Appendix A – HOST INVASIVE PLANT

Hound's-tongue *Cynoglossum officinale* L.

The plant

A herbaceous biennial to short-lived perennial, introduced with cereal seed from Europe and Asia Minor (Schwarzlaender 1996). The seeds germinate in the spring following winter stratification and produce tap-rooted rosettes in the first year. The rosette leaves are hairy, grow 7 to 30 cm long and are shaped like a dog's tongue (Figure 27). If sufficient biomass is accumulated ("a rosette diameter of about 30 cm" (Freese 1987)), the plant will bolt, producing flowers in its second year. The bolted plant grows up to 30-120 cm tall with smaller stem leaves that have no stalks (Upadhyaya et al. 1988) (Figure 28). Hound's-tongue flowers from May until July. Each flower produces a maximum of four seeds contained in a burred nutlet. A robust individual plant may produce up to 4000 seeds (Freese 1987). Hound's-tongue contains toxic pyrrolizidine alkaloids that can cause liver damage and even death to grazing animals (Schwarzlaender et al. 1995).

Habitat

Its numbers are relatively low in its native habitat but are widespread with the exception of the extreme south and north of Europe**.** The plant is found along road edges, open forests, sand dunes and damaged habitats (Schwarzlaender 1996). Additionally, Freese (1987) describes habitats conducive to hound's-tongue as "waste-grounds, along roadsides, on burrows ("rabbit-plant") and on overgrazed pastures". The upper elevation limit recorded in Europe is 1600 m (Freese 1987). No upper elevation has been established in B.C**.** The highest recorded elevation to date is 1568 m in the Cascades Forest District. In 1988, Upadhyaya described the plant as occurring in B.C. on disturbed sites in the Interior Douglas-fir (IDF), Ponderosa pine (PP) and Bunchgrass (BG) biogeoclimatic zones. These zones have hot, dry summers and cold winters with a precipitation and temperature range for the IDF and PP/BG zones of 44.8 cm and 26.8 cm and -5 to 21^{o}C and -7 to 22^{o}C mean for January and July, respectively (Upadhyaya et al. 1988). To date, hound's-tongue has also spread into the Interior Cedar-Hemlock (ICH), Coastal Western Hemlock (CWH), and Montane Spruce (MS) zones. (The Biogeoclimatic Ecosystem Classification (BEC) system (http://www.for.gov.bc.ca/hre/becweb/) groups ecosystems into hierarchical classifications. A unit within the BEC system is defined as a particular plant community and its associated physiography, soil and climate (Meidinger and Pojar, 1991).)

Growing conditions

Freese (1987) lists several indicator values for hound's-tongue's growing conditions in Europe:

1. dry, but not very dry soil;
2. pH 5.5 – 8.0;
3. nutrient rich soil;
4. medium contents of humus;
5. well aerated soil;
6. missing on saline soils;
7. main distribution in full light but able to bear shade part of the time;
8. montane areas (often also colline and subalpine) preferred; and
9. continental climate, low precipitation.

In eastern North America, Upadhyaya describes the plant as occurring on mostly gravelly, somewhat limey soils, in eastern Canada on rocky pastures in limestone regions, in Alberta on Brunisolic, Chernozemic, and Luvisolic soils and in B.C. on Eutric and Dystric Brunisolic, Brown and Dark Brown Chernozemic and Luvisolic soils (Upadhyaya et al.. 1988). Soil disturbance has been observed to enhance seed establishment, for example, where logging practices and ground squirrel activity occurs.

In B.C. where hound's-tongue is located under a dense canopy, plants take longer to build the biomass needed to flower. Plants commonly found where hound's-tongue has established in the former Kamloops Region portion of the Southern Interior Forest Region are:

<u>Trees</u>

Douglas-fir	Lodgepole pine	Poplar spp.	Birch	Willow spp.

<u>Shrubs</u>

Snowberry	Oregon grape	Wild rose spp.

<u>Grass, rush, sedge</u>

Bluegrass	Orchard grass	Pine grass

<u>Other plants and invasive plants</u>

Achillia	Bull thistle	Heart-leaved arnica
Clover spp.	Dandelion	Mullein*
Strawberry		

*Mullein was found at all sites monitored in the former Kamloops Region.

Figure 27 Hound's-tongue rosettes

Figure 28 Hound's-tongue bolts

Appendix B – COLLECTION EQUIPMENT REQUIRED

Below is a suggested equipment list for collecting *M. cruciger* weevils:

- Modified leaf blower complete with hoses and hard, narrow end (a spare is recommended). Vacuum hoses and accessory ends were used to build aspirators in the photos, however, it is preferable to have flexible hoses that do not contain ridges within so there is less lodging of material within.
- Catchment container (may want to include a bungee cord around the container for a handle)
- Intermediate container with closing lid
- Knee pads
- Ear muffs
- Soil sieves
- Funnel with scored/scratched inside
- Holding bucket with scored/scratched lower walls and lid with mesh screen
- Gas
- Rose clippers to cut hound's-tongue stalks
- Clipboard
- Collection forms

Note: The leaf blowers engines are not designed to run at full speed for a continuous length of time, therefore, vapour-locking is common. The machine will continue to run for a short time after shutting it off and will not readily start again. To mitigate this effect, it is best to run the machine at idle periodically while moving about the site and when stopping to transfer material to different containers. This allows air to be drawn into the engine to cool it down before it is shut off.

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Appendix D - MONITORING FORMS

BIOLOGICAL CONTROL RELEASE RECORD

SITE NUMBER: **D** ___ ___/___ ___ ___ ___ /___ ___ /___ ___ ___

District /Agent Code /YY /Release #

BIOAGENT: _____ /_____ **WEED SPECIES:** ___ ___ ___ ___ / ___ ___

SOURCE: _____ **STAGE:** ADULT PUPA LARVA EGG OTHER

COLLECTION:__ __ / __ __ / __ __ **RELEASE:**__ __ / __ __ / __ __ **TIME:**__ __: __ __
Y M D **Y M D**

 # RELEASED: _____

JURISDICTION: ___ ___ **RELEASED BY:** _____

DISTRICT: _____ **RANGE UNIT NAME:** _____

PRIVATE LAND: **Owner:** _____ **Phone:** ( ) ___ ___ ___ - ___ ___ ___

ADDRESS: _____

LOCATION: _____

BCGS MAP: __ __ __ __ __ __ __ **UTM:** | | ZONE | | | | | | EASTING | | | | | | | NORTHING **DATUM** _____

WEED DENSITY: < 1 plant/m^2 ☐ 2-5 plants/m^2 ☐ 6-10 plants/m^2 ☐ < 10 plants/m^2 ☐

SIZE OF INFESTATION: < 100 m^2 ☐ 101-400 m^2 ☐ 401-2500 m^2 ☐ 2501-5000 m^2 ☐

5001-10000 m^2 ☐ > 1ha. ☐

WEED DISTRIBUTION: Continuous Stand ☐ Scattered Patches: ☐

SLOPE %:___ **ASPECT^0:**___ **ELEVATION m:**___ **BIOGEO UNIT:** __ __ __/__ __ __/__ __ __
zone/subzone - variant/site series

MONITORING for ESTABLISHMENT

Date Established			Photo:			
Y	M	D	Yes	No	Yes	No
__	__	__	☐	☐	☐	☐
__	__	__	☐	☐	☐	☐
__	__	__	☐	☐	☐	☐

SKETCH MAP (Indicate North)

COMMENTS:

RELEASE SITE MONITORING FORM

DATE: **AGENT:**

SITE NUMBER: **SITE NAME:**

MAP NO.:

WEED DENSITY:

<1 plant/m^2	____	2-5 plants/m^2	____
6-10 plants/m^2	____	>10 plants/m^2	____

SIZE OF INFESTATION:

<100m^2	____	100-400m^2	____
400-2500m^2	____	2500-5000m^2	____
5000-10000m^2	____	>1 ha	____

WEED DISTRIBUTION:

Continuous Stand	____	Scattered Patches	____

ACCESS TO SITE:

Easy	____	Difficult	____

Describe if necessary.

SITE TOPOGRAPHY:

Flat	____	Bowl Shaped	____
Forest Openings	____	Close to River/Lake	____
Terraced	____	Hillside	____
Other (describe)	____		

TRAVERSABILITY OF SITE:

Easy	____	Difficult	____

Describe if necessary.

SOIL DESCRIPTION:

Moss covered	____	Gravel	____
Clay	____	Silt	____
Compact	____	Loose	____
Sandy	____	Other (describe):	____

SLOPE (%): ____ ASPECT (^{o}): ____ ELEVATION (m): ____

BIOGEOCLIMATIC CLASSIFICATION: ____

DISTANCE FROM _____ (City/Town) (km): ____

LAND OWNER:

RECOMMENDATION:

COMMENTS:

BIOCONTROL AGENT MONITORING FORM

SITE NUMBER:		DATE: (YR/M/D)	
AGENT:		LOCATION:	
RELEASE DATE:		TARGET PLANT:	

METERS	NORTH	SOUTH	EAST	WEST
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
MAX DIST.				

PERCENT ATTACK: _____

COMMENTS: _____