

**Title: Yellow Toadflax Population Dynamics in Different Environments**

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**Award Amount:** \$4,989 (awarded 2004)

**Proposal:**

*Abstract:*

Yellow toadflax (*Linaria vulgaris*) has invaded many environments in the Hebgen Lake area of southwest Montana. We have now studied the population dynamics of 3 *L. vulgaris* populations for 6 growing seasons, 1 population for 4 seasons, and another 10 populations for 3 seasons. Our research has indicated significant variation in the dynamics of the populations across environments and over years. To our surprise, seed production has been highly variable but generally low during the study period. Even in a spring following a fall with high seed production, seedling recruitment is very rare. This leaves us to believe that this species may only rarely accomplish new colonization through seed production and dispersal, and patch spread is by vegetative reproduction. At the patch scale, patch edges have been relatively stable with only occasional increases in perimeter through vegetative growth. Patch centers have been more variable, with increasing density in some patches and decreasing in others. As a result of these data we have developed an invasiveness index that we hope will be valuable to land managers who want to know which populations are increasing most rapidly or determine how well management practices are reducing a population. However, the manuscript describing the invasiveness index is being reviewed and we will make all the details available when it is accepted for publication.

*Problem Description:*

*L. vulgaris* has invaded a wide range of habitats in the Hebgen Lake area, but demographic studies in a couple of the environments have indicated that the populations are not invasive and, in fact, are on a trend to go extinct. These measurements do not coincide with our observation that this species is established in a wide range of local environments. That is, there must be conditions where and when it becomes highly invasive. We intend to discover the conditions required for this species to invade or become a source for new colonization so that management of this species can be strategically applied.

**Results:**

*Site Descriptions*

All populations studied were within the National forest in southwestern Montana. Site 1 is located at an elevation of 2200 m on a steep south facing slope (approximately 33°) and three populations are monitored at this site. The habitat type is big sagebrush (*Artemisia tridentata*)/Idaho fescue (*Festuca idahoensis*) (Despain 1990). Soils are limestone-derived clays that are relatively high in nutrient concentrations (Rodman, Shovic et al. 1996). The site is undisturbed by human actions, but has small-scale disturbances from natural slope movement, elk grazing and trampling and small mammal burrowing.

Site 2 is at an elevation of 1851 m on the valley floor where the topography is very flat, 3 populations are monitored at this site. The plant community is similar that of Site 1, but the soil is a relatively infertile rhyolite-obsidian sand that was formed on a glacio-fluvial outwash plain (Rodman, Shovic et al. 1996). In contrast to Site 1, this site is subject to human disturbance as it is a popular fishing access point to Hebgen Lake and is surrounded and crossed by unimproved roads.

Site 3 is in the immediate vicinity of Site 2, but only one population is monitored under a closed canopy of lodgepole pine (*Pinus contorta*).

Site 4 (Riparian) is located in the same area as Sites 2 and 3, but is slightly lower in elevation, and adjacent to a riparian area in the floodplain of the South Fork Madison River. One population is monitored at this site. It is occasionally flooded during spring snowmelt, and may contain additional deposits of alluvial sand and silt (USDA 1996). This site is dominated by willow (*Salix* spp.), sedges (*Carex* spp.) and native forbs.

Site 5 (Meadow) is a naturally occurring meadow situated on a north-northeast facing slope, and three populations are monitored. Soil here is a typic cryochrept formed on glacial drift weathered from granitic rock. The soil is medium textured and has a high water-holding capacity (USDA 1996). Vegetation at this site is dominated by big sagebrush (*Artemisia tridentata*) and *Poa pratensis*. Also present is a diverse array of herbs including aster spp., clover (*Trifolium* spp.), Western Yarrow (*Achillea millefolium*), sticky geranium (*Geranium viscosissimum*) and many others.

Site 6 (Clearcut) consists of two clearcuts located off of a Forest Service road approximately 3.5 miles west of West Yellowstone, MT and just south of Highway 20. The clearcuts are within an area commonly referred to as the “flats” because it is a glacial outwash plain and there is little topographic relief. Soils of the area are typic cryochrepts with an obsidian sand substratum. Soils are formed on glacial outwash and alluvial deposits weathered from obsidian and rhyolite. The alluvium is coarse textured and contains rounded pebbles and cobbles (USDA, 1996).

The clearcuts were populated by lodgepole pines (*Pinus contortus*) prior to being logged, and the dominant habitat type in unlogged areas is lodgepole pine / bitterbrush (*Purshia tridentata*). Tree regrowth has been sparse, and the dominant cover is now a grassland community including bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*) and associated herbaceous species. Numerous *L. vulgaris* infestations are present within clearcuts throughout this portion of the Gallatin National Forest, and 3 of these are being monitored for this study.

Site 7 (Wildfire) is an area that burned in a wildfire in 1988. It is located approximately 4 miles west of Highway 191 on the south side of the road to Rainbow Point. This site is also on the “flats”, at a similar elevation, and is underlain by the same soil type as the Clearcut site. Vegetation characteristics are also similar to that of the Clearcut, although lodgepole pine recovery at this site is progressing faster. While there are still areas without trees, there is a mosaic pattern of new tree growth. Several *L. vulgaris* patches of varying sizes are scattered throughout the burned area and again 3 populations are being monitored.

### Plot Establishment

Each patch was a discrete population within a metapopulation. A permanent grid with 1-m<sup>2</sup> sub-sections was established over each patch by marking the corners with rebar posts. The grids were positioned such that perimeter sub-sections straddled the edge of the *L. vulgaris* patch. Within the grid, 1-m<sup>2</sup> monitoring quadrats were randomly placed, stratified by edge and interior positions within the patch. Table 1 shows the number of quadrats monitored within each population for Sites 1-3.

Table 1. Number of interior and edge cells monitored in each population at Sites 1-3.

	Population <sup>1</sup>					
	1	2	3	4	5	6
Interior	112	96	64	48	48	48
Edge	96	96	64	48	48	48
Total	208	192	128	96	96	96

<sup>1</sup>Populations 1, 2 and 3 are at Site 1; populations 4 and 5 are at Site 2; population 6 is at Site 3.

Table 2 provides similar information for sites 4-7. These sites have far fewer cells monitored than at Sites 1-3 because most cells were devoted to treatments that will be reported on at a later date. Only the control cells are reported here, and individual populations within sites are combined.

Table 2. Number of interior and edge cells monitored at Sites 4-7.

	Site			
	4 (Riparian)	5 (Meadow)	6 (Clearcut)	7 (Wildfire)
Interior	12	24	20	20
Edge	40	48	48	48
Total	52	72	68	68

### Population Monitoring

Populations were monitored each spring at Site 1 from 2001 to 2005, at Sites 2 and 3 from 2002 to 2005, and at Sites 4 – 7 from 2004 – 2006. Spring monitoring consisted of counting the number of *L. vulgaris* vegetative stems and seedlings within the quadrats. A 1-m<sup>2</sup> PVC frame, subdivided into 1/16-m<sup>2</sup> units was used to facilitate counting and spatial mapping of plant locations. Stem counts for each 1/16 m<sup>2</sup> cell were recorded as separate entries.

### Calculation of Population Growth Rates

Annual and overall (i.e., 2001 or 2002 to 2005) growth rates ( $\delta$ ) were calculated for each population studied. Population  $\delta$ s were taken as the mean of all of the individual  $\delta$ s from the 1/16-m<sup>2</sup> cells. These individual  $\delta$ s were calculated as  $N_{t+1}/N_t$  where  $N_{t+1}$  is the number of stems within the cell at a given time and  $N_t$  is the number of stems in that same cell at the previous time step. The data were transformed by adding 1 to each stem count value so as to avoid the problem of dividing by zero in cases where there were no stems at time  $t$ . Analysis was performed using the software package R (version 2.1.1).

### Calculation of Invasiveness

We define invasiveness as a population increasing in density and / or spatial extent.

### *Results of Invasiveness Calculations*

Invasiveness of populations of *L. vulgaris* is quite variable between different populations and years. Populations at Site 1, tend to have higher invasiveness values than populations at other sites. The generally greater invasiveness at Site 1 could be an indication of more suitable habitat conditions at this site. The population at Site 3, which is entirely under a canopy of lodgepole pine, shows negative invasiveness (declining population) in all years and the overall invasiveness is strongly negative. Populations at Site 2 vary between being slightly invasive and slightly in decline. The populations at Sites 4 (Riparian) and 7 (Wildfire) tend to be invasive, although much less so than populations at Site 1. The populations at Sites 5 (Meadow) and 6 (Clearcut) have negative invasiveness values indicating that they are in local decline.

### **Publications:**

Despain, D. C. (1990). Yellowstone Vegetation. Boulder, CO, Roberts Rinehart Publishers.

Rodman, A., H. F. Shovic, et al. (1996). Soils of Yellowstone National Park. Yellowstone Center for Resources, Yellowstone National Park.

USDA. (1996). United States Department of Agriculture, Forest Service and Natural Resources Conservation Service. Soil Survey of Gallatin National Forest, Montana.

**Products:** An invasiveness index that can be used by land managers. This will become available when our manuscript is accepted. A “how to” document will be generated for download from the Weed Ecology Website.

**Long-term goal and continued progress of research:** This seed grant project covered the 2004 field season, we have since collected data in 2005 and plan to do so in 2006. We have established considerable variability in the invasiveness of *L. vulgaris* populations under different environmental conditions. We plan to correlate these invasiveness values with our probability of occurrence maps and test the hypothesis that population invasiveness increases along the probability of occurrence gradient. Such a correlation would help managers prioritize the populations to target for management. We would also like to start to manage portions of these populations and evaluate the effectiveness of such management under the different environmental conditions.

**Benefits of seed money:** We have received seed grant money to initiate this project, and again here in 2004 between obtaining funds from other agencies. The data have also been used as part of a National Research Council grant proposal which is currently under review, and a USDA-PREISM grant which we have received funding for. Thus, the seed money has been vital in securing nationally competitive grants and grants from the Forest Service to enable us to have a longer term data set on the population dynamics and invasiveness of *L. vulgaris*.

**Further assistance in advancing this research:** –The benefit of this research will be its longevity. Currently it is assumed that all noxious weeds are invasive under all circumstances – these data show that is not the case. In addition, it is currently assumed that all control is effective, we would like to seek additional funding to evaluate the populations and

environmental conditions that could be more effectively controlled, so that managers could target such populations first. This is the type of research that is difficult to obtain competitive grants for and assistance from CIPM for such applied research would make this possible.

**Website:** Not available