Final Report of 1986-1991

Alternative Control of Tansy Ragwort

Prepared for Seattle City Light
Environmental Affairs Division

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ALTERNATIVE CONTROL OF TANSY RAGWORT

ON THE SKAGIT TRANSMISSION RIGHT-OF-WAY

FINAL REPORT

June 1, 1986 - December 31, 1991

Prepared for

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SUMMARY

This report describes the results of a 5-year study to control tansy ragwort (*Senecio jacobaea*) on the Skagit hydroelectric transmission right-of-way near Darrington, Snohomish County, Washington. Seattle City Light (SCL) authorized the study in 1986 to compare the feasibility of biological control with traditional methods of ragwort control (hand weeding and herbicide). Depending on the success of biological control, SCL may reduce or eliminate the use of herbicide for controlling tansy ragwort on their right-of-ways.

Two insect species that feed on tansy ragwort, the cinnabar moth (*Tyria jacobaeae*) and ragwort flea beetle (*Longitarsus jacobaeae*), were released in the study area between 1986 and 1988. A third species, the ragwort seed fly (*Pegohylemyia seneciella*) colonized the area through dispersal from other sites. Insect populations and tansy ragwort densities were monitored from 1986 through 1991 in each of 3 experimental treatment areas on the right-of-way.

Results indicate that biological control of tansy ragwort was highly successful. Flea beetle and cinnabar moth populations established within 2-3 years of initial releases and exerted significant pressure on the ragwort population within 4-5 years. By 1991 the number of flowering plants in the study area was reduced 99% and the density of vegetative plants was reduced 87% compared to initial levels. Herbivory by the introduced insects was augmented by seed fly damage to ragwort seed production. Removal of cattle grazing may have enhanced the effectiveness of biological control by promoting the growth of competing vegetation. Insect populations declined in 1991, presumably due to the scarcity of ragwort.

Because of the reduction of ragwort in the study area, alternative treatments were unnecessary in 1991. SCL will continue monitoring ragwort and insect abundance on the right-of-way and will examine the need for further releases of insects or other measures to maintain effective control of the tansy ragwort population.

INTRODUCTION

This report describes the results of a 5-year study to control tansy ragwort (*Senecio jacobaea*) on the Skagit hydroelectric transmission right-of-way near Darrington, Snohomish County, Washington. Tansy ragwort is a biennial or short-lived perennial member of the aster family, introduced to North America from Europe. 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 1985). Land owners in Washington are required under RCW 17.10 to control and prevent the spread of ragwort and other noxious weeds to adjacent agricultural lands.

For several years, Seattle City Light (SCL) used the herbicide, dicamba (Banvel), to suppress tansy ragwort on upland portions of the right-of-way. Chemical control was supplemented with hand weeding of ragwort plants growing near streams. In 1986, SCL authorized a study to determine the feasibility of biological control of ragwort. The purpose of the study was 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 weeding, in suppressing ragwort. Ultimately, SCL would like to eliminate herbicide use for tansy ragwort control on the Skagit and other right-of-ways.

LITERATURE REVIEW

BIOLOGY OF TANSY RAGWORT

Tansy ragwort is native to Europe and western Asia where it ranges from Norway south through Asia Minor, and from Great Britain east to Siberia. 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 eastward beyond the Cascade Mountains (McEvoy 1985).

Ragwort is generally considered a biennial species. Germination takes place during fall or spring with seedlings developing into rosettes by the end of the first full growing season (Figure 1). The following year the plants enlarge, send up flowering stems, produce seed, and die. Seeds are dispersed mainly by wind, although dispersal distances are typically only a few meters at most (McEvoy and Cox 1987). If environmental conditions are poor or the ragwort plant is damaged it may develop as a short-lived perennial. Perennial ragwort plants often have large, woody rootstocks and multiple flowering stem (Macdonald 1983).

In the Pacific Northwest, tansy ragwort colonizes pastures, ungrazed meadows, and early successional forests following timber harvesting. Livestock normally avoid ragwort plants where more desirable forage is available, but small plants growing among palatable forbs

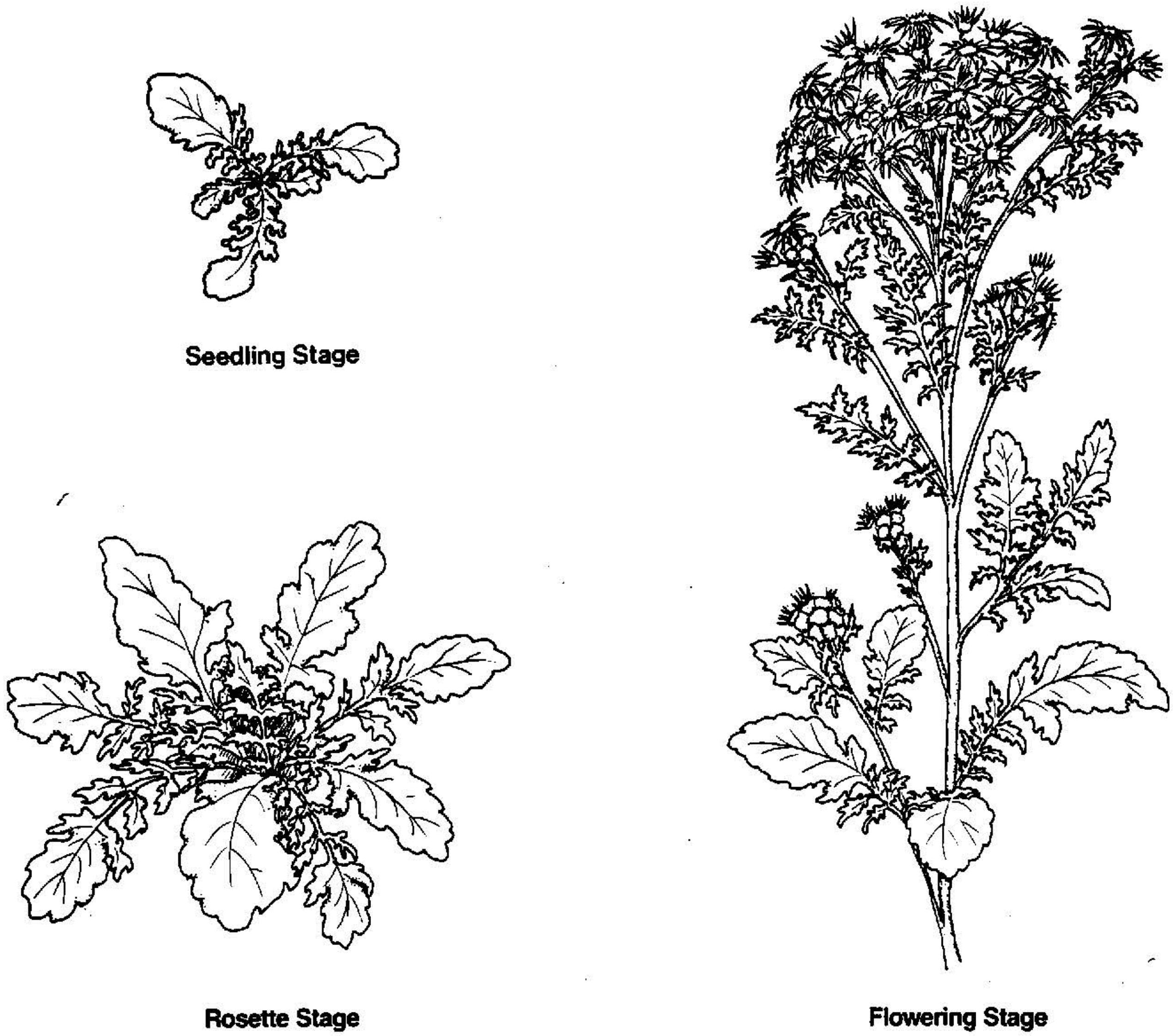


Figure 1.
The Three Life Stages of Tansy Ragwort

and grasses, or ragwort plant parts mixed with hay, cannot be selectively excluded by livestock. When ragwort is consumed, pyrrolizidine alkaloids in the plant tissues are metabolized to pyrroles, causing liver damage and eventually death of the animal that has eaten enough of the plant. Lethal doses accumulate with time. Alkaloids have also been found in the milk of cows and goats fed a diet of tansy ragwort (Bedell et al. 1981). Ungrazed ragwort-infested sites, though not a direct toxicity problem for livestock, are seed sources for ragwort invasions of grazed lands (Macdonald 1983).

In its native habitat of Europe and western Asia, tansy ragwort is kept partly in check by natural enemies. In England, Cameron (1935) documented over 60 species of insects that feed on ragwort. Where ragwort has been introduced without these controlling agents, it has become a serious rangeland pest. Since first being found in the early 1900's, tansy ragwort has spread to more than 3 million acres of western Oregon, and has infested more than 100,000 acres of pasture land in western Washington (Bedell et al. 1981).

SUPPRESSION OF TANSY RAGWORT

Cultural Treatment

Several methods have been successfully used to help prevent or control infestations of tansy ragwort. Since ragwort needs disturbed soils and plenty of light to become established, one of the best ways to prevent its occurrence is to maintain dense, continuous vegetative cover. Good pasture management, such as sequential grazing and avoidance of winter grazing by cattle and horses, helps maintain integrity of the turf and minimizes potential germination sites (Bedell et al. 1981).

Sheep grazing is used in some areas to reduce tansy ragwort infestations and to precondition pastures for cattle grazing. Sheep are resistant to ragwort's toxicity, actually showing a preference for ragwort during summer when other forage plants dry out (Bedell et al. 1981). Continuous sheep grazing can remove and keep ragwort out of a pasture by preventing the plants from going to seed. But heavy grazing by sheep also disturbs soils and damages competing vegetation, creating potential germination sites for ragwort. Removing sheep from a pasture where ragwort seeds are present can allow ragwort to become reestablished (Macdonald 1983).

Mechanical Treatment

Mowing is commonly used to stop ragwort plants from flowering and producing seed. Theoretically, mowing should eventually eliminate on-site seed sources, though it cannot prevent the spread of seeds from other areas. Since repeated cuttings are needed during a single growing season to prevent ragwort plants from flowering, and seeds remain viable in the soil for several years (McEvoy et al. 1991), mowing is not very effective in reducing ragwort populations. Mowing also disturbs soils and weakens many of the more desirable forage plants which might otherwise outcompete ragwort.

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

Hand pulling of ragwort plants produced poor results in a ragwort eradication program in eastern Oregon, where more than 50% of the treated sites had an obvious ring of regenerating plants 1 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 Treatment

Chemical control of ragwort can be achieved using the herbicides 2,4-D, dicamba, 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 or in mid-fall after rains have initiated new growth. Brewster (1978) reported 96-100% 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 the latter stage does not eliminate seed production, but reduces the viability of seeds (Macdonald 1983). Applications on small areas are commonly made with a backpack sprayer.

Two additional herbicides have been used to control ragwort in eastern Oregon (Cox 1986). Tordon (picloram and 2,4-D) pellets are reportedly effective for the control of scattered plants, and are less likely than sprays to affect surrounding vegetation. Glyphosate (Roundup) has been used to control ragwort growing in standing water. To minimize contact with water, the herbicide is wiped directly on the plant with a special applicator.

Although effective in controlling ragwort, herbicide use increases health risks to workers, the public, and the environment, as well as raising potential long-term liability resulting from improper use or disposal. For example, even though dicamba is one of the safer herbicides available, tests on some mammals indicate that it may injure developing fetuses. Because many herbicides including dicamba are water soluble, they can be carried in surface runoff or in groundwater to nontarget vegetation and wildlife. This problem is especially troubling with ragwort, as it tends to concentrate near streams. In recognition of these concerns, SCL has adopted a right-of-way maintenance policy requiring minimal use of herbicides.

Biological Control

Biological weed control involves the intentional use of exotic natural enemies (usually insects) to reduce the abundance of a plant that has spread and become a pest outside its native range. The practical aim of biological control is to maintain the target weed at reduced levels that can be economically tolerated, and to foster replacement with more desirable native vegetation (McEvoy et al. 1991). For successful long-term biological control, small numbers of the host plant and controlling insects must persist to assure a response to outbreaks of the host plant. The insects need not necessarily kill the host, but must cause enough damage to eliminate its competitive advantage over other plants. The controlling insects must also be highly specific to the host plant to prevent harm to non-target species.

Biological control of tansy ragwort has focused on 3 insect species: the cinnabar moth, ragwort flea beetle, and ragwort seed fly (*Pegohylemyia seneciella*). Host specificity tests, conducted before releasing these insects in the United States, showed that all were sufficiently specific to tansy ragwort to warrant introduction (Macdonald 1983, McEvoy et al. 1991).

Cinnabar Moth. The cinnabar moth was imported from France and released into northern California in 1959. A year later it was introduced in Oregon, and has since been redistributed throughout western Oregon and to parts of Washington and British Columbia (Harris et al. 1984, McEvoy et al. 1991). 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 has 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 (1986 personal communication) and Myers (1986 personal communication) observed that the cinnabar moth was subject to unexplained local extinctions following initial establishment in British Columbia.

Two environmental factors that help the cinnabar moth achieve effective control of ragwort are summer drought and autumn frost; both inhibit plant regeneration after the larvae have begun pupating (McEvoy 1986 personal communication). Release sites for cinnabar moth larvae 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) and are subject to predation by insectivores, mice, and ants (Cameron 1935, Brown 1986 personal communication).

Ragwort Flea Beetle. The ragwort flea beetle was introduced to northern California from Italy in 1969 to supplement existing biological control efforts (McEvoy 1985). 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 1986 personal communication).

Adult flea beetles are pit feeders, chewing small holes in the leaves of ragwort plants (McEvoy et al. 1991). After pupating in the soil, the adults emerge and feed briefly during the early summer. They become dormant again until fall, when they re-emerge to feed, mate, and lay their eggs on or next to the ragwort root crowns. Egg-laying continues throughout winter and early spring. The larvae hatch in about 3 weeks and tunnel into the roots and leaf petioles (Wilkinson 1986 personal communication). It is the larval feeding on the main root that causes the primary damage to the ragwort plant (Macdonald 1983, Harris et al. 1984).

There have been few studies isolating the impacts of flea beetles on ragwort populations, as the beetle was introduced to many areas after the cinnabar moth had already become established. Hawkes and Johnson (1978) reported that flea beetles had practically eliminated ragwort from a 12-acre area within 4 years of release in California, and within 10 years the beetles had dispersed nearly 20 miles from the release site. Shanks (1986 personal communication) noted similar success in southwestern 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 to new sites more readily than the moths (Brown 1986 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 occurs at a time when the moth is inactive. Herbivore pressure distributed over time and space may result in lower equilibrium levels of ragwort by reducing the number of plants that escape herbivory (McEvoy 1985).

Ragwort Seed Fly. The ragwort seed fly was imported from Europe and first released in the Pacific Northwest between 1966 and 1970 (Frick 1969, Harris et al. 1984). Early efforts to establish this species from California to British Columbia met with limited success (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 1986 personal communication). In 1986, naturally-dispersed populations of the fly first appeared in British Columbia (Wilkinson 1986 personal communication).

Seed flies overwinter as pupae in the soil and emerge as adults in June, just as tansy ragwort is developing flower buds. Eggs are laid in the central flower heads, with 1 larva developing per flower head during July and August. The larvae reduce ragwort seed production by feeding on the developing seeds. Seed fly 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 frothy material that cements the protruding florets together (Frick 1969).

By itself, the seed fly may not be particularly effective at reducing ragwort abundance in the Pacific Northwest (McEvoy 1986 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. However, combined with the effects of other biological control agents, predation by the seed fly may help achieve a satisfactory level of control. Potential competition between the seed fly and cinnabar moth, which both attack the flowers of ragwort, has not been studied (Macdonald 1983).

STUDY AREA

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 that joins the Sauk River about 1 mile downstream from the right-of-way. The creek generally flows from November through March, and has flooded the study area during 5 of the last 6 winters. Ragwort density has been highest near the creek in the northeastern part of the site.

Before our study, cattle from adjacent farmlands entered the site through coniferous forest bordering the right-of-way. To prevent interference with the study, the area was fenced to exclude cattle.

METHODS

This study was designed to assess the feasibility of biological control of tansy ragwort on SCL's Skagit transmission right-of-way. Control was evaluated in terms of success in reducing the ragwort population and the estimated cost associated with its control. Three experimental treatments — insects, hand weeding, and herbicide — were compared on a 7.5-acre section of the right-of-way (Figure 3). A fourth "insect reserve" area was established to accommodate insect releases and expanding insect populations, but was not involved in experimental measurements. Study design was influenced by the following factors:

- The need to establish insects in the area of highest ragwort density.

- A ban by SCL on herbicide use within 50 feet of the streambed.

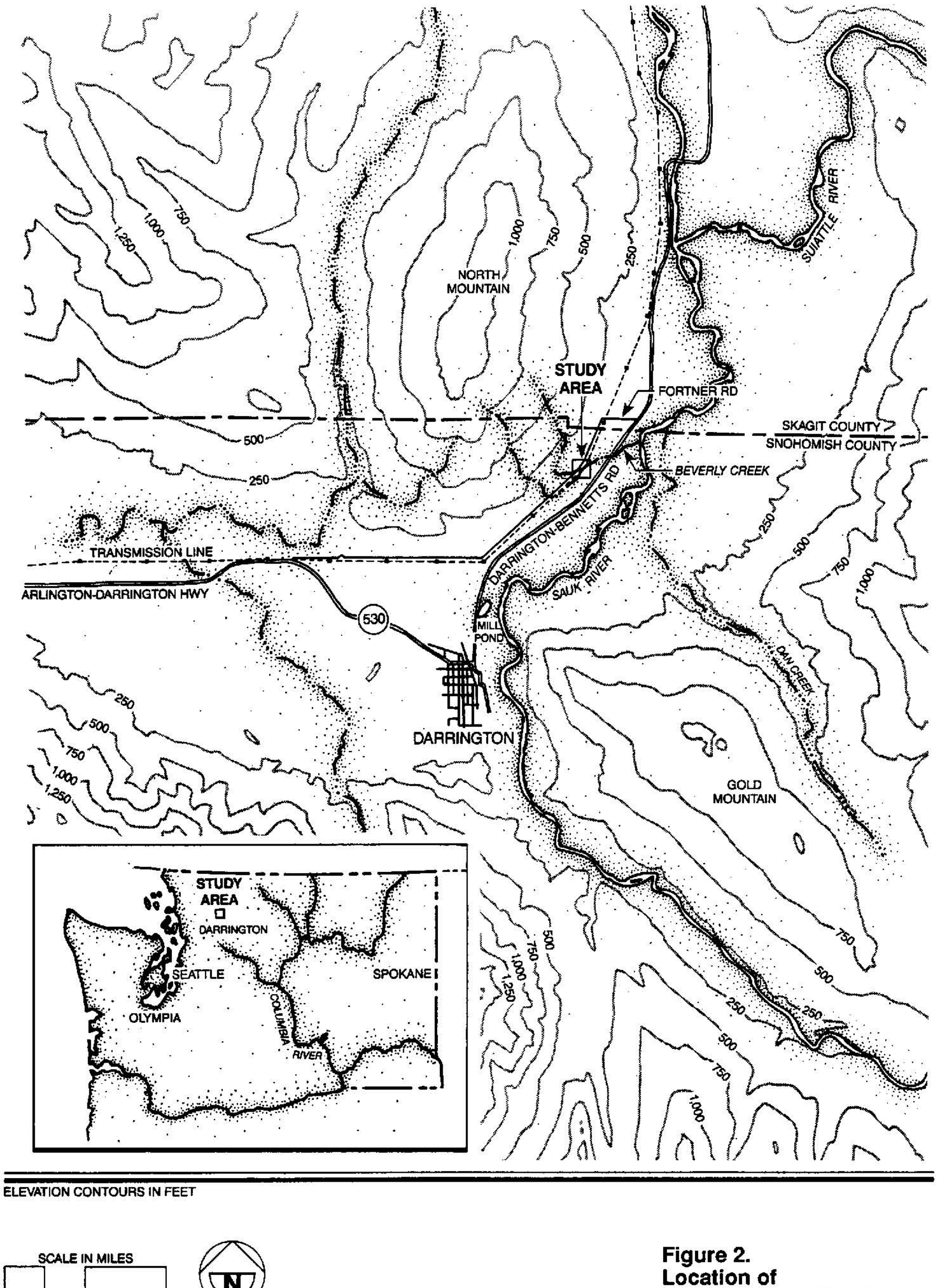


Figure 2.
Location of
Tansy Ragwort Study Area

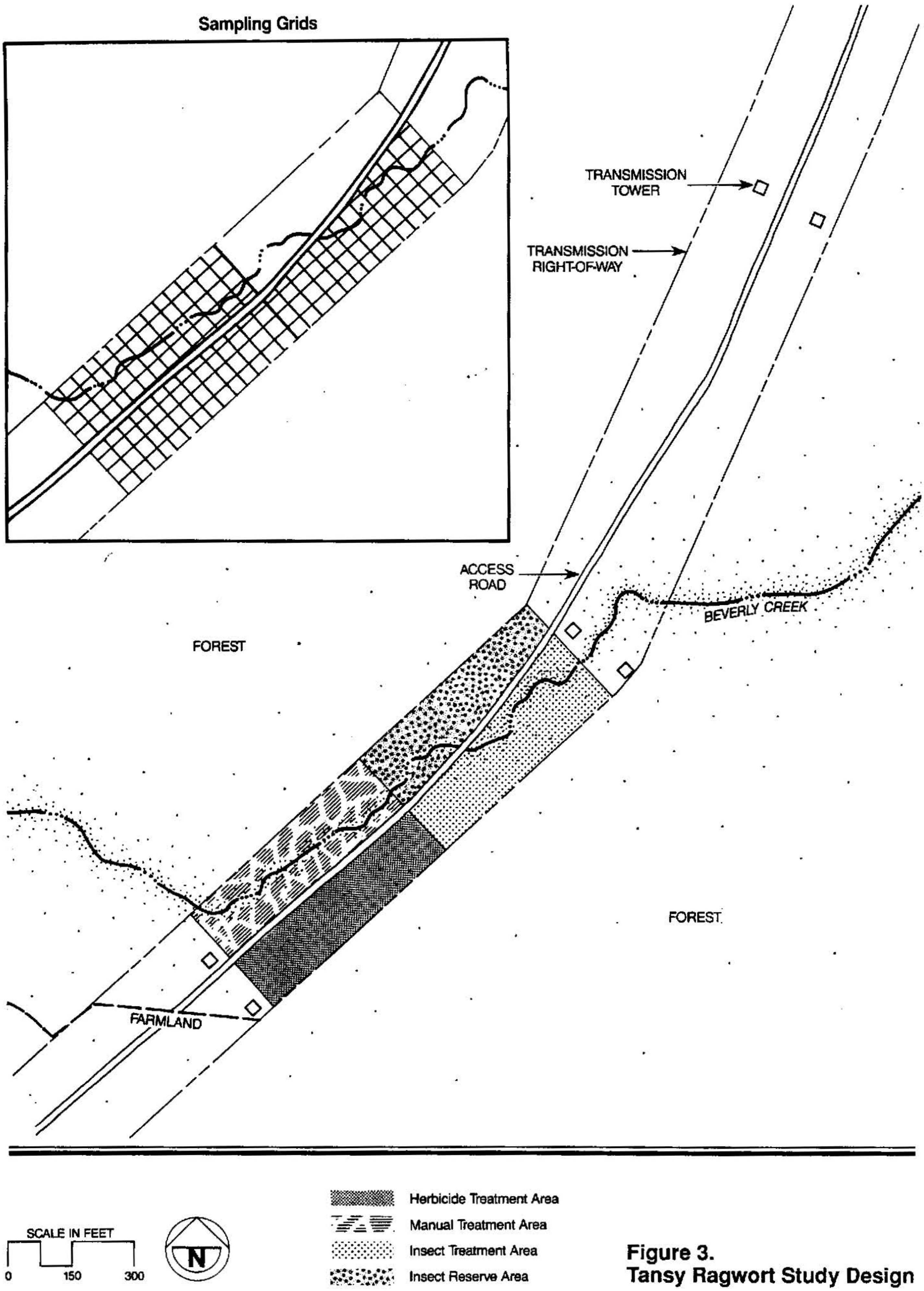


Figure 3.
Tansy Ragwort Study Design

- The need to clearly delineate treatment areas for right-of-way maintenance crews responsible for manual and herbicide treatments.

- A requirement by the Snohomish County Weed Control Board that some form of tansy ragwort control be administered on all parts of the study area.

As a result of these constraints, the study lacks several key elements of experimental protocol, including use of untreated controls, independence of experimental units, and random assignment of treatments (McEvoy 1988 personal communication). Despite these limitations, we obtained useful information on the establishment of insect populations and their effectiveness in controlling tansy ragwort relative to other concurrent treatments.

RAGWORT DENSITY

Tansy ragwort population density was sampled annually within treatment areas during the last week of May or first week of June, 1987-1991. Each treatment area was staked in a rectangular grid pattern with 51-68 individual grid cells measuring 30 x 30 feet (see Figure 3). Within each grid cell, ragwort plants were sampled within a single randomly-placed 0.25-m^2 quadrat. Plants were classified as seedlings ($<$7.5-cm diameter) or rosettes ($\geq$7.5-cm diameter) (McEvoy 1985) (see Figure 1). Sampling data were analyzed for statistical differences in ragwort densities. We compared mean seedling and rosette densities among treatment areas using the Kruskall-Wallis test, a nonparametric equivalent of ANOVA.

Flowering ragwort plants were counted annually within treatment areas during 1986-1991. Counts were made in late June or early July, before SCL applied manual and herbicide treatments. Total counts were needed because densities of flowering plants were generally too low to estimate reliably by sampling. Numbers of individual plants were used to estimate total number of ragwort stems in each treatment area, based on the ratio of stems per plant observed in a subsample.

In 1990, we monitored both the survival of individual ragwort plants and sources of plant mortality by marking 100 rosettes distributed throughout the study area. Plants were marked on 27 March using metal tags held in place by large nails driven into the ground near each plant. Tags were relocated on 28 August and surviving plants examined for evidence of damage from insects or other sources.

RAGWORT DISPERSAL

The occurrence of tansy ragwort downstream from the study area led the Skagit County Noxious Weed Inspector to speculate that tansy ragwort had spread from the right-of-way via Beverly Creek (Reynolds 1988 personal communication). Ragwort seeds falling into the water could be transported downstream to sites where they might germinate and establish new populations.

During 1989 we looked for possible evidence that ragwort seeds had dispersed downstream from the study area. In late July, we conducted a walk-through survey along Beverly Creek to document the occurrence of ragwort plants between the study area and the Sauk River. We also completed an 8.2-mile survey of the Sauk River by boat between Darrington and the Suiattle River to compare the incidence of ragwort upstream and downstream of the Sauk's confluence with Beverly Creek. The creek enters a side channel of the Sauk River near the midpoint of the float, about 4.3 miles upstream of the Suiattle (see Figure 2).

In December 1989, after a weekend of heavy rain, we took water samples from Beverly Creek to assess the abundance of ragwort seed entering and leaving the study area during early winter flood conditions. Using a bucket and fine-mesh wire screens (1.2- and 0.85-mm in series), we filtered a total of 150 gallons of water from 3 sample stations along the creek. One station was at the downstream end of the study area, one was at the upstream end, and the third was midway between in a flooded stand of ragwort. Creek flows entering and leaving the study area were estimated by measuring stream cross sections and visually estimating current velocities.

Screened creek samples were analyzed in the laboratory. Seeds were counted and identified with reference to known seeds of tansy ragwort and Canadian thistle, the other common member of the aster family onsite.

RAGWORT GERMINATION

The possibility of tansy ragwort dispersal by water was further investigated by conducting germination and transplant trials using seeds subjected to varied levels of soaking. The objective was to determine whether seeds soaked or submerged for different time periods would still be viable and capable of establishing themselves following dispersal downstream.

Seedheads were collected from tansy ragwort flower stalks in the study area during December 1989. These were allowed to dry at room temperature (21° C) for 2 weeks before the germination study. A large number of seeds were extracted from seedheads and mixed together. Fifteen groups of 50 seeds each were then randomly selected.

Seed groups were subjected to 14 different stratification treatments in distilled water to simulate various aerobic and anaerobic conditions to which seeds might be exposed during stream transport. Treatments consisted of 7 submerged sets and 7 floating sets, with one untreated control set. Treatments were divided into exposure times of 1, 6, 12, 24, 48, 72, and 144 hours. Treatments were performed at 2-4° C, except the control which was kept dry at room temperature.

For germination trials, seeds were placed in petri dishes on filter paper moistened with distilled water and kept at room temperature (21° C). The seeds were monitored for visible signs of germination approximately every 12 hrs over a period of 14 days. Sixteen germinated seedlings were later transferred to small pots filled with a 50/50 mix of potting soil and sand. Seedlings were kept moist at room temperature for approximately 1 month to determine whether they would become established.

INSECT ESTABLISHMENT

Insect Releases

Annual insect releases were made during 1986-1988, and averaged 4,500 cinnabar moth larvae and 4,500 adult flea beetles (Table 1). Insects were not released in the study area after 1988, although in 1991 we released 2,500 cinnabar larvae on the right-of-way about 1 mile northeast of the study area. The latter release was undertaken to establish cinnabar moths over a wider area.

Table 1. Insect releases on the Skagit transmission right-of-way, 1986-1991.

Insect Species	Date	Number	Origin
Cinnabar Moth (larvae)			
	7/10/86	2,500	Thurston County, Washington
	7/15/86	1,500	"
	7/01/87	4,500	"
	7/21/88	5,000	"
	7/30/91	2,500	King County, Washington
Ragwort Flea Beetle (adults)			
	10/09/86	5,000	Tillamook County, Oregon
	10/14/87	5,000	"
	10/13/88	3,500	"

Cinnabar moth larvae released during 1986-1988 were collected from ragwort-infested commercial forest lands near Olympia, Washington, under direction of the Thurston County Noxious Weed Control Board. Cinnabar larvae released in 1991 were collected from a SCL right-of-way near Cedar Falls, Washington. Larvae were kept in paper grocery bags and coolers and released within 24 hours onto flowering ragwort plants in the target areas. Preferred release sites were slightly elevated and had logs or stumps nearby to provide dry habitat for overwintering pupae.

Adult flea beetles were supplied by the Oregon Department of Agriculture from a collection site near Tillamook, Oregon. Beetles were collected during October when they were breeding and most active. We released the beetles within 24-72 hours of collection in areas of high rosette densities in the insect treatment and reserve areas. In 1988, we also released 1,000 flea beetles on the right-of-way north of Fortner Road.

Insect Surveys

We assessed cinnabar moth establishment and damage to tansy ragwort in late July or early August. The assessment involved estimating the number of larvae and the level of defoliation in a sample of plants inspected within each cell of the ragwort sampling grid. We also recorded the level of damage to flower heads caused by ragwort seed flies, which colonized the study area through dispersal from other areas. The assessment of cinnabar moth and seed fly damage was confined to the insect treatment area where ragwort was most concentrated and not affected by the other treatments.

Flea beetle surveys were conducted annually during October. Population trends were estimated by counting the number of adult beetles collected in timed vacuum samples using a backpack vacuum (D-Vac) insect collector. Sampling was conducted in stands of ragwort within the insect and hand-weeded treatment areas. We developed indexes to quantify abundance and damage levels of all 3 insect species.

ALTERNATIVE TREATMENTS

Hand weeding and herbicide treatments were administered annually between the first and third weeks of July, 1986-1990, by SCL right-of-way maintenance crews. Banvel (dicamba), diluted 1:100 with water, was applied with a backpack sprayer to individual ragwort flowering plants in the herbicide treatment area. Flowering plants in the hand-weeded treatment area were pulled and bagged to reduce the spread of seeds. All plant residues were buried offsite in a landfill. To compare the costs of treatments, labor and travel time were recorded and multiplied by the hourly rate of field crews. Alternative treatments were not administered in 1991 due to the lack of tansy ragwort in the study area.

In response to concerns raised by the Skagit County Noxious Weed Control Board, SCL agreed in 1989 to a limited control program for tansy ragwort within the insect treatment area. In mid-July and again in late August, flower heads of plants growing within the flood zone of Beverly Creek were clipped and bagged. Approximately one-third of the flowering plants within the treatment area were clipped. This procedure was not required in other years.

A supplemental task in 1988 was to investigate mechanical alternatives for controlling tansy ragwort. The purpose was to identify manual removal techniques that are effective, but pose less risk of worker back injury, than pulling the plants by hand. B-Twelve Associates completed this task by reviewing literature and interviewing people involved in tansy ragwort control throughout the Pacific Northwest. Their report is included here as Appendix A.

RESULTS

RAGWORT DENSITY

In most years, ragwort density was highest in the insect treatment area, intermediate in the manually-treated area, and lowest in the herbicide treatment area (Tables 2 and 3; Figure 4). Density differences between treatment areas were statistically significant for vegetative plants (seedlings and rosettes) during 1987-1990 ($H > X^2_{.05[2]}$). In 1991, the ragwort population declined to 0.1% of its peak density, and differences between treatments were not statistically significant.

Ragwort density exhibited annual variation within treatment areas (see Figure 4). Density differences were most pronounced in the insect treatment area, where abundance of flowering and vegetative plants fluctuated asynchronously during 1987-1989. This pattern changed in 1990 and 1991 when densities of vegetative and flowering plants both declined. Ragwort density also declined significantly in the hand-weeded area ($H > X^2_{.01[5]}$) and remained at very low levels in the herbicide treatment area.

RAGWORT DISPERSAL

The survey of Beverly Creek in July 1989 showed very little ragwort along most of the creek between the right-of-way and its confluence with the Sauk River. We attribute this to heavy forest canopy cover and lack of light. Near the confluence with the Sauk, where the forest canopy opened up, there were approximately 25 flowering plants on either side of the creek. Twelve more ragwort plants were found just downstream from the confluence. A resident living near the creek reported first seeing tansy ragwort on his property in 1985.

The survey of the Sauk River in July 1989 indicated that tansy ragwort was more common along the 4.3 river miles below Beverly Creek than in the 3.9 river miles above it. Of 12 observed groups of ragwort plants, 9 were downstream and 3 were upstream of Beverly Creek.

Water samples collected from Beverly Creek at the upper and lower ends of the study area in December 1989 did not contain any ragwort seeds. Only 2 seeds were collected from a flooded stand of ragwort in the middle of the insect treatment area. Creek flows during sampling were approximately 25 cubic feet per second (cfs) at the upstream end and 100 cfs at the downstream end of the study area below the junctions of 2 tributary channels.

Table 2. Tansy ragwort seedling and rosette densities, 1987-1991[1].

Year	Treatment	Sample Size	Size Class	Density ($\#/m^2$)
1987	Insect	68	Seedling	44.000
			Rosette	0.882
	Manual	68	Seedling	2.000
			Rosette	0.765
	Herbicide	51	Seedling	1.020
			Rosette	0.471
1988	Insect	68	Seedling	2.824
			Rosette	1.235
	Manual	68	Seedling	0.353
			Rosette	0.529
	Herbicide	51	Seedling	0.157
			Rosette	0.000
1989	Insect	68	Seedling	145.471
			Rosette	2.706
	Manual	68	Seedling	0.000
			Rosette	0.000
	Herbicide	51	Seedling	0.000
			Rosette	0.000
1990	Insect	68	Seedling	9.176
			Rosette	0.529
	Manual	68	Seedling	0.353
			Rosette	0.118
	Herbicide	51	Seedling	0.000
			Rosette	0.000
1991	Insect	68	Seedling	0.294
			Rosette	0.353
	Manual	68	Seedling	0.000
			Rosette	0.000
	Herbicide	51	Seedling	0.000
			Rosette	0.000

[1] Sampling data collected in 1986 were invalidated by the late start of project and heavy grass cover obscuring ragwort seedlings.

Table 3. Tansy ragwort flowering plant densities, 1986-1991.

Year	Treatment	Number: Stems	Number: Plants	Ratio	Density (#/m^2): Stems	Density (#/m^2): Plants
1986	Insect	NA[1]	767	NA[1]	NA[1]	0.094
	Manual	NA[1]	89[2]	NA[1]	NA[1]	0.012[2]
	Herbicide	NA[1]	84[2]	NA[1]	NA[1]	0.013[2]
1987	Insect	465	294	1.58	0.057	0.036
	Manual	889	366	2.43	0.122	0.050
	Herbicide	NA[1]	88	NA[1]	NA[1]	0.013
1988	Insect	6,760	4,507	1.50	0.830	0.553
	Manual	696[3]	286	2.43[3]	0.096[3]	0.039
	Herbicide	10	5	2.00	0.001	0.001
1989	Insect	2,239	1,419	1.58	0.275	0.174
	Manual	710	293	2.42	0.098	0.040
	Herbicide	10	8	1.25	0.001	0.001
1990	Insect	573	405	1.41	0.070	0.050
	Manual	174	93	1.87	0.024	0.013
	Herbicide	11	9	1.22	0.002	0.001
1991	Insect	5	5	1.00	0.001	0.001
	Manual	0	0	--	0.000	0.000
	Herbicide	0	0	--	0.000	0.000

[1] No data collected.
[2] Count and density underestimated (field data collected after treatment).
[3] No data collected; estimate based on average stem/plant ratio in 1987 and 1989.

RAGWORT GERMINATION

Ragwort germination and transplant trials were conducted to determine the viability of seeds soaked or submerged for various periods. For all treatments, 1-2 seeds germinated within the first 24 hours. All but one treatment (floating for 144 hours) required a minimum of 2 days to begin appreciable signs of germination. Most of the seeds germinated within 5-9 days regardless of treatment, and no seeds germinated after 12 days. None of the treatments showed any appreciable difference in the timing of seed germination.

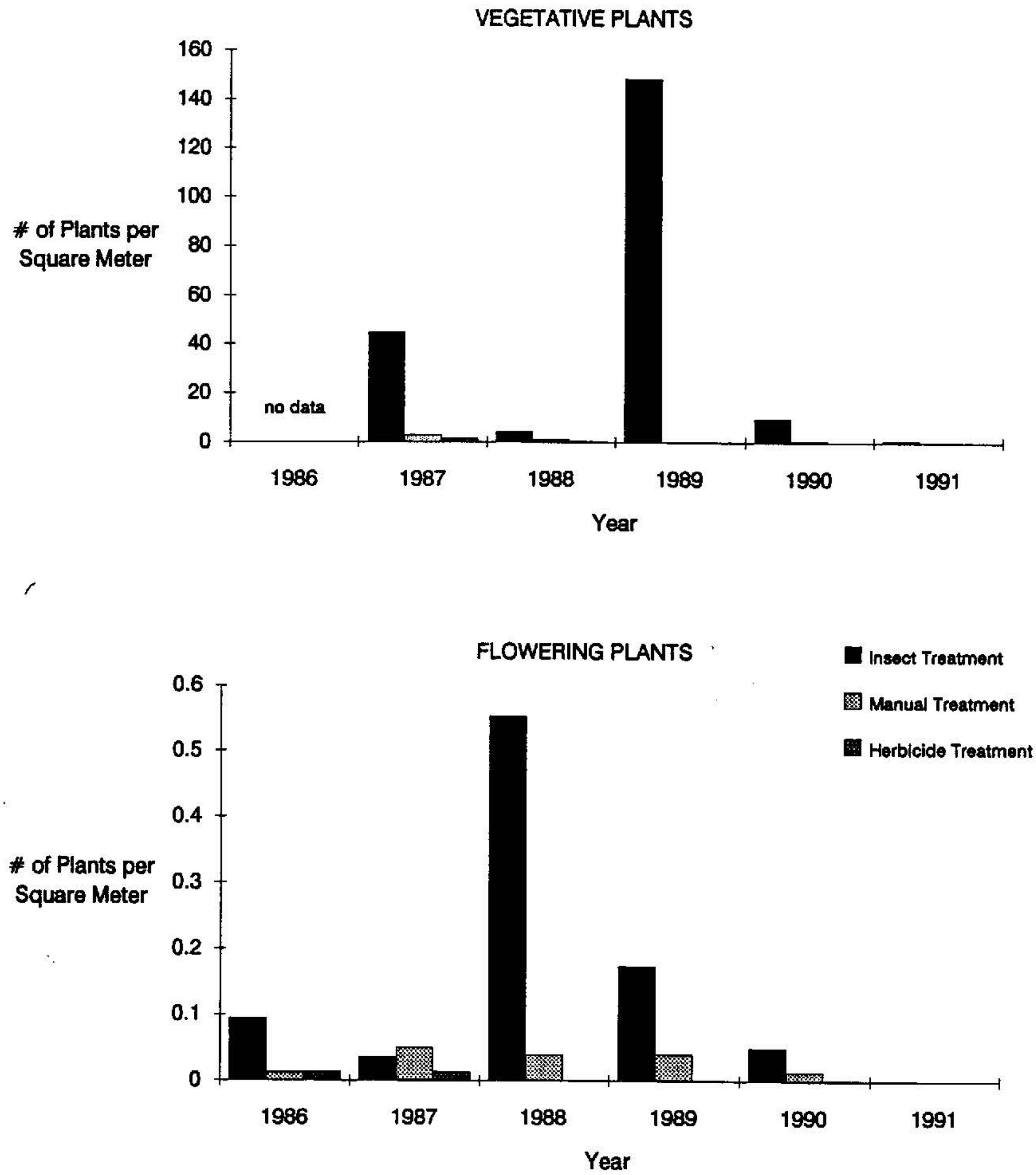


Figure 4.
Density of Tansy Ragwort
Vegetative and Flowering Plant
Stages in Study Area, 1986-1991

Viability of ragwort seed did not differ significantly among the control (54%), floating (52%), and submerged (55%) treatments. Germination of floating treatments ranged from a maximum of 66% at 6 hours to a low of 30% at 144 hours. Germination of submerged treatments was a maximum of 62% at 1, 6, and 24 hours and a low of 40% at 72 hours. There was a slight downward trend in seed germination with longer treatment periods (Figure 5).

Seedling transplant trials resulted in most seedlings dying within 2 weeks and no seedlings progressing beyond cotyledon stage.

INSECT ESTABLISHMENT

Between 1986 and 1988, we made 3 annual releases of 4,000-5,000 cinnabar moth larvae on the right-of-way. At the time the larvae were released in 1988, a small population of cinnabar moths had become established. Larval infestation and damage to tansy ragwort increased substantially during the next 2 years, and by 1991, 100% of the few remaining ragwort plants on the study area were damaged (Figure 6). Cinnabar larvae remained in highest densities within the insect treatment area, but gradually spread north and south along the right-of-way. By 1991, small numbers of caterpillars were found as far as 1 mile from the study area.

Flea beetle population growth in the study area was exponential, reaching a peak 4 years after the initial release (Figure 7). The combined capture rate for flea beetles in the insect treatment and hand-weeded areas increased from 1 beetle per minute in 1987 to 688 beetles per minute in 1990. In 1991 the combined capture rate dropped to 97 beetles per minute, probably due to the lack of tansy ragwort. During 1991 we found an established population of flea beetles on the right-of-way about 1 mile north of the study area. This group probably originated from our earlier releases of flea beetles on the right-of-way.

Observations of adult flea beetles during late fall floods in 1989 and 1990 suggested the possibility that flea beetles might be dispersed downstream by high water. We investigated the immersion tolerance of flea beetles by placing an adult beetle in a jar of water, shaking it up, and then setting the jar aside at room temperature for 24 hours. The next day the flea beetle was still floating and hopped away when we removed it from the jar. This observation confirms the hardiness of adult flea beetles and suggests that they could survive a trip downstream if they happened to land in the water.

The presence of ragwort seed fly in the study area was unexpected. Apparently this species immigrated naturally from other release sites, and probably had colonized only recently when discovered in 1986. Seed flies also appeared in British Columbia in 1986 after several years of apparently unsuccessful introductions (Wilkinson 1986 personal communication). Seed fly damage to tansy ragwort on the right-of-way was evident during all years of the study. In 1989 and 1990, respectively, 72% and 94% of flowering plants had damaged

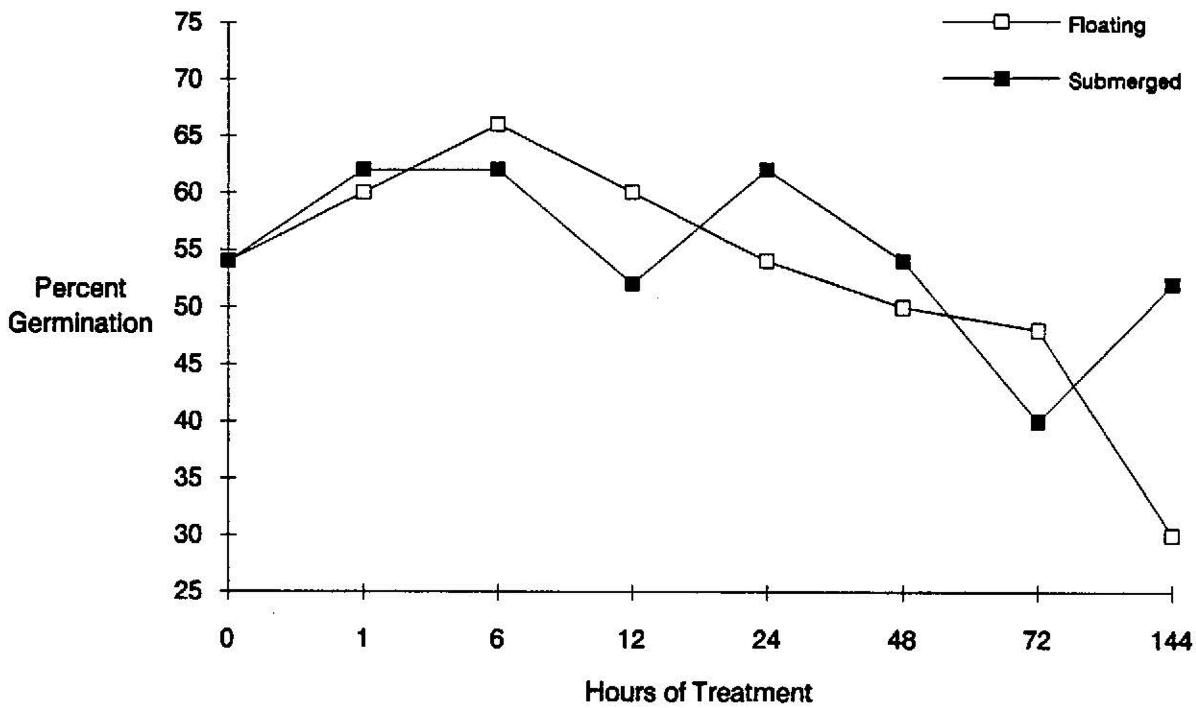
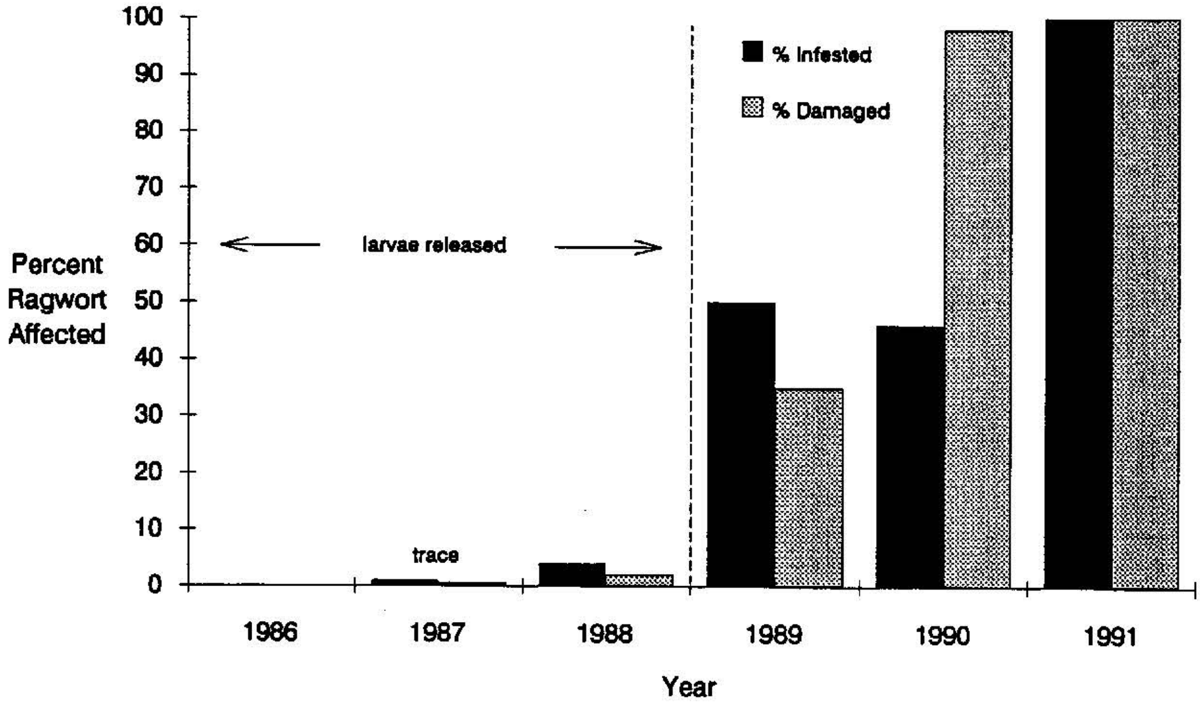


Figure 5.
Effects of Treatment and Time on
Tansy Ragwort Seed Germination



Note: the high ratio of insect damage to infestation in 1990 resulted from a late sampling date.

Figure 6.
Cinnabar Moth Infestation Levels and Damage to Tansy Ragwort in Study Area, 1986-1991

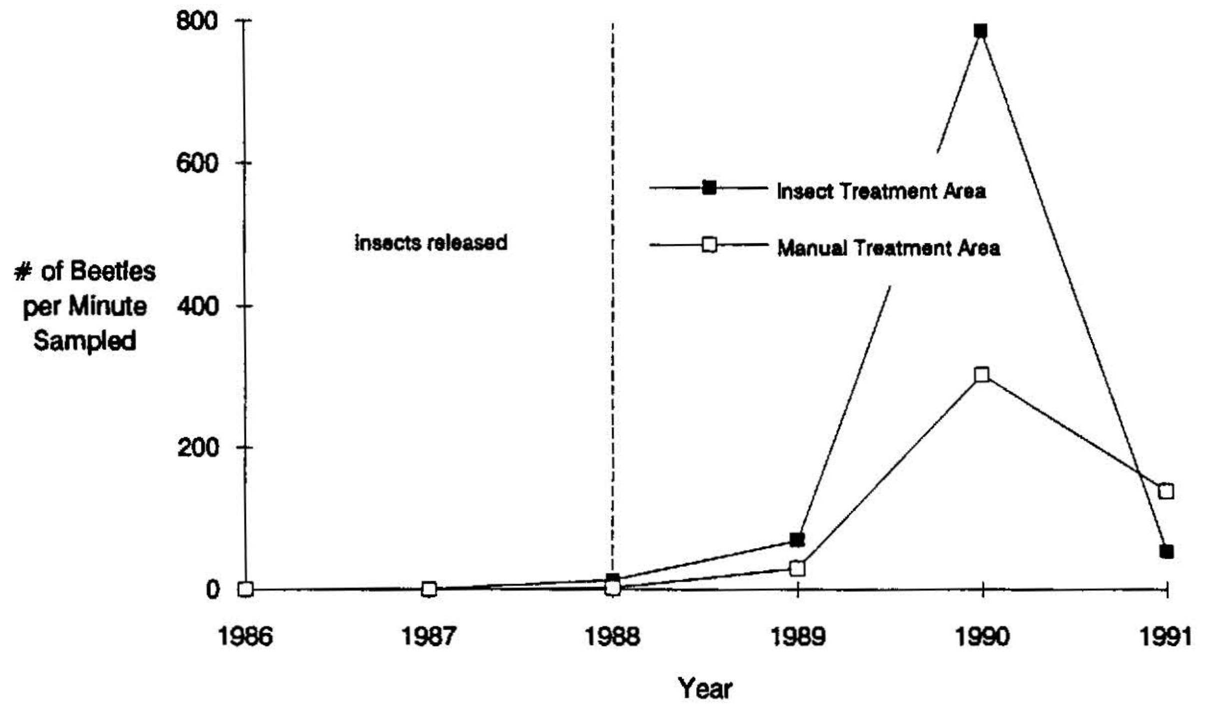


Figure 7.
Flea Beetle Population Trend in Tansy Ragwort Study Area, 1986-1991

seedheads, with most of the damage light to moderate. Damage levels were not quantified in other years.

ALTERNATIVE TREATMENTS

Cost Analysis

A comparison of treatment costs during 1986-1988 suggested that biological control was initially the most expensive of the 3 treatment methods. However, when treatment costs were adjusted for differing ragwort densities, herbicide and manual treatments were far more costly than biological control (Table 4). The higher overall set-up cost for biological control reflected the experimental nature of the project and the expense of establishing insect populations. Once the insects were established, biological control was essentially free.

Estimated treatment costs did not account for employee training, equipment, or potential liability due to worker sickness or injury. These costs are likely to be greater for herbicide and manual treatments than for biological control. Monitoring costs also were not included in these estimates, but are expected to be about the same for all treatments.

Mechanical Alternatives

The study of mechanical alternatives for controlling tansy ragwort concluded that manual removal can be effective on small, scattered populations (Appendix A). Larger infestations of ragwort require an integrated approach, such as a combination of biological and manual control. All methods require yearly monitoring for plant outbreaks, due to the resilient nature of ragwort and the longevity of its seeds.

DISCUSSION

RAGWORT DENSITY

Patterns of tansy ragwort abundance during the first 4 years of the study appeared to be determined largely by the seasonal presence of surface water, with added effects due to manual and herbicide treatments. Ragwort was noticeably associated with Beverly Creek and its tributary channels, and was most abundant within the insect treatment area where winter stream flows were highest and insects had not yet reached sufficient numbers to affect the ragwort population. Ragwort was considerably less dense within the manual treatment area, where stream flows were lower and flowering plants were pulled annually. Very little ragwort was present in the herbicide treatment area, which lacks any direct influence from the creek and where plants were sprayed annually. The association of tansy ragwort with Beverly Creek may have been largely a result of winter flooding, which

Table 4. Average annual cost comparisons of tansy ragwort treatments in study area, 1986-1988.

Treatment	Hours[1]	Rate[2]	Cost	Cost/Plant
<u>Insect</u>				
Flea Beetle			$275.00	
Labor	3.0	$56.00	168.00	
Travel	3.0	56.00	168.00	
Cinnabar Moth			$0.00	
Labor	6.0	$56.00	336.00	
Travel	6.0	56.00	336.00	
Total			**$1,283.00**	**$0.69**
<u>Manual</u>				
Labor	17.0	$28.00	$476.00	
Travel	8.5	28.00	238.00	
Total			**$714.00**	**$2.89**
<u>Herbicide</u>				
Labor	2.0	$28.00	$56.00	
Travel	5.5	28.00	154.00	
Chemical			2.00	
Total			**$212.00**	**$3.59**

1 Labor hours do not include annual employee training.
2 Hourly rate for manual and herbicide treatments was for City right-of-way maintenance crews. Hourly rate for insect treatment was consultant rate.

disturbed soils in and near the streambed and created seasonally high moisture levels favorable for germination.

By 1991, results of field surveys indicated that biological control of tansy ragwort was successful. Five years after first releasing cinnabar moth larvae and ragwort flea beetle adults in the study area, only 13 flowering ragwort plants were detected. Total number of flowering plants was reduced 99.5% compared to the initial (1986) population and 99.9% compared to the peak (1988) population. Density of vegetative plants (seedlings and rosettes) was reduced 86.8% compared to the initial (1987) density and 99.6% compared to the peak (1989) density. Flowering plants were increasingly damaged by grazing of cinnabar moth larvae, and vegetative plants were increasingly attacked by larval and adult flea beetles. As the insects spread throughout the study area, it became impossible to separate the effects of the other treatments from that of biological control. Manual and herbicide treatments were unnecessary in 1991 due to the marked reduction of tansy ragwort.

Results of insect introductions in our study paralleled survey findings of the Oregon Department of Agriculture at ragwort-infested sites in western Oregon (McEvoy et al. 1991). At 14 sites surveyed 6 years after flea beetle release, mean flowering plant density declined 93%. At 6 sites surveyed 10 years after beetle release, mean density of flowering plants in survey plots was zero, although occasional plants were observed near the plots. Median time at 20 sites to reach a target density of zero flowering plants was 5 years. The abundance of cinnabar moth and ragwort seed fly were not recorded in these surveys. However, it is likely that both species were present throughout the survey area since the moth had been extensively distributed prior to introductions of the flea beetle and the seed fly had dispersed throughout the state (McEvoy et al. 1991). Since tansy ragwort can quickly reoccupy disturbed habitats from its reservoir of buried seeds, it is vital that treatment effectiveness be assessed over the long term.

RAGWORT DISPERSAL

The occurrence of tansy ragwort at the mouth of Beverly Creek, and its distribution along the Sauk River, suggested that wintertime floods may have dispersed some ragwort seed downstream where it became established outside the study area. But it is also clear that other local seed sources contributed to the spread of ragwort. At least 10 tributaries enter the surveyed reach of the Sauk River, and several groups of ragwort plants were found along the Sauk River upstream of its confluence with Beverly Creek. The lack of ragwort seeds collected from Beverly Creek in the early December sampling probably resulted from the removal of most ungerminated seeds from the soil surface during earlier fall floods.

RAGWORT GERMINATION

Results of the tansy ragwort seed germination study indicated that seeds transported downstream from the study area would remain viable in water for at least 6 days. The viability of our seeds, collected late in the season, was within the range of 50-86% viability found in other studies (Cameron 1935, Poole and Cairns 1940). These other studies also noted that the majority of seeds germinated within 8 days of exposure to water.

Tansy ragwort seeds that are dispersed downstream must reach a suitable rooting medium before germination to become established. Cameron (1938) found that seeds sown on open soil and overgrazed pasture established much more readily than seeds sown in well-established vegetation. After germination, tansy ragwort seedlings did not readily establish even if they came in contact with soil (Poole and Cairns 1940).

Because ragwort seeds tend to germinate quickly when exposed to water, but do not establish readily following germination, seeds washed downstream from plants growing along Beverly Creek must reach a suitable site for germination within 2-3 days of entering the stream. Otherwise, the potential for establishment appears to be extremely low.

EFFECTIVENESS OF BIOLOGICAL CONTROL

The marked reduction of tansy ragwort on the study area, together with the increase in cinnabar moth and flea beetle populations and associated damage levels, is empirical evidence of biological suppression of ragwort. The flowering plant population in the insect treatment area declined in 1990 despite a proliferation of ragwort seedlings in 1989. By 1991, total flowering and vegetative plant densities in the study area were <1% and <14%, respectively, of previously measured lowest levels. The annual fluctuations in numbers of vegetative and flowering plants, typical of an invasive biennial species, ceased by 1990.

Root and foliar damage caused by the feeding of larval and adult flea beetles is believed to be the chief cause of ragwort mortality and lack of seedling establishment toward the end of the study. Only 4% of rosettes marked in spring 1990 survived through midsummer, and most of the surviving plants had damaged roots. The high concentration of flea beetles in 1990 and the sharp decline of seedling densities in 1991 suggest that many of the smaller plants were devoured by the flea beetles. Herbivory of flowering plants by cinnabar moth larvae was augmented by colonization of ragwort seed flies, which inhibited ragwort seed production.

Removal of cattle grazing may have enhanced the suppression of tansy ragwort by reducing soil disturbance and increasing the vigor of competing vegetation. However, without data on other plant species in the study area, and lacking untreated controls and the ability to exclude cinnabar moths and flea beetles from the manual and herbicide treatments, we could not determine the relative importance of insect herbivory vs. other environmental factors in the decline of tansy ragwort.

ALTERNATIVE TREATMENTS

The higher initial cost of biological control was more than offset by its lower cost per plant than either of the other treatments. This demonstrates one of the many advantages of biological control, i.e., its cost is independent of plant density. Manual and herbicide treatment costs, on the other hand, are density-dependent; the more plants there are in an area, the more time and expense required to control them. The greater overall cost of biological control resulted from the experimental nature of the project, the initial expense of establishing insect populations, and the lower density of ragwort in the other treatment areas.

Over the long term, biological control of tansy ragwort would be much cheaper than the alternative treatments. The only expected long-term cost would be for monitoring ragwort and insect populations, and, if necessary, periodically reintroducing insects. Manual and chemical control methods would require ongoing monitoring, as well as continued annual treatment costs and employee training. Results of this study, and the success of biological control in other areas, indicate that chemical and manual treatment of tansy ragwort on the SCL right-of-way may eventually become obsolete.

CONCLUSIONS

Results of insect introductions and alternative treatments of a tansy ragwort infestation on the SCL right-of-way indicate that biological control of ragwort has been highly successful. Ragwort flea beetle and cinnabar moth populations established within 2-3 years of initial releases and began exerting significant pressure on the ragwort population within 4-5 years. These effects were augmented by the ragwort seed fly and by removal of cattle grazing which may have enhanced competing vegetation. Manual and chemical treatments of ragwort were unnecessary in 1991 due to the lack of ragwort plants.

Establishment of the flea beetle and cinnabar moth on the right-of-way and the presence of the seed fly offer good long-term prospects for successful biological control. McEvoy et al. (1991) found a 99.9% reduction in ragwort during an 8-year period following introduction of natural insect enemies at a site on the Oregon coast. Similarly, a regional survey of sites throughout western Oregon recorded a 93% decline in ragwort abundance in 6 years, with plant density remaining at relatively low levels in subsequent years.

Many successful biological control systems are characterized by local extinctions and reinvasions of host plants and their natural enemies (Murdoch et al. 1985). Populations of cinnabar moth, flea beetle, and seed fly could conceivably disappear from the study area if the declining trend in ragwort continues. Ragwort's large, persistent seed bank provides a buffer against its natural insect enemies (McEvoy et al. 1991), and once the pressure of herbivory is removed, the ragwort population could quickly regenerate. It is important, therefore, that insect populations be well-distributed so they can respond to future outbreaks of the plant. Recent sightings of flea beetles and cinnabar moth larvae on parts of the right-of-way outside the study area indicate that populations are beginning to disperse and establish themselves successfully on other sites.

Lasting biological control of tansy ragwort on the SCL right-of-way will require maintenance of vigorous competing plant communities as well as continued monitoring of ragwort and insect populations. Reintroductions of flea beetles and cinnabar moths should be considered in areas where their populations appear to have dropped below levels capable of sustained biological control.

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APPENDIX A

MECHANICAL ALTERNATIVES FOR CONTROL OF TANSY RAGWORT

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Land Consulting

MECHANICAL ALTERNATIVES FOR CONTROL OF TANSY RAGWORT
(*Senecio jacobaea*)

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MECHANICAL ALTERNATIVES FOR CONTROL OF TANSY RAGWORT
(*Senecio jacobaea*)

INTRODUCTION

Manual or mechanical means of tansy ragwort control can be an effective management tool. Much of the information contained in this report comes not from the literature, which focuses on the more commonly used biological control, but from personal communications. Various alternatives and combinations of methods have been suggested by those working directly with control of this weedy biennial herbaceous species and are discussed in detail below. All experts contacted and literature sources reviewed emphasized the absolute necessity of yearly inventory and monitoring. It is stressed by all sources that mechanical or manual control success relies on preventing tansy populations from getting out of control. Any of the recommendations made at the end must therefore be understood to include allocation of manpower to inventory sites and make corrections as necessary.

ALTERNATIVES

A. Mowing

Mowing as a tool is not generally recommended by the experts contacted or in the literature. However, Dave Humphrey of Oregon State Department of Agriculture (OSDA) recommends that in some sites it may be preferable to remove the seed producers by using a motorized mowing machine. The next best alternative would be an annual mowing one or two times a year if it is a heavy stand (Humphrey, pers. comm.)

Bill Rogers, Lincoln County (Oregon) Extension Agent, feels that mowing can help in emergency situations (Rogers, pers. comm.). This might be applied to roadside situations where mowing machines can reach to control the spread of stands from the roadside to pasture areas. However, Larry Burrill, Oregon State Extension Agent, disagrees. Burrill has observed that mowing turns tansy essentially into a perennial. In good growing conditions, tansy generally completes its life cycle within two years. However, if damaged, for example by mowing, or in poor growing conditions, tansy can adopt a perennial habit. Once mowing is started it must be done constantly "like turf management" (Burrill, pers. comm.).

Mowing is reported as not effective in reducing tansy populations (Beddell 1981) since it is virtually impossible to achieve perfect timing on clipping the seed heads. Mowing can actually increase rosette density, although it may prevent flowering (MacDonald 1983). One of the drawbacks of mowing is that it is necessary to repeat mowings in order to prevent flowering. It is also ineffective for control of germination of plants from the seed bank and those moving in from other areas.

A combination of mowing and hand pulling might be appropriate in certain situations where the mowing would reduce seed set and early reproduction, and the more time intensive hand removal could take place once a year for actual plant removal.

B. Grazing

Several workers recommended grazing of goats and sheep as an alternative control method. Beddell reports that continuous sheep grazing will remove tansy and keep it out (Beddell 1981). Sharrow reports that "sheep can reduce tansy to acceptable levels" (Sharrow 1980). Sheep worked quite well to control tansy on Forest Service land in the Oregon Coast Range. Dave Humphrey, OSDA, also reports good results with sheep and goat grazing tansy in his area (Humphrey, pers. comm.). The sheep apparently do not respond to the toxicity of the alkaloids in the plants in the same manner as horses and cows.

Grazing by sheep must be continued for at least three years to keep third year plants from flowering. Both sheep and goats could be used to rid pastureland of tansy before reintroduction of horses and cows into a pasture, however, this must be done carefully as increased disturbance brought about by overgrazing of sheep and goats may provide additional disturbed areas where tansy can reinvade.

C. Seed Head Clipping

Some experts preferred the alternative of clipping tansy seed heads for short term control of reproduction. Dave Pickering, an organic farmer in Lincoln County, Oregon, suggests that each seed head be clipped and placed in a garbage bag. These should be disposed of in a land fill or burned. Whatever method of disposal is used, it is of tantamount importance especially to the small landowner, to destroy the flowering head (Pickering, pers. comm.).

Phil Mooney, Biologist with the Range Management Team, U.S. Forest Service, suggests that optimum timing for clipping seed heads is critical--so the plant will not reflower later in the season. In his experience the first week of July is a critical time for priority areas. Clipping must be accomplished by July 20th (Mooney, pers. comm.). Depending on site characteristics, exposure, and local microclimate conditions, critical clipping time for sites in Washington may differ.

D. Manual Removal

Results are mixed on the effectiveness of hand removal. One of the problems with hand removal is enabling those participating in removal to identify the plant before it flowers. Because some of the manual removal programs depend on convict or untrained manual laborers, it is difficult to ensure proper identification without the presence of the flowering stalk. This leads to conflicting recommendations from the experts. Those working with trained personnel recommend removal before the plant flowers. Those working with untrained workers must depend heavily on the easy identification of the flowering stalks for effective removal efforts. Removal of the plant before it flowers obviously prevents any sexual reproduction from occurring, however, effectiveness of the removal program is impaired if tansy plants are not identifiable to workers, and are left to flower after crews move to other areas.

Cathy MacDonald, Ecologist with The Nature Conservancy advises hand pulling only after populations have been controlled. However, she does recommend hand pulling for spot control. Effectiveness of hand removal can be increased if soils are moist at the time of removal. The moisture allows plants to be removed with minimal breakage, reducing the possibility of resprouting from root fragments (MacDonald 1983).

Work done by Beddell, Whitesides and Hawkes shows that hand pulling can be effective. However, they stress that hand pulling "requires persistence and intensive effort and it is most applicable to spot infestations." Regrowth, however, frequently occurs from root fragments left in the soil (Beddell et al 1981).

Mark Musick in an article in "Tilth", echoes other researchers in recommending that the entire tansy plant must be dug up before it can set seed to control reproduction, and to extirpate that particular population. He reports that this is being done in the localized infestations along mountain passes to eastern Oregon to stop the spread of tansy eastward. (Musick 1980)

Craft, in an OSDA Bulletin on the control of tansy, reports that hand pulling is not the most acceptable or effective method of ragwort control. He does say, however, that if chemicals cannot be used, "hand pulling can be used to prevent the plants from going to seed and spreading to nearby uninfested areas" (Craft 1979). He does not comment on whether hand pulling activities induce the perennial habit in tansy.

Elton Moffitt, Weed Control Agent for Lincoln County, Oregon feels that "pulling is not effective for large stands but will help for scattered plants." He stresses that the plants must be removed before they start to bloom and that infested areas must be checked two or three times during the summer season.

Moffitt's recommendations included the July 1st start time for hand pulling. Workers should wear heavy gloves and pull tansy when it is three to four feet tall. Larry Burrill, OSU Extension Service, reports that pulling is good "in theory" if it can be done when the soil is damp and one can get the roots. He also stresses that timing is critical and pulling should be done before it flowers. (Burrill, pers. comm.)

School of Agriculture (OSU) researcher and weed scientist, Bill Brewster comments that, "the problem is that if you pull it, you must keep repeating it. Tansy can come back in into the area you have hoed or pulled." He adds, "the question is, is it a reinvasion or resprouting or what? Pulling works for one year but you must repeat it." (Brewster, pers. comm.)

Phil Mooney, (USFS) relates that in the past, Youth Conservation Corps or prison crews were used to manually pull tansy. He also reinforces that the July 1st date is critical for pulling. Crews work as teams in which one clips and bags the heads and another person follows and pulls the plant. He also recommends the use of a shovel or planting bar (3-4 foot long bar used to plant trees; see Figure 1) as the tool to use if it is necessary to dig the plant.

Mooney emphasizes that it is absolutely mandatory to check the site two times during the summer season. He recommends that workers pin flags on the perimeter of known infestation areas and come back to recheck for later germinating and flowering plants.

Dave Humphrey (OSDA) was most specific that manual control could be effective. Humphrey recommends use of a regular garden hoe to chop the tansy plant out if the ground is too hard to easily pull the roots out. If the ground is still moist, he said that the plant can be pulled. The recommended method of removal depends on the requirements of the site and time of pulling. It is his recommendation to use 5 people per 10 foot wide area to remove the plants. He also emphasizes that you "must remove it just before it sets seed" to prevent reproduction.

There are several drawbacks to the use of manual methods exclusively for tansy control. One is the level of effort and the number of people required to do the field work. Another is that this must be repeated annually until the infestations are controlled, and subsequently monitored for a long period of time.

The third drawback concerns the potential for workers involved in control efforts to injure their backs due to the nature of the work. This can be minimized through proper use of the tools available, and through screening participants that are assigned to this type of work (Anderson 1980).

Because the epidemiology of back pain is "an embarrassing array of possibly significant associations" (Wood and Bradley 1980), it is impossible to design a tool for the specific task of digging tansy to avoid back injuries. Back injuries are so various as to prevent a specific design from addressing all possible problems that could be encountered.

However, Roy Lebsack, Training Coordinator in the Loss Control Services with the Workmen's Compensation System, Washington Department of Labor and Industries, makes some general recommendations regarding this type of problem (Lebsack, pers. comm.).

* Keep manual materials handling at a minimum, and for those tasks that need manual work, make the work convenient for people.

* Organize the work site for convenience. Provide workers with tools they prefer and that are appropriate for the site and task to be performed.

* Provide a type of tool, or way of manual removal that minimizes the time a worker is bent over. This could include long handled tools included in Figures 1 and 2 and avoidance of pulling the plant without the aid of a tool.

* Give the worker a chance to vary movement patterns; for example, a team of tansy controllers could revolve jobs through the day in order introduce variety of movements.

* Provide a warm-up at the beginning of the day, after break times, and a cool-down at the end of the day before sitting in the truck.

* Provide supervisors with training for recognition of early back distress while on the site.

There is already available a wide array of tools such as shovels, planting bars, tile spades, garden and planting hoes, and one-pronged weeding hoes that one can chose from to work with the specific body needs and field conditions. Sufferers of back pain are advised to use tools that allow the task to be done with comfort. It appears that there is sufficient choice and successful use of these various tools proven for this task, and that restriction to a new tool design would not take advantage of the variety of tools already proven appropriate. Line drawings of several types of tools are included at the end of this report in Figures 1 and 2. Lebsack also recommends the retention of a kinesiologist to analyze the tasks being performed to make specific recommendations for avoidance of back injury (Lebsack, pers. comm.).

COMBINATION EFFORTS

Mooney's experience is that with a combination of biological and manual techniques, tansy can be controlled in approximately six years. But he stressed that even with 95% control, yearly checks and inventories are vital (Mooney, pers. comm.). The Lincoln County (Oregon) program stresses a combination of methods that include pulling and introduction of the flea beetle. This integrated approach, he feels, has resulted in a 90% containment of tansy in Lincoln County. Moffitt also states that, in his opinion, this was the most economical way of controlling tansy (Moffitt, pers. comm.).

Carolyn Cox, a researcher working on tansy control in the Department of Entomology at Oregon State University reports that "joint effects are dramatic." She states that since biological controls take two to three years to show an effect, combining manual reduction (pulling) with biological controls can speed up the control time. However, "the agency must examine the cost of shortening the lag period. The decision must be made -- is the time period worth the extra dollars?" (Cox, pers. comm.)

Cox also states that long term research has not been done on manual control of tansy. In her article in the Journal of Pesticide Reform she argues for a minimum two year trial period for manual control. Costs might be higher for the annual control efforts needed for manual control of tansy, but in small acreage areas it may be the preferred alternative (Cox 1986). She also stresses the necessity of getting competitive plants established (Cox, pers. comm.)

Humphrey suggests that rototilling the area or scarifying the area might help if grass seed is broadcast on the area to gain competitive planting. Humphrey stated that native grasses or other introduced species would be best. Humphrey added, "Tansy is not a strong competitor. You must get other ground covers established." He also stressed that for long term controls having biological agents present was important. But he emphasized that establishing competitive plantings was also vital. He recommends that until the area is controlled, it should be checked and individual plants removed manually. "It's also important to train the employees so they recognize it and can get rid of it. The lineman, maintenance workers--everyone should know tansy and help remove it" (Humphrey, pers. comm.)

Humphrey also feels the absolute necessity for a written management program. He has come to the conclusion from his experience with the problem, that removal by rototilling or grubbing (digging), introducing biological controls and planting a competitive ground cover should solve any tansy problem (Humphrey, pers. comm.).

CONCLUSIONS/RECOMMENDATIONS

Most experts feel that a combination approach is the best procedure to control tansy. Manual/mechanical means are definitely one of the methods that can be effectively utilized in a combination approach. There are, however, drawbacks to some of the means for mechanically removing tansy.

Mowing is not generally recommended for control, except as an emergency measure. Grazing of sheep and goats has been used successfully, but it is very important to avoid overgrazing an area and disturbing the soil to prevent reinvasion of tansy. Seed head clipping is viewed as a short term control of reproduction, but provides no long term eradication benefits. Finally, a program of manual removal has been shown to be very effective in a program of control and eradication.

There are serious drawbacks, however, to use of manual control exclusively. One of the more serious problems of manual control is the necessity to constantly monitor and repeat the treatment. Also, the cost of hand labor and the potential for on-the-job injury is high.

It appears that manual removal could be an effective method in the control program for tansy along Seattle City Light Utility Corridors. Manual removal, however, is most effective in conjunction with insect infestation and competitive planting methods. A combination program appears to provide a viable alternative to the use of herbicides along Seattle City Light corridors.

As all of those active in the field emphasized, the program, no matter what it includes, requires serious commitment to extensive monitoring of infestations over the summer period, and on an annual basis. An annual budget that enables the program director to treat new infestations and reinvasions of tansy is also very important to an effective control and eradication program.

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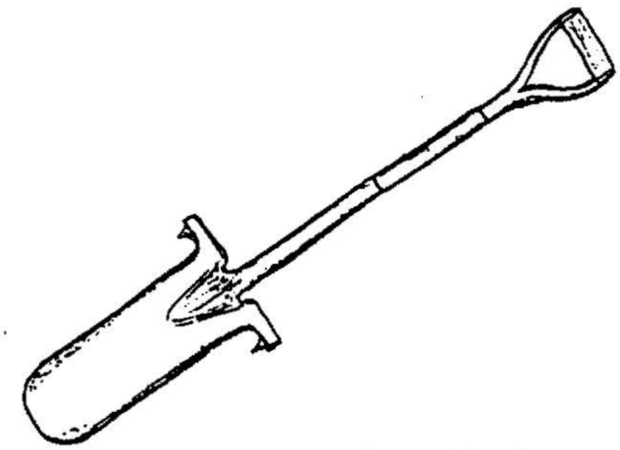
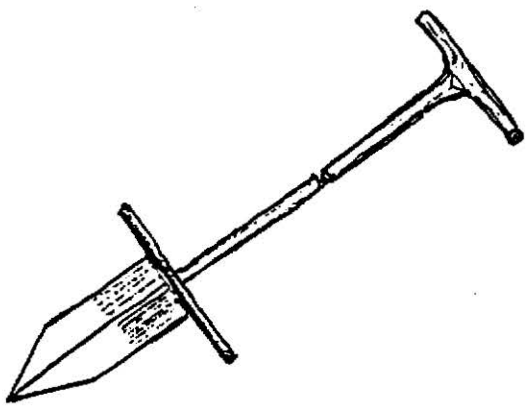
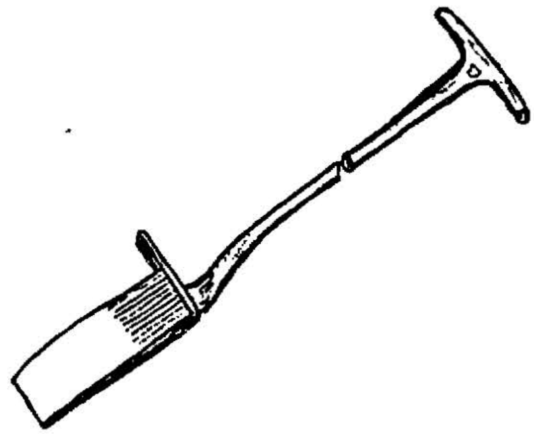


TILE SPADE PLANTING SHOVEL



PLANTING BAR (KCB BAR)



DIBBLE BAR

FIGURE 1

Spade-type tools

B-twelve Associates
527 South Washington Ave. • Kent, WA 98032

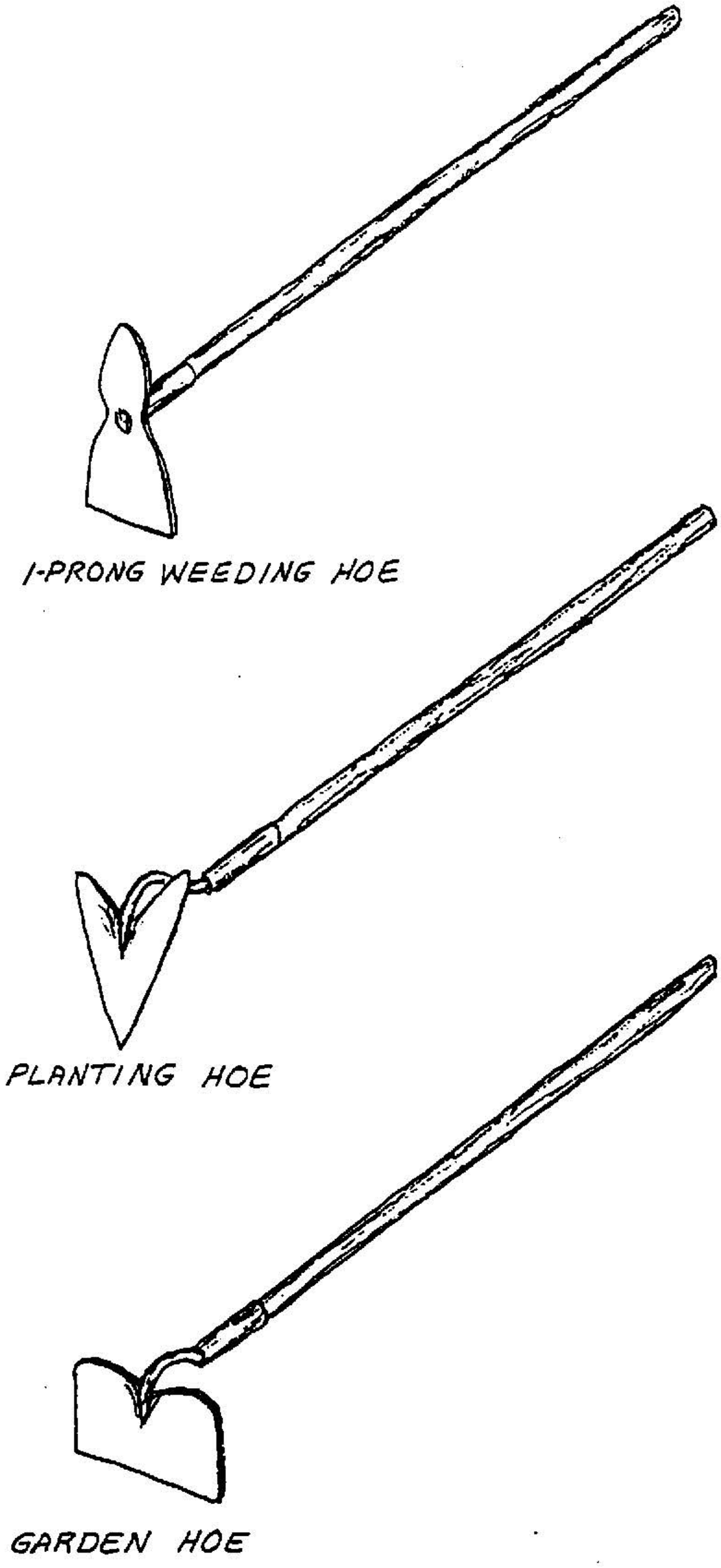


FIGURE 2

Hoe-type tools

B-twelve Associates
527 South Washington Ave. • Kent, WA 98032

APPENDIX B

SOURCES AND PROCEDURES FOR COLLECTING AND RELEASING CINNABAR MOTHS AND RAGWORT FLEA BEETLES

SOURCES AND PROCEDURES FOR COLLECTING AND RELEASING CINNABAR MOTHS AND RAGWORT FLEA BEETLES

SOURCES OF INSECTS

<u>Cinnabar Moth</u>

Mr. Rick Johnson
Noxious Weed Control Supervisor
Thurston County Noxious Weed Control Office
3054 Carpenter Road SE
Olympia, WA 98503

1-800-624-1234

<u>Ragwort Flea Beetle</u>

Mr. Eric Coombs
Biological Control Entomologist
Oregon Department of Agriculture
635 Capitol Street NE
Salem, OR 97310

(503) 378-4987

FEDERAL APPROVAL PROCESS

Insects being considered for importation to the United States to control exotic weeds must undergo an extensive scientific review including an overseas and domestic testing program. Administered by the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA APHIS), this program is carried out to ensure that introduced insects damage only the target plant species and do not pose a risk to other vegetation, including native plants, food crops, and ornamentals. Candidate insects are reared for several generations under laboratory conditions with a variety of likely host plants to study insect life cycles and the potential for successful reproduction and feeding on nontarget plant species. Testing can take up to 10 years (Brown 1992 personal communication).

Once an insect species has been judged safe and effective, the USDA may authorize its introduction into the United States. Prior to importation, individual shipments of insects are quarantined and monitored for parasites and diseases. Environmental assessments are prepared for new species being released onto federal lands, and landowner permission is required for insect releases onto private property. USDA works with the states to monitor insect survival and plant responses to the initial insect introductions. Further control efforts may be undertaken by the states in cooperation with the counties, landowners, and USDA.

Host plant specificity studies were conducted on the cinnabar moth and ragwort flea beetle during the 1950's and 1960's, respectively. Both species were initially released in the United States at Fort Bragg, California (Frick and Holloway 1964, Frick and Johnson 1973). Subsequent releases were made in Oregon, Washington, and British Columbia.

COLLECTION AND RELEASE PROCEDURES

Cinnabar Moth

Cinnabar moth larvae released in this study were collected from ragwort-infested commercial forest land near Olympia and along Seattle City Light's transmission right-of-way near Cedar Falls. Both sites are in western Washington. Collections near Olympia were coordinated by the Thurston County Noxious Weed Control Office with permission of the landowner. Caterpillars were collected by Parametrix investigators during early to mid-July when a variety of ages and sizes were available.

Larvae were gathered by gently shaking them off flowering ragwort plants into paper grocery bags. Care must be taken not to handle the larvae, as they may be harmed by oils from human hands. For smaller caterpillars it was usually easiest to clip the ragwort plant and place it in the bag with the larvae still attached. Placing ragwort foliage and flowers in the bag also provided the larvae with food during their trip to the release site. When the bottom of the bag was covered with larvae (numbering about 1,000) the bag was folded and stapled at the top.

Whenever possible, larvae were released on the same day they were collected. Otherwise the bags were placed in coolers and kept overnight for release the next day. Larvae were freed by inverting the bags over groups of flowering ragwort plants and dumping out the contents directly onto the plants. Foliage with larvae was also placed by hand on the flowering plants. Larvae that fell off were able to crawl back onto the plants and begin feeding. Preferred release sites were slightly elevated or had logs and stumps nearby to provide dry habitat for overwintering pupae. Cinnabar moth larvae should not be released in areas subject to flooding or trampling by cattle.

Ragwort Flea Beetle

Adult flea beetles were supplied by the Oregon Department of Agriculture. Beetles were collected in October when they were breeding and most active, using a D-Vac backpack vacuum insect collector. Beetles were placed in large paper cups (approximately 500 beetles per cup) ventilated with tiny holes in the lids. Ragwort foliage was placed in the cups as food for the beetles during shipment. Beetles were shipped overnight in cardboard cartons and were released in the study area within 24-72 hours of collection. Beetles should be released as soon as possible to minimize stress and enhance their survival. Releases were made by inverting the cups and dumping out the contents into areas of high tansy ragwort rosette and seedling concentrations. Usually two or three cups were dumped together to facilitate mating of the adult beetles.

Due to the widespread success of biological control of tansy ragwort in Oregon, good collecting sites for flea beetles have become scarce in recent years (Coombs 1992 personal communication). The Oregon Department of Agriculture recommended that Seattle City Light investigate local areas along the Skagit transmission right-of-way as a possible source of flea beetles before purchasing the insects from out of state.