ALTERNATIVE CONTROL OF TANSY RAGWORT

ON A TRANSMISSION RIGHT-OF-WAY

Final Progress Report

1 June 1986 - 30 June 1987

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INTRODUCTION

Tansy ragwort (Senecio jacobaea) is a biennial or short-lived perennial member of the daisy family, introduced to North America from Europe (Figure 1). It is considered a major noxious weed in Oregon and Washington, causing economic losses by poisoning cattle, horses, and goats (Bedell et al. 1981, Macdonald 1983) and by displacing desirable forage (McEvoy 1984). Land owners in the state of Washington are required under RCW 17.10 to control and prevent the spread of ragwort and other noxious weeds to adjacent agricultural lands. Seattle City Light has been using the herbicide Banvel (and hand pulling near streams) to suppress ragwort on a transmission right-of-way near Darrington, Snohomish County, for several years. In 1986 the City authorized a study of the feasibility of biological control of ragwort on the right-of-way.

The purpose of the study is to establish populations of two insect species--the cinnabar moth (Tyria jacobaeae) and ragwort flea beetle (Longitarsus jacobaeae) -- and test their effectiveness, relative to herbicide and hand pulling, in keeping tansy ragwort at low densities. The ultimate goal is to eliminate the use of herbicides to control tansy ragwort on the right-of-way. Elimination of herbicides is desired to minimize health risks to workers, the public, and the environment, as well as to reduce maintenance costs.

Biological control of ragwort has been shown to be effective in other areas, but may take several years to accomplish, depending on how quickly the insect populations establish themselves. This report describes the first stage of the study, from 1 June 1986 to 30 June 1987, in what is viewed as a multi-year experiment.

BACKGROUND

Tansy ragwort is native to Europe and western Asia where it is a species of minor importance on roadsides and grasslands (Poritz 1979). Ragwort was first recorded in western North America on Vancouver Island in 1913, and in Oregon in 1922. It now ranges from northwestern California to British Columbia, extending from the coast to beyond the Cascade Mountains (McEvoy 1984).

Tansy ragwort is generally considered a biennial species. During the first growing season, seedlings typically develop into rosettes (defined in this study as plants greater than 7.5 cm in diameter). The following year, the rosettes enlarge, send up flowering stems, produce seed, and die. Seeds are primarily dispersed by wind, although dispersal distances are typically very short (a few meters or less) (McEvoy 1984). If conditions are poor or the plant is damaged, it may adopt a perennial habit. Perennial plants often have large, woody rootstocks and more than one flowering stem (Macdonald 1983).

Ragwort colonizes pastures, ungrazed meadows, forest clearcuts, and roadsides. Livestock normally avoid the plant where more desirable forage is available, but small plants growing among grasses and clovers, or plants

Figure 1.
Tansy Ragwort.

mixed with hay cannot be selectively excluded. Chemicals contained in the plant (pyrrolizidine alkaloids) are converted to pyroles in the presence of liver enzymes, causing liver damage and eventually death of the animal which has eaten the plants. The effect is cumulative with time and dose. Pyrrolizidine alkaloids have also been found in the milk of cows and goats fed a diet containing tansy ragwort (Bedell et al. 1981). Although ragwort toxicity is not a direct problem on ungrazed lands, these sites are seed sources for ragwort infestation of nearby grazed areas (Macdonald 1983).

In its native habitat of Europe and western Asia, tansy ragwort is kept partly in check by natural predators. Cameron (1935) documented 56 species of insects which feed on ragwort in England. Where it has been introduced without these controlling agents, ragwort has become a serious rangeland pest (Macdonald 1983). In western Oregon, ragwort is estimated to occur on more than 3 million acres, and in western Washington it occupies over 100,000 acres of pasture land (Bedell et al. 1981).

Several methods have been employed to help prevent or control tansy ragwort infestations. Ragwort needs openings (i.e. disturbed, bare soils and plenty of light) to become established in a community (Macdonald 1983); thus, one of the best ways to prevent its occurrence is to maintain a dense, continuous vegetative cover. Good pasture management, such as sequential grazing and avoidance of winter grazing by cattle and horses, helps maintain the integrity of the turf and minimizes potential germination sites (Bedell et al. 1981).

Mowing is commonly used in an effort to stop ragwort plants from flowering and producing seed. Theoretically this practice should eventually eliminate on-site seed sources, although it would not prevent the spread of seeds from other areas. Repeated mowings are needed to prevent regrowth of mown plants and eliminate successive generations of new plants. Seeds remain viable in the soil for several years (Macdonald 1983). Bedell et al. (1981) considered mowing an ineffective method of reducing ragwort populations.

Sheep grazing is used in some areas as a means of reducing ragwort infestations. Sheep are apparently unaffected by the potential toxicity of ragwort, and actually show a preference for the plant in summer when other plants are dried out (Bedell et al. 1981). Sheep can be used to precondition pastures prior to cattle grazing, or can be grazed along with cattle. Continuous sheep grazing will remove ragwort and keep it out, apparently by preventing the plants from going to seed. However, heavy use by sheep also disturbs vegetation and creates potential germination sites for ragwort, so if sheep are removed from an area where ragwort seeds are abundant, ragwort can become reestablished (Macdonald 1983).

Hand pulling and digging can be an effective method of keeping ragwort plants from setting seed (Bedell et al. 1981). Hand removal is most effective when soils are moist and holes are mulched after the plants are removed (Macdonald 1983). Moist soils allow the plants to be pulled with the least breakage, reducing the chance that new plants will sprout from root fragments left in the soil. Mulching makes the disturbed site less suitable for ragwort germination.

Hand-pulling has had poor results in a ragwort eradication program in eastern Oregon, where over half the pulled sites had an obvious ring of regenerating plants the year after treatment (Cox 1986). Hand labor requires persistence and intensive effort, and is most applicable to small infestations of ragwort (Bedell et al. 1981).

Chemical control of ragwort can be achieved using the herbicides 2,4-D; dicamba (Banvel); or a combination of the two compounds. 2,4-D is used when the plants are small or in the rosette stage, preferably during early spring (April) or mid-fall after rains have initiated new growth. Brewster (1978, cited by Macdonald 1983) reported between 96 and 100 percent control of ragwort from spring applications of 2,4-D at 20 locations in western Oregon. Dicamba (with or without 2,4-D) is used on large rosettes or plants with flowering stalks (Bedell et al. 1981). Treatment in this stage does not eliminate seed production, but apparently reduces the viability of seeds (Macdonald 1983). Applications on small areas are commonly made with a backpack sprayer.

Two additional herbicides have been used in eastern Oregon (Cox 1986). Tordon (picloram and 2,4-D) pellets are reported to be effective for the control of scattered ragwort plants, and are less likely than sprays to affect surrounding vegetation. Round-up (glyphosphate) has been used to control ragwort growing in standing water. To minimize entry of the herbicide into the water, it is wiped directly on the plant, using a special applicator.

Although apparently effective (at least in the short term), herbicide use increases risks to workers, the public, and the environment. It also increases potential long-term legal liability resulting from improper use or disposal. For example, even though Banvel is one of the safer herbicides available, some tests on mammals indicate that it may injure developing fetuses. Herbicides such as Banvel are also extremely mobile in water. They can be carried in surface runoff or in groundwater to nontarget vegetation, fish, and wildlife. This problem is especially troubling with ragwort, as it tends to concentrate near streams. In recognition of these concerns, City Light has adopted a right-of-way maintenance policy calling for minimal use of herbicides.

Biological control involves the use of plant-eating organisms (usually insects) to reduce and maintain the population of a target species to an economically tolerable level. For biological control to work, small numbers of the host plant and controlling insect must persist to assure that the insect can respond to outbreaks of the host plant. The insect need not kill the host, but only reverse its competitive advantage over other plants. The controlling insect must also be quite specific to the host plant to prevent harm to non-target species (Poritz 1979).

Biological control of tansy ragwort has focused on three insect species: the cinnabar moth, the ragwort flea beetle, and the tansy seedhead fly (Hylemya seneciella). Host specificity tests, conducted before releasing these

insects in the United States, showed that all three species were sufficiently specific to warrant introduction (Poritz 1979, Macdonald 1983).

The cinnabar moth was imported from France and released in northern California in 1959. A year later it was first introduced to Oregon, and since that time has been redistributed to parts of Washington and British Columbia (Poritz 1979, Harris et al. 1984, McEvoy 1984). Adult cinnabar moths emerge from overwintering pupae in late spring, and lay their eggs on the undersides of ragwort leaves. The larvae (caterpillars) hatch in June and feed on the foliage and flowers of the host plants. In large numbers they can totally defoliate the plants.

The effect of the cinnabar moth on ragwort populations has varied with the location and environmental conditions of release sites. In some areas, ragwort nearly disappeared following establishment of the moth; in other areas the moth has not lowered ragwort density, but has reduced its biomass (Harris et al. 1984). Wilkinson (personal communication) and Myers (personal communication) observed that the cinnabar moth was subject to local extinctions following initial establishment in British Columbia.

Two factors which help the cinnabar moth achieve effective control of ragwort are summer drought and autumn frost, both of which inhibit plant regeneration after the larvae have begun pupating (McEvoy personal communication). Release sites should be well-drained and free of winter flooding, because the pupae overwinter in litter on the soil surface and will drown on wet or soggy sites. The pupae are also prone to livestock trampling (Bedell et al. 1981).

In areas where the cinnabar moth has not suppressed ragwort to satisfactory levels, additional biological control agents are needed. The ragwort flea beetle was introduced to northern California from Italy in 1969 to supplement existing biological control efforts (McEvoy 1984). Subsequent releases were made in Oregon, Washington, and British Columbia, using west coast stock that originated in Italy, and additional stocks imported directly from Switzerland and England (Harris et al. 1984, Wilkinson personal communication).

Adult flea beetles are pit feeders, rasping small holes in the leaves of seedling and rosette ragwort plants (McEvoy 1984). After pupating in the soil, they emerge and feed briefly during the early summer, and then become dormant again until fall. In the fall they reemerge to feed, mate, and lay their eggs on or next to the ragwort root crowns. The larvae hatch in about 3 weeks and spend the winter and spring tunneling and feeding in the roots, stems, and petioles of the plants (Wilkinson personal communication). It is the larval feeding on the main root that causes the most damage to the ragwort (Harris et al. 1984, Macdonald 1983).

Studies of flea beetle impacts on ragwort populations appear to be relatively few, as the beetle was introduced to many areas after the cinnabar moth had already become established. Hawkes and Johnson (1978, cited by Harris et al. 1984) reported that flea beetles had practically eliminated ragwort from a 12-acre area within 4 years of release in California, and within 10 years had dispersed nearly 20 miles from the release site. Shanks (personal communication) noted similar success in southwest Washington, starting with a release

of 200 flea beetles in a heavily-infested ragwort stand. Flea beetles are hardier than cinnabar moths, and are better equipped to survive on wet or heavily-grazed sites. Once established, they also disperse more readily to new sites (Brown personal communication).

A combination of the cinnabar moth and flea beetle apparently works better to suppress ragwort populations than either species by itself (Bedell et al. 1981). Root feeding by the flea beetle augments the foliar damage caused by the cinnabar moth, and comes at a time when the moth is inactive. McEvoy (1984) found that ragwort density and biomass declined to 3 percent of baseline levels following the introduction and eruption of the two insect species. The ragwort population on his study area rebounded during the current season, and more study is needed to determine whether predator and prey populations will stabilize at low levels (McEvoy personal communication).

The seedhead fly was imported from Europe, and was first released in the Pacific Northwest between 1966 and 1970 (Frick 1969, Harris et al. 1984). Early efforts to establish the species met with limited success from California to British Columbia (Harris et al. 1984). However, in recent years the flies have become widely distributed. They now occur along much of the Oregon coast (Macdonald 1983), and are widespread in southwest Washington (Shanks personal communication). In 1986 wild populations of the fly first appeared in British Columbia (Wilkinson personal communication).

Seedhead flies overwinter as pupae in the soil, and emerge as adults in June, just as the tansy ragwort is developing flower buds. Eggs are laid in the central flower heads, with one larva developing per flower head during July and August. The larvae reduce ragwort seed production by feeding on the developing seeds. Seedfly damage is easily detected by examining the florets; infected florets first turn brown and are then pushed out beyond the healthy florets. As the larva matures it exudes a sticky material that cements the protruding florets together (Frick 1969).

By itself, the seedhead fly may not be particularly effective at reducing ragwort abundance in the Pacific Northwest (McEvoy personal communication, Shanks personal communication). This is because the fly attacks primarily the central flower heads of the plant, allowing the peripheral heads to flower and produce seed after the fly pupates. Enough seeds escape predation to produce another generation of plants.

Combined with the effects of other biological control agents, however, predation by the seedhead fly may help achieve a satisfactory level of control over ragwort populations. The seedhead fly appears to be more compatible with the flea beetle than with the cinnabar moth, because the fly and moth both prey on the same part of the plant. Potential competition between the two species has not been studied (Macdonald 1983).

STUDY AREA AND METHODS

The tansy ragwort study area is located north of Darrington near the Snohomish-Skagit county line (Figure 2). The site is part of a 300-ft wide transmission right-of-way used to convey power from the Skagit Hydroelectric Project to Seattle.

Vegetation on the right-of-way consists of early successional forest communities (shrubs, grasses, and forbs), interspersed with pasture. The terrain on the study area is relatively flat, and is bisected by Beverly Creek, an intermittent stream which joins the Sauk River. The creek flows from approximately October through April, and has flooded during the past two winters.

Ragwort density is highest near the creek in the northeast part of the study area. Prior to the study, cattle from adjacent farmlands had access to the study area through coniferous forest bordering the right-of-way. However, their use of the area has since been curtailed.

The study is designed to evaluate biological control, both in terms of success (i.e. the numbers of tansy ragwort plants remaining after treatment, and the types and amount of damage), as well as cost. Three experimental treatments -- insects, hand pulling, and herbicide -- are being compared on a 7.5-acre section of the right-of-way (Figure 3). The experimental design was influenced by the need to establish insects in the area of highest ragwort density, a City Light ban on herbicide use within 50 ft of the streambed, and the need for easy interpretation by right-of-way maintenance crews which are responsible for hand pulling and herbicide treatments. A fourth area, which would remain untreated, was sought as a control, but was disapproved by the Snohomish County Weed Control Board. This area was therefore set aside as a reserve area for insect release, but is not included in the sampling scheme.

In 1986, tansy ragwort density was sampled from 13 June to 8 July, prior to treatment of each area. A regular sampling scheme was used, in which plots were evenly distributed over the study area (Figure 3 Inset). Each treatment area contained 18 transects, spaced at 30-ft intervals and oriented perpendicular to the right-of way. Transects contained 3-5 sampling plots each, also spaced at 30-ft intervals, resulting in a total of 54-71 plots per treatment. Plots were marked with rebar center stakes and flagging.

Ragwort was sampled within a 4-ft radius of each center stake (producing a 50-ft^2 circular plot) and was initially classified as either vegetative or flowering, depending on the presence of flowering stems. Vegetative plants were later divided into seedling (< 7.5-cm diameter) and rosette (> 7.5-cm diameter) size classes as recommended by McEvoy (personal communication).

In 1987, sampling was changed to a stratified random design to allow statistical comparisons of ragwort densities using analysis of variance (McEvoy personal communication, Wilkinson personal communication). The regularly-spaced plots from 1986 were used as a grid system, and plants were randomly sampled within each grid cell, using a 1/4-m^2 quadrat. There were 51-68 samples per treatment under this system. Sampling took place on 26 May.

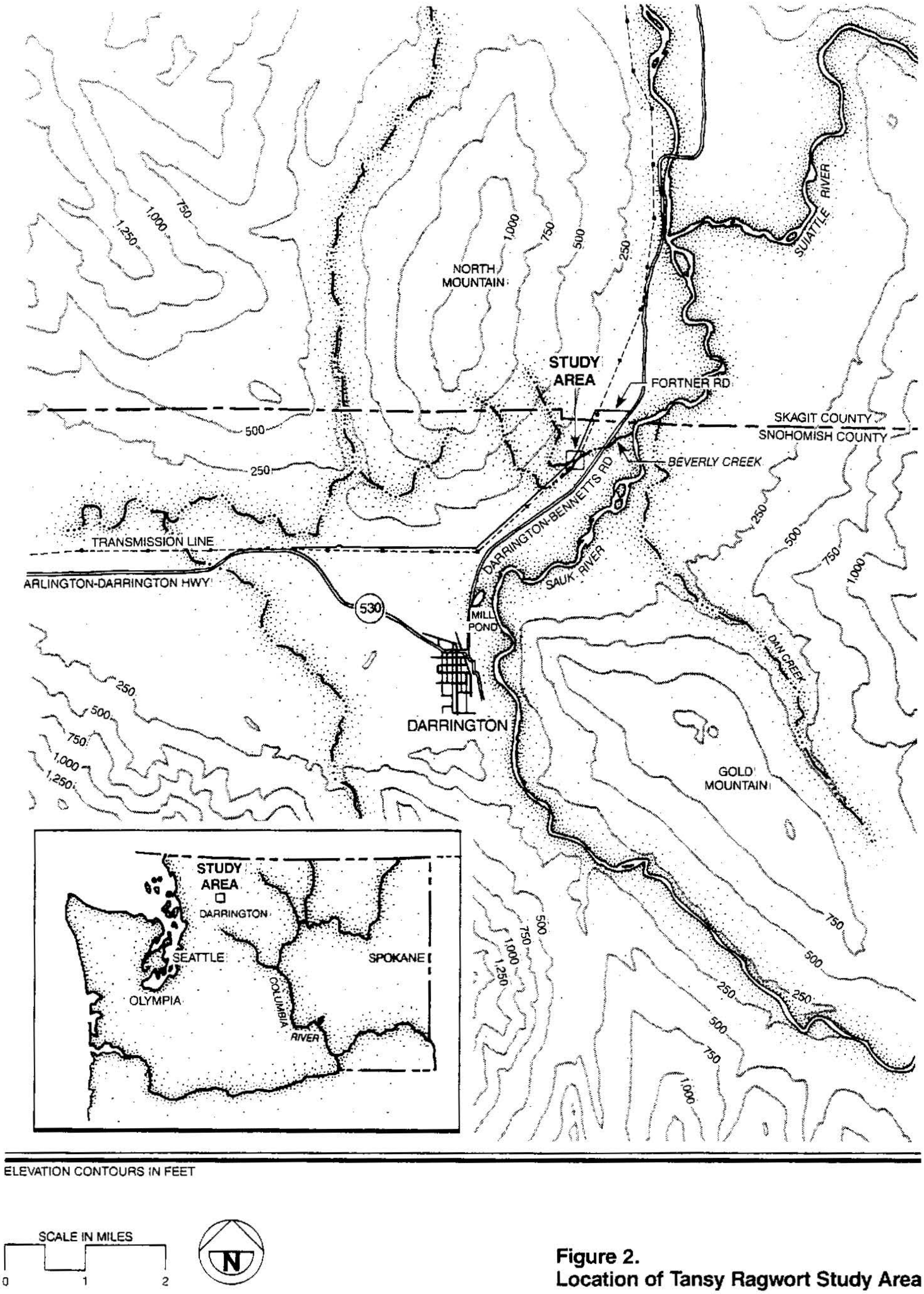

Figure 2.
Location of Tansy Ragwort Study Area

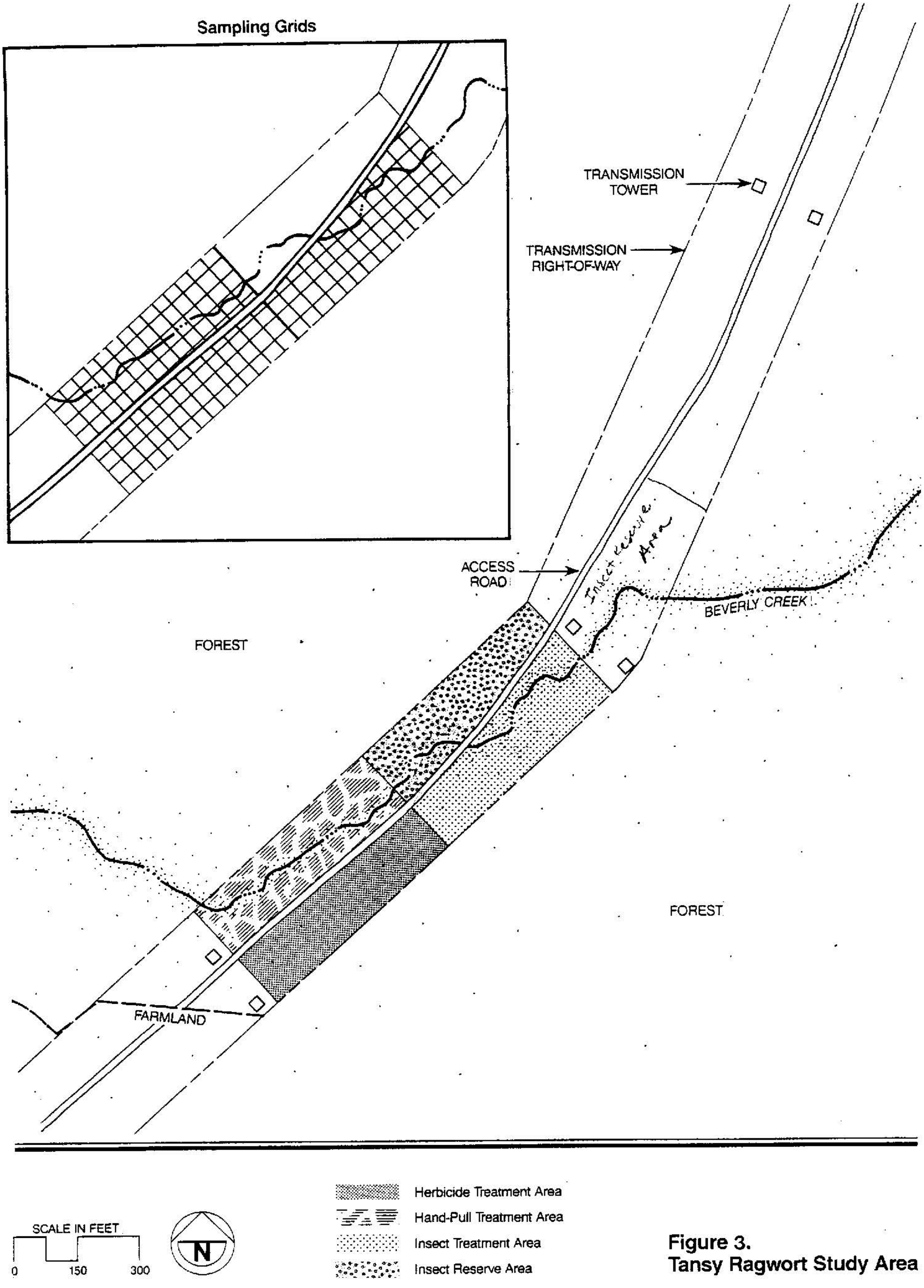

Figure 3.
Tansy Ragwort Study Area

In addition to sampling, complete counts of flowering ragwort plants were made on 8 July (1986) and 16 June (1987). The 1986 counts were made before the release of insects, but after the hand pulling and herbicide treatments. The 1987 counts were made prior to all treatments. Complete counts of flowering plants were necessary because densities of flowering plants were too low to estimate reliably by sampling. Furthermore, sampling was carried out earlier in the growing season, before most flowering stems had begun to elongate. Counts of flowering plants provided a reliable estimate of density at a time when the plants were most visible.

Hand pulling and herbicide treatments were administered by right-of-way maintenance crews from 23-25 June 1986. In 1987, hand pulling also took place on 23 June, but herbicide treatment was delayed until July. As in the past, Banvel herbicide was applied using a backpack sprayer. Labor and travel time were recorded and multiplied by the hourly rate to compare the cost of the two treatments.

Insect treatments began with the release of a total of 3,000-4,000 cinnabar moth larvae on 10 and 15 July 1986. The larvae were collected from a ragwort-infested clearcut southwest of Olympia, with assistance of personnel from the Thurston County Weed Control Board. Larvae were released on the insect treatment area within 24 hours of collection, in concentrations of about 5-50 individuals per flowering plant. Preferred release sites were slightly elevated and had logs or stumps nearby to provide dry habitat for overwintering pupae.

On 9 October 1986, 5,000 flea beetles, collected near Tillamook, Oregon, were released on the study area. The beetles were provided by Mr. Bob Brown of the Oregon Department of Agriculture, after visiting the site and determining the number of beetles needed for release. Mr. Brown estimated that the beetles would become well established on the right-of-way within 2-3 years. The flea beetles were released in areas of vigorous rosette concentrations within the insect treatment area and insect reserve area, approximately 24-36 hours after collection. Concentrating the beetles facilitates mating, which takes place during the fall.

An evaluation of insect establishment and damage from the first year's releases was made during May and June of 1987. The evaluation was semi-quantitative, consisting of observations on the number and location of adult cinnabar moths, the presence and abundance of moth eggs or caterpillars on flowering plants, the occurrence of flea beetle larvae or damage on roots, and the level of adult beetle damage to seedlings and rosettes. Observations of above-ground damage were recorded during sampling of ragwort densities and censusing of flowering plants. Plants from several parts of the site were dug to look for root damage.

RESULTS AND DISCUSSION

Results of the first year's study must be considered preliminary, given that several years are generally needed to establish insect populations which can

exert measurable levels of biological control. The comparative successes and costs of treatments can only be measured over the long term.

Sampling densities of tansy ragwort during 1986 and 1987 are shown in Table 1. In 1986, pre-treatment density of vegetative (i.e. non-flowering) plants was highest in the insect treatment area, intermediate in the hand-pulled area, and lowest in the herbicide treatment area. Pre-treatment density of flowering plants was approximately 7-8 times higher in the insect treatment area than in either of the other two treatment areas. Comparison of seedling densities in 1986 was not possible, because sampling was carried out for two of the treatments prior to the decision to distinguish seedling and rosette size classes.

The 1986 flowering plant counts also showed that ragwort levels were highest in the insect treatment area (Table 2). Although counts in the hand-pulled and herbicide-treated areas were made after the treatments, most of the sprayed plants in the herbicide-treated area were probably counted. Approximately 3/4 of those plants had been sprayed. In the hand-pulled area, an unknown number of plants were removed before counting took place.

In 1987, rosette sampling densities were similar among treatment groups, whereas seedling densities were substantially higher in the insect treatment area (Table 1). Analysis of variance showed that the latter difference was nearly significant at the 5 percent probability level. Differences in seedling densities during 1987 reflect differences in flowering plant densities during 1986 (Table 2).

Counts of flowering plants during 1987 showed a large reduction on the insect treatment area compared to 1986 (Table 2). No significant change occurred on the herbicide treatment area, whereas a large increase in flowering plants was recorded on the hand-pulled area.

The reduction of flowering plants on the insect treatment area is probably due to an illicit control effort during the fall of 1986, in which someone sprayed approximately 2/3 of the rosettes and clipped all the flowering plants on the insect treatment area. The effect is temporary, as indicated by the high seedling density in 1987. A large increase in flowering plants is expected on the insect treatment area during 1988. The apparent increase in flowering plants on the hand-pulled area is at least partly a result of the treatment having occurred before the plants could be counted in 1986, and after the counts in 1987.

Results of insect introductions during 1986 are inconclusive. Short-term survival of cinnabar moth larvae appeared to be high, based on the presence of many caterpillars the week after their first release. Overwinter survival of pupae, however, was apparently quite low. Only one moth was observed during 14 hours on the site in Spring 1987, and no egg masses or caterpillars were found. Potential causes of the poor survival include winter flooding of Beverly Creek, trampling by cattle, and predation by insects or vertebrates. The survival of cinnabar larvae reintroduced to the site during July 1987 will be evaluated during the second year of the study.

Table 1. Tansy ragwort sampling densities during 1986 and 1987.

		Number of Plots	Mean Density (number of of plants/m²)	Standard Deviation
1986 Results				
Insect Area	seedlings	69	0.346	0.797
	rosettes	69	0.200	0.333
	flowering plants	69	0.203	0.531
Handpull Area	seedlings	0(1)	0.000	0.000
	rosettes	71	0.152	0.344
	flowering plants	71	0.027	0.120
Spray Area	seedlings	0(1)	0.000	0.000
	rosettes	54	0.016	0.071
	flowering plants	54	0.024	0.176
1987 Results				
Insect Area	seedlings	68	44.000	199.449
	rosettes	68	0.882	2.836
	flowering plants	68	0.059	0.485
Handpull Area	seedlings	68	2.000	14.104
	rosettes	68	0.765	3.738
	flowering plants	68	0.235	1.173
Spray Area	seedlings	51	1.020	7.281
	rosettes	51	0.471	2.845
	flowering plants	51	0.157	1.120

(1) Sampling was performed prior to the decision to distinguish seedlings from rosettes.

Table 2. Results of flowering plant census on tansy ragwort study area during 1986 and 1987.

		Plant Numbers	Plant Density per m^2
1986	insect	767	0.075
	handpull	89[1]	0.009
	spray	84[1]	0.008
1987	insect	294	0.029
	handpull	366	0.036
	spray	88	0.009

[1] Counts were made after treatments.

Flea beetles may have overwintered successfully, but adult feeding damage to vegetative plants was not discernible from slug damage; the latter occurred quite frequently, both on leaf margins and in the centers of leaves where it resembled the small holes created by flea beetles. No evidence of flea beetle larvae or damage was found on the roots of several large plants which were examined. The illegal spraying of ragwort rosettes during Fall 1986 resulted in fewer potential feeding and egg-laying sites for flea beetles, and may have lowered their survival. Flea beetle survival will be further evaluated during Summer 1987, and additional releases made during the fall if needed.

The biggest surprise of the study was the discovery of seedhead fly larvae on the study area during August 1986. The species was found by Mr. Bob Brown during his evaluation of the area for flea beetle release. The flies apparently entered the area through natural dispersal, and were at relatively low levels of infestation. The species also appeared for the first time in British Columbia in 1986, after several years of apparently unsuccessful attempts to introduce it (Wilkinson personal communication). The presence of the seedhead fly on the study area is beneficial, and is expected to add to the biological control exerted by the flea beetle and cinnabar moth.

Cost comparisons for 1986 show that insect application was approximately twice as expensive as hand pulling, and eight times as expensive as the herbicide treatment (Table 3). However, initial cost comparisons do not reflect the long-term situation. Biological control efforts tend to be relatively expensive in the first years, with markedly reduced costs once the insects become well established. The only expected long-term cost of biological control would result from periodic reintroductions of insects necessitated by reduced levels of ragwort. In contrast, manual and chemical control methods require constant or increasing efforts and costs over time. Reliable estimates of cost and effectiveness for all three control methods will be more accurately compared through long term analysis.

Table 3. Preliminary cost comparisons of treatments on tansy ragwort study area during 1986[1].

HAND-PULL	Hours	Miles[2]	Rate	Cost
Labor	15		$ 28.00	$ 420.00
Travel	7		28.00	196.00
TOTAL				**$ 616.00**
HERBICIDE				
Labor	2		$ 28.00	$ 56.00
Travel	3.5		28.00	98.00
TOTAL				**$ 154.00**
INSECTS				
Cinnabar Moth:				
Moths				$ 0.00
Labor	6		$ 45.00	270.00
Travel	6		45.00	270.00
Mileage		400	.21	84.00
Subtotal				624.00
Flea Beetle:				
Beetles				$ 300.00
Labor	3		45.00	135.00
Travel	3		45.00	135.00
Mileage		200	.21	42.00
Subtotal				612.00
TOTAL				**$1,236.00**

(1) Initial cost comparisons reflect higher set-up costs for biological control, including the experimental nature of insect treatments. Long-term maintenance costs of biological control are expected to be markedly reduced.

(2) Mileage is included in hourly rates for Seattle City Light maintenance crews.

CONCLUSIONS AND RECOMMENDATIONS

The ideal conditions for comparing biological control with other forms of tansy ragwort control would be a large, uniform study area, with a high density of ragwort and plenty of room to assign treatments randomly and isolate them from one another. Unfortunately, such conditions seldom occur in nature.

On the Seattle City Light right-of-way, tansy ragwort is unevenly distributed and is primarily concentrated in a relatively small area selected for this study. Preliminary results show that, within the study area, the plant is also unevenly distributed. Experimental treatments were not assigned randomly, but rather to establish insect populations as quickly as possible, and to comply with environmental regulations banning herbicide use near streams. A no-treatment area was also impractical, weakening the inference that a reduction in ragwort is due to treatment effects, rather than resulting from other environmental variables.

Despite these limitations, the study is expected to generate some useful information on the feasibility of establishing insects, and their effectiveness in controlling ragwort populations. Monitoring the insects over time will determine whether repeated introductions are necessary, and whether both the cinnabar moth and ragwort flea beetle are suited for introduction in the region. Several releases may be needed for locally-adapted insect strains to develop. If the insects do become established, the success of biological control may be inferred from a significant reduction in ragwort density on the insect treatment area, relative to the other treatments. This process may take several years.

The spread of insects on the right-of-way may reduce or eliminate the need for other methods of ragwort control. Continued monitoring of hand pulling and herbicide treatments will permit a comparison of the cost and effectiveness of the two methods, either relative to, or in combination with, biological control. Should biological control prove worthwhile, reintroductions of insects can be considered elsewhere within region where the insects are not already established.

Recommended work during the next 14 months (1 July 1987 to 31 August 1988) consists of: 1) reintroducing cinnabar moth larvae; 2) evaluating flea beetle survival and reintroducing them if necessary; 3) estimating ragwort populations and insect establishment; 4) analyzing and comparing treatment effects; and 5) preparing a yearly progress report describing study results and recommendations. Sampling and analytical methods will be the same as used during 1987. A proposed schedule and budget will be submitted separately.

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