

The role of pre-release studies in developing a biocontrol strategy for hound's-tongue in Canada

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Abstract. There are benefits to obtaining weed population information before biocontrol releases and these benefits are examined for the biennial rangeland weed, hound's-tongue (*Cynoglossum officinale*). Originally from Eurasia, hound's-tongue has been targeted for biocontrol in Canada because of its impact on the British Columbia (BC) cattle industry. The dynamics, size and life-stage structure of hound's-tongue populations in BC were studied in anticipation of releases and the European root weevil, *Mogulones cruciger*. Variation among populations suggests three strategies for release to enhance the establishment and increase of the weevil. First, because of the ovipositional preference of *M. cruciger* for large plants, initial releases should be in host populations where the majority of plants are large. Second, *M. cruciger* also prefers flowering plants for oviposition, hence release sites should have a high proportion of plants in the reproductive stage. Third, releases should be made in host populations that are either increasing or are stable in size to ensure adequate food resources for the weevil. Also, population studies of hound's-tongue will allow more accurate assessment of *M. cruciger* impact after its release. The results suggest that BC hound's-tongue densities fluctuate locally over relatively short periods, which may mask the impact of released insects on its numbers if populations are not monitored beforehand. It is important to monitor biocontrol agent impact at both a local and larger (i.e. metapopulation) scale for accurate assessment of agent impact. A method of defining metapopulations, and determining metapopulation change, using cattle, is suggested.

Introduction

Since its introduction from Eurasia in the 1800s, hound's-tongue, *Cynoglossum officinale* L., has become an important rangeland weed in British Columbia (BC), Canada. It is particularly abundant in the Interior Douglas Fir and Ponderosa Pine - Bunchgrass biogeoclimatic zones of BC, where it occurs in forest openings cleared by logging and road-building (Upadhyaya *et al.* 1988). Cattlemen consider hound's-tongue a noxious weed of primary concern, mainly because it produces an abundance of barbed nutlets, or 'burrs', which cling to the hair of cattle. Cattle covered with these unsightly burrs may fetch a reduced price at market and reduce a rancher's reputation (Upadhyaya and Cranston 1991; personal communication with ranchers). Hound's-tongue is also toxic to livestock and hinders the establishment of valued forage species on rangeland (Upadhyaya *et al.* 1988).

Release of the European root weevil, *Mogulones*

cruciger Herbst, in BC for the control of hound's-tongue is anticipated within the next year or two, but successful establishment of this biocontrol agent will be contingent upon the choice of appropriate sites for initial releases. Larvae hatch from eggs laid at the base of plants and feed on root tissues (Jordan *et al.* 1993). However, female weevils preferentially oviposit on large and, or, flowering plants (Prins *et al.* 1992; Jordan *et al.* 1993) and avoid plants with root crown diameters of < 6 mm (Prins *et al.* 1992). Consequently, the establishment of *M. cruciger* may rely upon the initial and continued abundance of plants in the host population that have root-crown diameters greater than a critical size, or that are at an appropriate stage of development.

The objective of the current study was to examine the dynamics, and size and life-stage structure of hound's-tongue populations in BC, with the intent that this information be used to identify optimal sites for the anticipated release of *M. cruciger*. Despite detailed ecological studies of hound's-tongue in Europe (e.g.

Boorman and Fuller 1984; De Jong and Klinkhamer 1988; Van der Meijden *et al.* 1992), little is known about the population dynamics of this important rangeland weed in North America. Information on population dynamics of hound's-tongue prior to the release of *M. cruciger* is needed to assess the possible long-term impact of this biocontrol agent on target populations following its release.

Materials and methods

Resource variability

To determine the availability and quality of resources for *M. cruciger* within and among hound's-tongue populations, information on plant size and proportion of flowering plants was collected at sites near the towns of Jaffray and Wardner, in the Cranbrook area of southeastern BC (Fig. 1). Plant size, measured as root-crown diameter (RCD) to the nearest 0.1 mm, was obtained for 100 randomly-chosen plants from each of four populations in spring 1995. Root-crown diameter distributions were then plotted for each population. Mean RCD among sites was compared using an ANOVA ($p = 0.05$). Tukey's test was used to detect differences between individual sites. Only plants older than one year were sampled, because seedlings were assumed to be a minor resource for the root weevil. Each of the four populations comprised several hundred plants growing on sites of 1-5 ha that had been recently disturbed by logging activities and ongoing grazing by cattle. Wapiti #1 and #2 populations were within 100 m of each other on Wapiti pasture, Colvalli Range Unit/rotation (Fig. 1). Big Hill and Purvis populations were 5 km apart on adjacent pastures of the South rotation of Peckham's Range Unit (Fig. 1). These four populations were revisited in July, when bolting plants could be discerned, to assess the proportion of flowering plants in a random sample of 50-150 individuals per site.

Variation over time in the incidence of flowering was determined for four pastures in the Cranbrook area from 1992 to 1995. Brush East, Wapiti and Horseshoe were pastures within the Colvalli Range Unit/rotation, and Big Hill pasture was within the South rotation of Peckham's Range Unit (Fig. 1). The density of hound's-tongue flower stalks in each pasture was determined by a thorough search of such stalks in areas of disturbance; i.e. recently logged areas and roads. This method provided a good approximation of the total number of flower stalks on each pasture, because

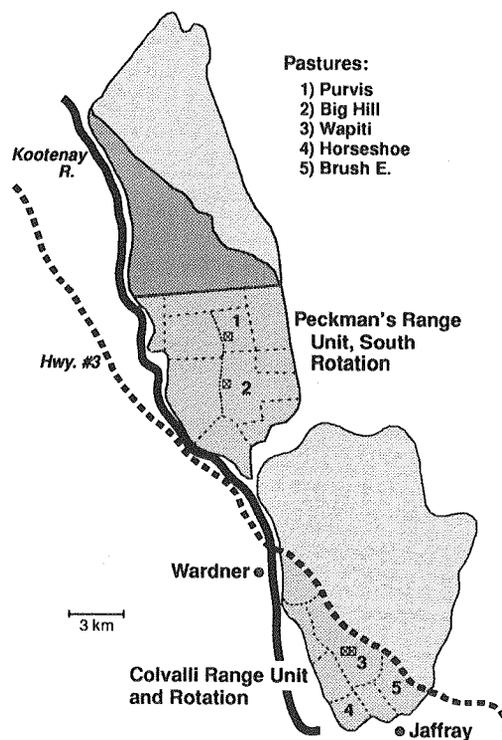


Fig. 1. Range units and rotations used in the Cranbrook, BC area for hound's-tongue population studies. Range units are tracts of public land where cattle grazing is allowed. Rotations are smaller units of land within the range units which are leased to a rancher for cattle grazing. Peckham's Range Unit has three rotations, one of which was used in this study. Colvalli Range Unit has one rotation. Each rotation is divided into 5-7 fenced pastures, each about 200-700 ha in area, and a herd of cattle is moved on a monthly basis between the pastures of a rotation from May to September/October. Pastures are only shown and labelled for those rotations used in the study. Dashed lines indicate fences between pastures, and squares with x's denote hound's-tongue populations used in the resource availability study.

hound's-tongue is closely associated with disturbed sites (Van der Meijden *et al.* 1992; personal observations).

Local population trends

The population dynamics of hound's-tongue was monitored at seven local sites in the interior of BC. All sites were in the Interior Douglas Fir biogeoclimatic zone at latitudes of 50.49 N (Turtle Valley) to 49.02 N (Tuzo Creek and Bubar Creek). At each site, 30, 1m² permanent quadrats, were placed at regular intervals along three equidistant transects within a patch of hound's-tongue approximating 50 m² in area. The total

number of hound's-tongue plants (i.e. seedlings, vegetative and reproductive plants) in each quadrat was subsequently counted in July 1994 and 1995. Differences in plant densities between years at each site were determined using paired t-tests ($P = 0.05$).

Results

Resource variability

Hound's-tongue populations differed in their resource availability and quality for *M. cruciger*. Plants comprising Purvis and Wapiti #2 populations were significantly larger than plants comprising Big Hill and Wapiti #1 populations (Table 1). Plants comprising Purvis and Wapiti #2 also had the widest range in sizes among the four populations (Fig. 2). However, RCDs of plants at all sites generally were < 12 mm, and about 30% of the plants sampled from Big Hill, Wapiti #1 and #2 populations had RCDs of < 6 mm, which is the threshold size for *M. cruciger* (Prins *et al.* 1992). Less than 20% of the plants at Purvis had RCDs of < 6 mm (Fig. 2). The percentage of flowering plants varied from 2-17% among the four populations (Table 1).

Fluctuations in flowering were evident on pastures monitored over several years. In pastures surveyed for flower-stalk density, peak flowering occurred in 1993, with large reductions in flower-stalk counts in 1995 (Table 2). Between 1994 and 1995, flower stalk densities declined 44% in Wapiti, 90% in Horseshoe, and 80% in Big Hill.

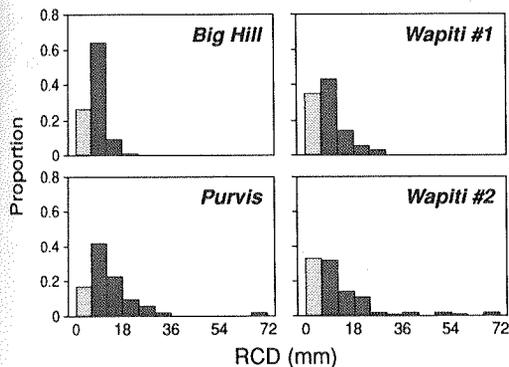


Fig. 2. Hound's-tongue plant-size distributions within four local populations in southeastern BC, sampled in 1995. Big Hill and Purvis are populations on separate pastures of the same rotation (South rotation of Peckham's Range Unit). Wapiti #1 and #2 are populations on the same pasture on another rotation (Colvalli Range Unit/rotation). Plant size was measured as root-crown diameter (RCD). Light-shaded bars indicate plants < 6 mm in RCD, which is the threshold size for *Mogulones cruciger* acceptance.

Table 1. Mean plant size and incidence of flowering for local hound's-tongue populations, 1995 ($n=100$ plants/population; plants were > 1 yr in age). Values with the same letters are not significantly different at $p > 0.05$.

Population	Mean RCD (mm) \pm S.E.	% plants flowering
Big Hill	7.9 \pm 0.3 ^a	2
Purvis	12.2 \pm 0.8 ^b	15
Wapiti #1	8.9 \pm 0.6 ^a	17
Wapiti #2	12.9 \pm 1.3 ^b	11

Local population trends

Densities of plants at each of the seven sites monitored for local population dynamics changed significantly from 1994 to 1995 (Fig. 3). Densities declined at sites in the Cranbrook area and Turtle Valley near Kamloops, and increased at all other sites. The most dramatic increase between years (95%) occurred at Tuzo Creek. In contrast, the greatest reduction in plant density (80%) occurred at Wapiti #1.

Rapid local changes in density were mainly attributed to variation in the number of seedlings between years. Seedlings typically comprised the majority of individuals in local populations in both years (55-83% for all populations sampled in 1994 with the exception of Tuzo Creek at 16% and no seedlings at Bubar Creek, and 54-86% for populations in 1995, except for Turtle Valley at 22.5%). Total percentage change in seedling density (increases or decreases) averaged 77% (range 61-100%) between the two years.

Fluctuations in the density of plants older than one year also occurred between 1994 and 1995. Reductions or increases in the density of flowering plants averaged 58% and ranged between 14 and 98%. All populations, except for Turtle Valley, showed a decline in the density of flowering plants between years. The largest reductions (90 and 98%) were noted for the Cranbrook area populations. In general, the density of vegetative

Table 2. Hound's-tongue flower-stalk densities (ha^{-1}) on four pastures, 1992-1995.

Pasture	Size (ha)	1992	1993	1994	1995
Brush East	309	44.2	60.4	-----	24.3
Horseshoe	276	4.4	-----	19.8	1.9
Wapiti	661	17.9	26.7	16.7	9.3
Big Hill	653	-----	68.1	59.0	12.1

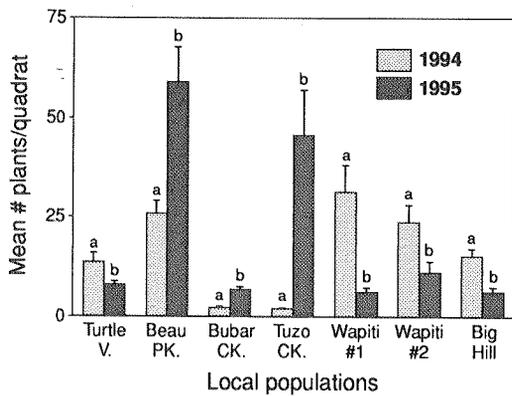


Fig. 3. Local hound's-tongue population changes over a two-year period (1994 and 1995). Turtle Valley (50.49 N 119.41 E) and Beau Park (50.17 N 119.19 W) are near Kamloops, BC and about 100 km apart; Bubar Creek (49.02 N 118.45 W) and Tuzo Creek (49.02 N 118.27 W) are near Grand Forks, BC and about 50 km apart. The remaining populations are located near Cranbrook, BC at 49.30 N 115.00 W. Wapiti #1 and #2 are within 100 m of each other on the same pasture; see Fig. 1. Plant counts were obtained from 30, 1 m² quadrats per population. Vertical bars indicate one standard error. Values with different letters are significantly different within each population.

plants older than one year remained relatively stable between years within local populations, with an average percentage change in either direction of 30% and a range of 7.5 to 57%.

Differences in the dynamics and structure of hound's-tongue populations could not be attributed solely to variations in regional factors. Despite a separation of < 100 m, the decline of plant density observed for the Wapiti #2 population between 1994 and 1995 was almost half that experienced by the Wapiti #1 population (Fig. 4). The difference in decrease between populations was related to a greater variation in seedling density between years, and to a greater loss of plants in 1994 due to flowering for the Wapiti #1 population.

Discussion

Optimal sites for *M. cruciger* releases

Variations in the dynamics and structure of hound's-tongue populations in BC suggest three strategies for release of *M. cruciger* to enhance the weevil's establishment and subsequent increase.

First, initial releases of the insect should be in populations of hound's-tongue where the majority of plants are large in size, and hence of optimal quality for *M. cruciger*. It is logical to assume that a released

biocontrol insect will not be resource limited in its new home, because the targeted weed generally is abundant. However, the insect-carrying-capacity of a weed population may not be determined by the total number of host plants, but by a subset of resources that are preferred for oviposition (Price 1992). Insect traits, such as fecundity and development time, which affect the potential for population increase, can be strongly influenced by resource quality (Whitham 1980; Rossiter 1992). Because *M. cruciger* demonstrates distinct ovipositional preferences for large plants, the proportion of these plants within hound's-tongue populations will probably limit the weevil's establishment and population growth. A good strategy for initial releases of the insect would be to choose local hound's-tongue populations, such as those at Purvis and Wapiti #2 (Fig. 2) that have a wide range of plant sizes, and a high mean RCD. Also, it is important that the majority of plants be above the threshold RCD for acceptance, i.e. 6 mm (Prins *et al.* 1992), to encourage population increase. The Purvis population would make a good site for release, because less than 20% of the measured plants were below the threshold size.

Second, release sites should have a high proportion of flowering plants. Plant size and flowering are not mutually exclusive as resources, since the largest plants in a population tend to flower (Wesselingh *et al.* 1993). However, when Prins *et al.* (1992) controlled for plant size, *M. cruciger* preferred flowering over vegetative hound's-tongue plants. A 1993 survey in Meijndel, the Netherlands, also revealed that 90% of the flowering and 50% of the vegetative plants were attacked by *M. cruciger* (R. Wesselingh personal communication). This suggests that the root-weevil carrying-capacity of hound's-tongue populations would be limited by both the number of flowering plants and the availability of vegetative plants above 6 mm in RCD. Based on data for the four populations in southeastern BC, the percentage of plants that flowered in 1995 was low, making these populations less attractive as release sites than similar populations with high numbers of flowering plants (Table 1).

Third, releases should be in hound's-tongue populations that are either increasing in size, or show signs of being relatively stable over a 2-5 year period. This would ensure adequate food resources for weevil increase after release. Local hound's-tongue populations tend to peak and then decrease, sometimes to the point of extinction, within 7-10 years in the

Netherlands (Van der Meijden *et al.* 1992). Preliminary information suggests that BC hound's-tongue populations also fluctuate (Fig. 4, Table 2). Hence, care should be taken not to release insects during a natural decline in local population size. Another strategy pertaining to hound's-tongue population dynamics is to release weevils at sites with a large proportion of vegetative host plants older than one year. Vegetative plants stabilize local hound's-tongue populations over time because of their tendency to delay flowering for several years (De Jong and Klinkhamer 1988). For instance, the populations at Wapiti #1 and #2 both experienced a reduction in plant number between 1994 and 1995, but this reduction was less for Wapiti #2, which had a larger proportion of vegetative plants (Fig. 4). Hence, Wapiti #2 would make the better site for *M. cruciger* release.

Hound's-tongue population dynamics and assessment of herbivore impact

In addition to identifying suitable sites for the release of biocontrol agents, pre-release studies of the host plant can be used to assess the likely effect of biocontrol agents on target populations. For example, declines in the target population coinciding with the release of a biocontrol agent might be incorrectly attributed to the agent unless information is available on the dynamics of the host population. Although more information is needed, BC local populations probably behave similarly to local populations in the Netherlands, where they fluctuate asynchronously and become locally extinct (Van der Meijden *et al.* 1992). If there is a difference, it may be in the persistence of

populations. Unlike in the Netherlands, the presence of cattle in BC provides the continuous disturbance and seed dispersal needed to maintain local populations over a longer period of time. Knowledge of the general pattern of fluctuation of BC populations will determine the best method of sampling for agent impact. For instance, the preliminary results of this study suggest that adjacent populations, even if in the same habitat and a short distance apart (see Fig. 4), should not be used to compare impacts in control and treatment plots, unless there are several years of data, before insect release, documenting similar dynamics. Alternatively, researchers could monitor weed numbers within cages, with and without biocontrol insects, that are set up within the same local hound's-tongue population. Another solution is to create new, adjacent populations of known successional stage, which are then arbitrarily assigned to control and treatment categories and monitored after insect releases (e.g. McEvoy *et al.* 1993).

Monitoring the dynamics of metapopulations

The grazing system for cattle in BC may provide an opportunity to monitor the effect of *M. cruciger*, or other biocontrol agents, on metapopulations of hound's-tongue. A metapopulation is defined as a group of interacting local populations (Van der Meijden *et al.* 1992). Long-term survival of hound's-tongue, as with most biennials, is possible because of a balance between the number of extinctions and establishments of the local populations that comprise each metapopulation (Van der Meijden *et al.* 1992). Hence, it is only at the metapopulation level that an overall picture of population change emerges.

In the interior of BC, the highly-regulated movement of cattle between pastures of a rotation (see Fig. 1) provides a unique and practical way of defining hound's-tongue metapopulations. For hound's-tongue, the interaction that occurs among local populations of a metapopulation primarily takes the form of seed dispersal (Van der Meijden *et al.* 1992), and in BC, cattle are the major dispersers of hound's-tongue seed (Upadhyaya and Cranston 1991). Since the same cattle are moved between the pastures of a rotation throughout the summer, there is little movement of seeds between different rotations. Typically, seed acquired by cattle is lost either on the same pasture where it was gained, or soon after the move to another pasture (personal observation). Hence, the sum of all hound's-tongue local populations within a pasture or

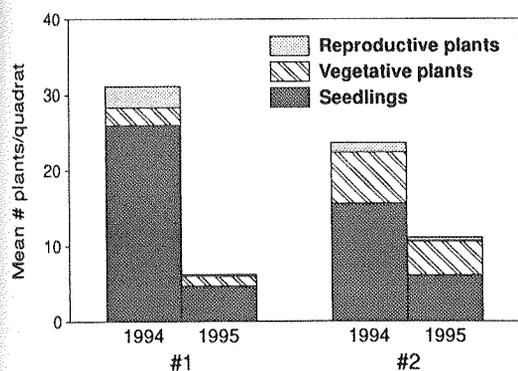


Fig. 4. Proportion of plants at three stages of development (vegetative and reproductive plants older than one year, and seedlings) within Wapiti #1 and #2 local populations, in 1994 and 1995.

rotation, involved in the exchange of seed, form a functional metapopulation.

The cattle, through their contact with many local populations in one season, also become a tool for obtaining a more holistic view of hound's-tongue density change. Recently, I have shown that there is a significant, positive correlation between the number of burr-producing stalks on pastures and the mean number of burrs on the photographed faces of cattle grazing these pastures ($R^2 = 0.77$, $p < 0.001$, $n = 13$ pastures; R. DeClerck-Floate unpublished). Although I must next relate burr-stalk number to the actual hound's-tongue density on pastures, the burr counts should be a good reflection of the metapopulation size. I hope to refine the use of cattle to monitor biocontrol agent impact at the metapopulation level.

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