Quantifying tansy ragwort (Senecio jacobaea) population dynamics and recruitment in northwestern Montana

by Meghan Ann Trainor

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Resources and Environmental Sciences
Montana State University

Abstract:
The weed tansy ragwort (Senecio jacobaea) attained noxious weed status after colonizing areas burned in northwestern Montana after a 1994 wildfire. Therefore, it was important to develop a preliminary understanding of the biotic and abiotic factors that influence tansy ragwort colonization and population dynamics in burned and unburned areas. A field experiment was designed to parameterize a transition matrix model to evaluate the effects of four different environments on dynamics of tansy ragwort in northwestern Montana including areas: 1) burned and salvage-logged, 2) burned, 3) undisturbed forest, and 4) undisturbed meadow. Based upon results from the first two years, tansy ragwort was increasing (invasive) in the burned and salvage-logged and the burned environments (&lamba;> 1.0). In the forest, the population growth rate was nearly stable (&lamba; = 1.0) and in the meadow the growth rate was less than one, indicating a decreasing population (&lamba;< 1.0). Elasticity analysis determined that the over-winter survival of rosettes is the most important demographic process to tansy ragwort population growth.

A greenhouse experiment was also conducted to address the subject of tansy ragwort seedling emergence in response to environments associated with fire (litter, burned litter, bare soil, heated bare soil). Tansy ragwort emergence rates were higher in litter-covered soil, burned, or unburned environments versus bare soil or heated bare soil environments. The results may parallel previous findings that tansy ragwort emerges and establishes faster in environments with higher N levels, relative air humidity, small oscillations in soil temperature, and more light. The findings do not fully explain the observation that tansy ragwort densities are higher following wildfire or are often present where slash bums occurred.

A thermal gradient plate experiment was also conducted to determine the optimum and range of temperatures where tansy ragwort seed can germinate. Results show that Montana tansy ragwort seeds respond similarly to temperature as the seeds from western Washington and The Netherlands. The lack of difference in germination response to temperature across different geographic populations raises the question of whether genotypic variability and phenotypic plasticity are factors in the success of tansy ragwort as an introduced species.

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date 30 May 2003

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ABSTRACT

The weed tansy ragwort (*Senecio jacobaea*) attained noxious weed status after colonizing areas burned in northwestern Montana after a 1994 wildfire. Therefore, it was important to develop a preliminary understanding of the biotic and abiotic factors that influence tansy ragwort colonization and population dynamics in burned and unburned areas. A field experiment was designed to parameterize a transition matrix model to evaluate the effects of four different environments on dynamics of tansy ragwort in northwestern Montana including areas: 1) burned and salvage-logged, 2) burned, 3) undisturbed forest, and 4) undisturbed meadow. Based upon results from the first two years, tansy ragwort was increasing (invasive) in the burned and salvage-logged and the burned environments ($\lambda > 1.0$). In the forest, the population growth rate was nearly stable ($\lambda = 1.0$) and in the meadow the growth rate was less than one, indicating a decreasing population ($\lambda < 1.0$). Elasticity analysis determined that the over-winter survival of rosettes is the most important demographic process to tansy ragwort population growth.

A greenhouse experiment was also conducted to address the subject of tansy ragwort seedling emergence in response to environments associated with fire (litter, burned litter, bare soil, heated bare soil). Tansy ragwort emergence rates were higher in litter-covered soil, burned, or unburned environments versus bare soil or heated bare soil environments. The results may parallel previous findings that tansy ragwort emerges and establishes faster in environments with higher N levels, relative air humidity, small oscillations in soil temperature, and more light. The findings do not fully explain the observation that tansy ragwort densities are higher following wildfire or are often present where slash burns occurred.

A thermal gradient plate experiment was also conducted to determine the optimum and range of temperatures where tansy ragwort seed can germinate. Results show that Montana tansy ragwort seeds respond similarly to temperature as the seeds from western Washington and The Netherlands. The lack of difference in germination response to temperature across different geographic populations raises the question of whether genotypic variability and phenotypic plasticity are factors in the success of tansy ragwort as an introduced species.

REVIEW OF LITERATURE

Introduction

Tansy ragwort (*Senecio jacobaea* L., Asteraceae) is an introduced, herbaceous plant that has invaded and established in areas of North America, including northwestern Montana. It colonizes disturbed habitats most frequently including pastures, clearcuts, and along roadsides. This first chapter describes the origin and distribution of tansy ragwort as well as a biological description of the species and its response to various types of management. A discussion of transition matrix models and population viability analysis concludes Chapter 1. Chapter 2 describes a field experiment I conducted in which a life history model was developed for tansy ragwort in northwestern Montana. The methodology for collecting data used as input by the model, and the technique of using a population viability analysis in invasive plant ecology is detailed. Results presented demonstrate how the population growth rate (λ) of tansy ragwort differs across environments. Results presented also demonstrate the sensitivity of population size to small changes in the elements of the model, identifying vulnerable life stages in the life cycle of tansy ragwort that may be targeted to encourage population decline under an ecologically based weed management strategy. Chapter 3 describes a greenhouse experiment designed to answer questions not answered by the field study. Measurements are reported on how tansy ragwort responded to different soil surface environments associated with fire. Finally, Chapter 4 describes a temperature gradient plate experiment designed to determine the optimum and range of temperatures where tansy ragwort seed collected in Montana can germinate.

Senecio jacobaea

Origin and Distribution

Tansy ragwort was first recorded in North America in eastern Canada around Pictou, Nova Scotia in the 1850's, most likely disseminated in ships' discharged ballast (Harris et al. 1971). Tansy ragwort is native to Europe, Asia and Siberia and is generally found in meadows in oak and conifer woodlands, livestock pastures, and roadsides (Coombs et al. 1997b). Tansy ragwort's native range extends as far north as Norway and south into Romania, Hungary, and Bulgaria (Harper and Wood 1957). It is considered rare in both the north and south extremes of its range. Tansy ragwort has been introduced into Australia, New Zealand, South Africa, South America, and North America.

Tansy ragwort is a problem on both the east and west coast of North America, in the maritime regions and particularly in Oregon. In the east, tansy ragwort is found in Newfoundland and New England and in the west from Southern British Columbia to Northern California (Bain 1991). The weed was first recorded in western North America in 1913 from Vancouver Island (Harris et al. 1971). Tansy ragwort was first recorded in Oregon in 1922 from Portland (McEvoy and Rudd 1993). In the Pacific Northwest, tansy ragwort is found from the upper beaches along the Pacific Ocean up to the 900 m level in the Cascade Mountains. The largest infestations occur west of the Cascade Mountains, but tansy ragwort is also found east of the Cascade Mountains in areas previously considered inhospitable to its establishment. In areas east of the Cascades, tansy ragwort is generally found at disturbed sites in mountains where precipitation exceeds 40 to 51 cm per year (Coombs et al. 1997b).

Tansy ragwort was first recorded in Idaho in 1987 (Burrill et al. 1994). In 1990, tansy ragwort was first reported in Western Montana (Markin 2001). Contaminated straw and hay have been principal carriers of tansy ragwort seeds. It is speculated by some land managers that logging equipment has transported tansy ragwort seeds, as well. Open areas, south-facing slopes and disturbed areas appear to be the most vulnerable to invasion. In the western United States, Douglas fir (*Pseudotsuga menzeizii*) habitat types are a potential tansy ragwort habitat (Coombs et al. 1997b) (Figure 1) .

Figure 1. Map of northwest region of North America. Shaded areas indicate counties (U.S.) or regional districts (B.C.) in which tansy ragwort has been reported.

Morphology

Tansy ragwort is herbaceous, growing 0.3 - 2 m tall, and is usually regarded as a biennial, overwintering either as seeds or rosettes. However, it is capable of perennating from the rootstock or caudex and so may behave as a true perennial (Forbes 1977). Tansy ragwort becomes more glabrate with age, arising from a tap root. The stems are described as strict, erect, and arising singly or in clusters from an erect caudex, branching only in the inflorescence. Leaves are alternate, becoming smaller in size upward, broadly ovate to ovate, deeply bi- or tripinnatifid, 7 – 20 cm long, 2 – 6 cm wide. The lower leaves are often petiolate and early deciduous, with middle and upper leaves subsessile and weakly clasping.

The inflorescence is broadly corymbiform and cymose with 20 – 60 heads. Heads are usually radiate, discs 7 – 10 mm wide, with 13, 3 - 4 mm long dark-tipped involucral bracts. The female ray florets number 13. Disc florets are numerous and perfect. The achenes of the ray florets are glabrous, while those of disc florets are pubescent along prominent ribs (Bain 1991).

Senecio jacobaea is easily distinguished from other *Senecio* species in North America by its comparatively large size and highly dissected leaves. It most closely resembles *S. eremophilus* (Richards), but is clearly identified by the pattern of leaf dissection. The leaves of *S. eremophilus* taper to a point and are once-parted, whereas those of *S. jacobaea* are rounded and 2 – 3 parted (Frankton and Mulligan 1987). *Senecio jacobaea* is also often confused with common tansy (*Tanacetum vulgare* L.), most likely due to the similarity in their common names. The two plants are similar in height and leaf characteristics, but can be differentiated by *T. vulgare's* discoid heads, phyllaries with dark margins, and strong odor.

Seed Biology and Fecundity

Tansy ragwort's high rate of seed production and development of two different forms of achenes contribute to this species' success as a weed. Also, the ability of both the root and the caudex to regenerate allows for vegetative reproduction, especially after disturbance.

Seeds of tansy ragwort do not show evidence of innate dormancy (Baker-Kratz and Maguire 1984), however, vegetation cover in the field may inhibit germination and dormancy may be induced by frost or drought (Meijden and Waals-Kooi 1979)or by burial (Thompson and Makepeace 1983). Meijden and Waals-Kooi (1979) observed that flowering is in part controlled by the attainment of a minimum rosette size with the probability of flowering positively correlated with rosette size.

Numerous insects visit the flower, mainly from the families of Hymenoptera and Diptera (Harper and Wood 1957). The flowers produce nectar and give off a faint odor. No conclusions have been drawn on the degree of self-compatibility.

Much variability exists among localities with regard to number of capitula and seeds (achenes) produced per plant (Wardle 1987). At their study site in New Zealand, Poole and Cairns (1940) reported that 1000 – 2500 capitula/ plant were produced per season and that each capitulum contained 55 seeds (achenes). In the U.K., Cameron (1935) found that individual plants produced between 68 and 2489 capitula and 70 seeds per capitulum. Thompson (1980) found that seed production reached 15,000 – 25,000 seeds m $^{-2}$ in peak years in New Zealand.

Dispersal

The flowering head opens when the expanding disc florets exert pressure on the involucral bracts. One may expect that tansy ragwort would be wind dispersed because the achenes have a pappus. However, Wardle (1987) concluded that it was a poor wind disperser. It was estimated that only 0.5% of the seeds produced were actually wind borne. Of the seeds released, 60% traveled only a few meters downwind (Poole and Cairns 1940). Seeds are dispersed via water or spread by livestock, either through ingestion or by being carried in the mud adhering to hooves (Schmidl 1972). Viable seed have been found in bird droppings (Bain 1991).

Each type of achene is adapted for a different habitat and mode of dispersal (McEvoy 1984b). The central disc achenes retain the pappus, have trichomes, and are lighter and more numerous than the peripheral ray achenes, which do not have a dispersal structure at maturity. McEvoy (1984b) suggested that tansy ragwort uses two separate strategies for colonization: 1) open disturbed habitats over a wide area, but including the home site, are colonized by disc achenes and 2) nearby, closed habitats may eventually be colonized by ray achenes.

Germination and Establishment

On the Oregon coast, tansy ragwort seeds mature in late summer and early fall. Maximum germination occurs relatively quickly at 18 and 21 days after flowering for peripheral and central achenes, respectively (Baker-Kratz and Maguire 1984). There are two peaks of germination: fall and spring. However, some germination occurs year round (Harper and Wood 1957). The results of numerous studies unanimously agree that the viability of tansy ragwort seeds is high. Germination rates between 80 and 90% were achieved when seeds were subjected to alternating 12 h day/night periods with day/night temperatures of 30°/25° C and 60% germination rates for seeds produced by late flowering individuals (Schmidl 1972). Baker-Kratz and Maguire (1984) observed similar results overall in Washington. Wardle and Rahman (1987) found that achenes with the flower parts either abscised or removed were more viable than those with the perianth still attached.

Ideal germination temperatures are between 5 and 30° C (Meijden and Waals-Kooi 1979). Germination patterns were strongly correlated with variations in humidity at the soil surface, where desiccation of the soil inhibits germination (Sheldon 1974). Disturbance which brings seeds closer to the soil surface may break dormancy induced by burial. Both Meijden and Waals-Kooi (1979) and Poole and Cairns (1940) recorded higher germination rates among seeds buried 1 – 2 cm below the surface when compared with both those buried deeper and those on the soil surface. Thompson and Makepeace (1983) observed seeds to have a relatively high viability percentage (24%) after being buried for 6 years. Additionally, McEvoy (1984b) found that under similar conditions (20° C and 12 h light/dark), ray achenes were slower to germinate than disc achenes.

Both achene germination and seedling establishment in tansy ragwort are variable. Meijden and Waals-Kooi (1979) observed in the Netherlands that during the same season, the percent germination rate of achenes produced by an individual in the field varied between less than 1 and 10%. They also found that survival of seedlings varied with habitat (from 2.2 to 8% in one season). The amount of pasture cover was found to significantly affect establishment. Meijden and Waals-Kooi (1979) found that surrounding vegetation affected seedling survival. In grassy areas few rosettes survived compared to cleared or woodland areas. The highest rates of survival and establishment were in cleared areas of grassland. They concluded that open habitats (soil and canopy) were most favorable to establishment.

Growth and Development

Once tansy ragwort is established, it is a good competitor at the rosette stage, since its leaves cover and suppress neighboring short plants such as grasses and clover (Harper 1958). McEvoy (1984a) observed that the death of a rosette provided an open site favoring germination of tansy ragwort. He found seedling establishment to be 4.3 times higher in openings left by ragwort plants that recently died than in immediately surrounding vegetated areas. Allelopathic effects of compounds produced by tansy ragwort, including the pyrrolidizine alkaloid jacobine (Wardle 1987), have been speculated, but no studies have evidenced such properties. Rosettes may grow to 30 cm in diameter under optimal conditions in the first season (Harper 1958). Vesicular-arbuscular mycorrhizal (VAM) associations have been observed from both European and United Kingdom (U.K.) populations (Hawker et al. 1957, Harley and Harley 1987), but similar associations have not been reported in North America.

In general tansy ragwort prefers mesic habitats. In Australia, tansy is found in high rainfall areas (Schmidl 1972) and in New Zealand it is found in areas where rainfall is greater than 870 mm yr $^{-1}$. Barkley (1978) described tansy ragwort to be established in areas with cool, wet, cloudy weather in North America.

Many different soil types have been found to support tansy ragwort, although it typically occurs on lighter, well-drained soils such as Podzolic grey loams or grey sands. Tansy ragwort is generally absent where the water table is high or the soil is very acidic (Meijden 1974).

Economic Significance

Tansy ragwort is of economic concern because the foliage contains pyrrolidizine alkaloids, which are toxic to cattle, deer, horses, and goats (Goeger et al. 1981, Giles 1983, Wardle 1987). Sheep are less affected by the alkaloids (Wardle 1987). The alkaloids accumulate in the animal's liver, and over time result in degradation of liver function and sometimes cancer. Species susceptibility appears to be correlated with the rate of production of pyrroles, a derivative of pyrrolidizine alkaloids, by the animal (Shull et al. 1976). Certain pyrrolizidine alkaloids have been shown to be carcinogenic, mutagenic and teratogenic (White et al. 1983).

Cattle do not generally graze tansy ragwort directly, except in severely overgrazed pastures. However, the alkaloids are still toxic in silage so the plant's presence in hay often results in the abandonment of the crop. The alkaloids also flaw honey produced by bees that have gathered ragwort pollen. The honey is usually too bitter and off-color to market (Deinzer et al. 1977).

Response to Management

The early phases of colonization are when tansy ragwort may be controlled most easily. Thus, early detection of tansy ragwort in new areas is important (Harper 1958). Common methods used to manage tansy ragwort include, chemical, mechanical, biological, and cultural practices. Dicamba (as Banvel®) at label concentrations was recommended by Whitson et al. (1985) for ragwort control with chemicals. Three significant problems confound the use of herbicides for tansy ragwort management. First, damage to competitive dicots by the herbicide is a common occurrence. Second, increased palatability of the weed to livestock just after spraying poses a threat to livestock health (Irvine et al. 1977). Livestock must be kept out of pastures for at least 3 – 4 weeks after spraying with herbicides in the spring. The third problem, is that studies have shown that herbicides were not effective in killing tansy ragwort plants because the herbicide leached out of the roots without being transported throughout the plant (Poole and Cairns 1940).

A single mowing during flowering might result in an increase in infestation levels because tansy ragwort is able to reproduce vegetatively. Conversely, repeated mowing may deplete nutritional reserves due to radical reduction in available photosynthetic tissue, thereby eventually causing the population to crash. Mowing may be effective if it is done every six weeks during spring and summer months and during a time of moisture stress (Cox and McEvoy 1983). Deep plowing has also been unsuccessful in controlling tansy ragwort because it tends to sever roots that can be the origin of new shoots and facilitate distribution over a wide area. Plowing also unearths buried seeds and thus can contribute to increased infestation levels. Management techniques promoting dense vegetation in pastureland appear to be effective in controlling tansy ragwort spread, both because it does not readily establish from seed on closed canopy sites and because individuals are poor competitors during establishment (Thompson 1980). Hand pulling has been the most common mechanical management technique used on small areas in the early stages of infestation.

Three insects from tansy ragwort's native habitat have been introduced into the United States for use as biological control agents (Watt 1987a). The agents include the ragwort seedhead fly (*Botanophila seneciaella* Meade), the ragwort flea beetle (*Longitarsus jacobaea* Waterhouse) and the cinnabar moth (*Tyria jacobaea* L.). The seed fly larva feeds on the developing seeds and receptacle through the summer and can completely destroy the contents of a capitulum. The ragwort flea beetle adults feed externally on tansy ragwort foliage before entering summer diapause. The adults then resume feeding in the fall when conditions are cool and moist. Larvae feed internally on leaves, stem, and the root crown. Larval feeding often results in the killing of plants, and adult feeding can kill seedlings. The cinnabar moth larvae feed externally on the flowering shoots of tansy ragwort in spring and summer. The larvae are capable of completely stripping the shoots of flowers and leaves; however, this rarely kills the plant along the Pacific Coast, where fall rains regularly cause regrowth from the base of defoliated plants to occur (McEvoy et al. 1991).

Large decreases in tansy ragwort infestation levels have resulted with the introduction of these three biological control agents in western Oregon. At a study site located along the central coast of Oregon, a 99.9% reduction in tansy ragwort standing crop was observed during an 8-year period following introduction of the three aforementioned insects. A decline of 93% was reported from a regional survey of 42 sites in western Oregon over 6 years.

The three biocontrol agents were released in northwestern Montana, beginning in 1997. In the area burned by the Little Wolf wildfire in 1994, the cinnabar moth decreased tansy ragwort infestation levels in the Flathead National Forest. However, the cinnabar moth has failed, so far, to establish despite repeated releases over three years. The seedhead fly has established in all parts of the main tansy infestation. The Oregon strain of the tansy ragwort flea beetle is still established in Montana five years after its initial release. The populations remain quite low, however, and have not moved beyond the release sites (Markin 2002).

Response to Burning

Early studies on tansy ragwort's response to burning are inconclusive. Poole and Cairns (1940) experimented with using a flame thrower to control tansy ragwort, but their results were inconclusive and have not been reproduced by others. Mastroguiseppe et al. (1982) conducted several control burns at an infested site in Redwood National Park, California, but those results were also inconclusive. However, observations in northwestern Montana indicate that tansy ragwort expands after wildfire.

The Final Environmental Impact Statement (FEIS) for the Tansy Ragwort Control Project for the Flathead National Forest in Montana cites that tansy ragwort was present in the Tally Lake Ranger District prior to the Little Wolf Fire in 1994 (Richardson 1997).

The FEIS states that in 1996, two years after the wildfire, a large population of tansy ragwort was discovered on the landscape. By late fall 1996, tansy ragwort infested approximately 1000 acres of national forest land, most of which had been burned by the Little Wolf Fire. The FEIS cites that the probable reason why a larger tansy ragwort population was not detected within the fire area in 1995 is that the new germinants were in the small rosette stage. The rosettes are relatively inconspicuous and may have escaped notice or proper identification as a noxious weed.

Justification for Research

Tansy Ragwort in Northwestern Montana

Management of weeds is often set in motion before monitoring is completed or even begun. Just as the weed can impact the ecosystem it has invaded (Mack et al. 2000), many management practices can have negative effects on the ecosystem. In some instances, it is quite obvious that the weed is increasing in density and/or spatial extent (i.e. invasive). However, the invasive plant may vary in invasion potential across different environments which can make management prioritization difficult. The purpose of my research was to quantify the invasiveness or potential for invasiveness of a new weed across environments where it has become established. I determined that conducting a population viability analysis would be the most effective method to quantify invasiveness of tansy ragwort.

Tansy ragwort was first discovered on the Flathead National Forest by a Tally Lake Ranger District forestry technician who conducted vegetation surveys in the Griffin

Creek drainage during the first week of August 1993. Peter Stickney, a forest ecologist with the USDA Intermountain Research Station, confirmed the discovery. Other surveys in 1993 confirmed the presence of more small "spot" infestations of tansy ragwort on the Tally Lake Ranger District. Tansy ragwort seeds may have been transported from Oregon on logging equipment used in site preparation within previously harvested units in these drainages, since four of the five populations discovered were located in harvest units that had been logged within the last ten years (Richardson 1997).

In 1994 several wildfires, most notably the Little Wolf wildfire, occurred in Northwestern Montana. The fire burned approximately 10,000 acres of the Tally Lake Ranger District in the Flathead National Forest and approximately 5,500 acres of the adjacent Kootenai National Forest. The following summers, populations of tansy ragwort were observed in the Flathead and Kootenai National Forests. U.S. Forest Service employees noticed that tansy ragwort colonized burned areas (Richardson 1997). These new populations were of particular concern due to use of the forest for cattle grazing and the related studies showing that tansy ragwort is poisonous to livestock and some wildlife (Goeger et al. 1981, Giles 1983, Wardle 1987). Tansy ragwort was also found in nearby unburned patches of forest and meadow. Only one other small tansy ragwort infestation is known in Montana, located on approximately twenty acres of private land in Mineral County near St. Regis in western Montana, west of Missoula (Richardson 1997).

The Montana tansy ragwort infestations are of particular significance because this species was thought to be limited to maritime climates. Montana sites were considered resistant to tansy ragwort invasion due to the prevailing low annual temperature, soil