Demographics of Selected Exotic Plants In the Chewuch Watershed, Methow Valley, Washington – A Status Report

June 2003

By Pacific Biodiversity Institute
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Acknowledgements:
This work was supported by a two-year grant from the Kongsgaard – Goldman Foundation and a grant from the Center For Invasive Plant Management. Additional private contributions of labor and resources helped to enable this project.

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I. Introduction

This study was undertaken to determine the demographic and habitat characteristics of invasive plants in the Chewuch Watershed of North-central Washington. This report deals with the distribution of six target species in the roaded portion of the watershed. Factors studied include species' range limits, habitat preferences, disturbance response, and population trends over time, whether advancing or retreating.

Within the watershed, questions were asked about a selected group of "study" species to try and answer some of the following questions:

- What is the past, present, and expected future range of these species?
- What is the rate of population growth or decline?
- What features of the landscape and habitat increase or decrease the range or rate of growth?
- How can better knowledge of plant invasions enhance management of alien species?

Six species were chosen for detailed analysis. These species include:

- Diffuse knapweed (*Centaurea diffusa* Lam.)
- Russian knapweed (*Acroptilon repens* (L.) DC. syn. *Centaurea repens* L.)
- Spotted knapweed (*Centaurea maculosa* Lam.)
- Dalmatian toadflax (*Linaria dalmatica* ssp. *dalmatica* (L.) P. Mill.)
- Whitetop (*Cardaria draba* (L.) Hand.)
- Hairy whitetop (*Cardaria pubescens* (C.A. Mey.) Jarmolenko)

These species were chosen for this study based on their propensity for dominance, persistence, invasiveness, and rate of spread, as well as their abundance within the study area.

In addition to details about these six species, additional site and species data was recorded over a period of five years beginning in 1998. Additional studies and personal interviews were used to complement the available information wherever it was possible to incorporate such data.

II. Background

The study area is the Chewuch watershed north of Winthrop, Washington, which is a tributary within the Methow Valley Basin. The Chewuch watershed covers about 334,000 acres (1,352 square km), with environments ranging from Ponderosa pine/shrub-steppe to alpine summits. The watershed lies within the dry interior in the rain shadow of the adjacent North Cascades. Average mean annual precipitation varies throughout the watershed, but ranges from 12 inches annually at Winthrop to over 35 inches at the higher elevations of the study watershed.

Most of the land is National Forest, with private lands concentrated primarily in the valley bottoms. Several dozen invasive, exotic species are commonly encountered throughout the area. The number of invasive species is generally highest on the more highly modified private lands, however some invasive, exotic species have successfully invaded natural areas on public lands as well. Invariably, the process of invasion is asymmetric. Understanding the nature of this invasion process was a primary goal of this research, which may eventually lead to effective weed management strategies.

III. Methods
A. Field Methods

This study was designed to sample the range of variation of the target species' abundance as well as their ecological amplitude. In order to be comprehensive, this posed some logistic difficulties, the primary one being the size of the watershed. The final design reflected a compromise between gathering detailed information and efficient use of time.

In order to systematically sample a representative portion of the area, hundreds of sample stations needed to be established. Mountain bikes were chosen for transportation between stations for a number of reasons, including their ability to traverse difficult terrain, ability to travel slow enough to observe roadside vegetation, and ease of mounting and dismounting at stations. Automobiles were used to reach some more remote locations. Cross-country foot travel was also used to access areas away from roads in later stages of the study.

The distance between plots was determined primarily by the requirement for efficient use of time, and was established at 0.50 mile. Odometers on the bikes allowed accurate placement of the sample stations, and GPS receivers allowed a record to be kept of sample locations.

Most of the sampling occurred along roads. In order to measure the abundance of vegetation away from roads, each station along the road included two sub-plots, one with its sides touching the road, and another with its center 10 meters away from the road. In addition, a separate study was included that measured the abundance of weeds up to 200 meters from roads. Considering that most of the 334,000 acres within the watershed is roadless, it was felt that this was the only practical way to assess species occurrences both on and off of roads. Based on a familiarity with the study area, the target study species were known not to occur to any great extent in roadless or undeveloped areas. This study bore that assumption out to some degree.

Prior to the beginning of the field season, a National Forest road map was used to mark roads that would be sampled, based on obtaining broad distribution across the watershed, and equitable distribution between the 15-20 subwatersheds in the Chewuch basin.

This system was judged to be suitable for studying species' ranges. Finer details of species' individual distribution patterns and relationships between different individuals were assessed by measurements taken within the pair of 3-meter radius plots established at each roadside station. A plot radius of 3 meters was chosen because it offered easy visibility and convenient access; at the same time it was large enough to contain hundreds of individual stems of any of the target species.

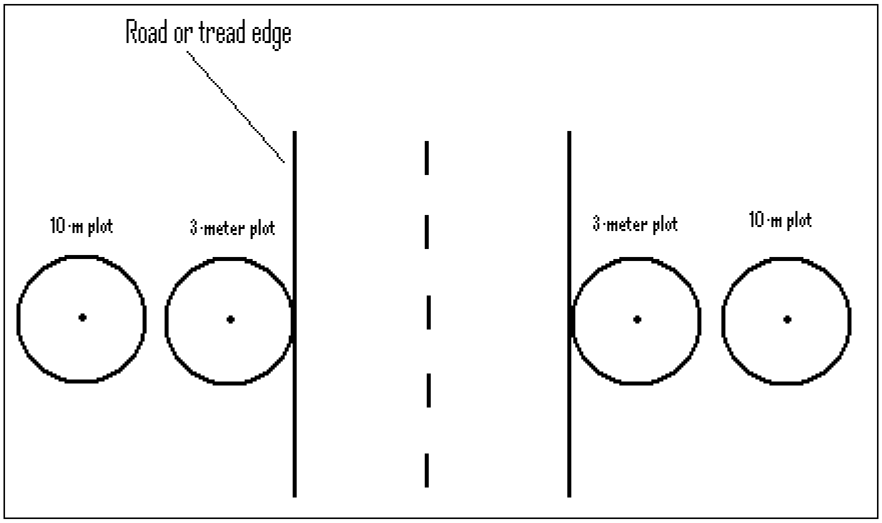
1. Preparation: At the beginning of the field season, the surveyors became thoroughly acquainted with the flora and measurement methods. Methods for quality control (Appendix A) and equipment (Appendix B) aim to standardize field methods.

2. Identifying and Establishing Plots:

a. Roadside plots. Desired sampling locations were determined prior to the field season using a topographic road map. The sampling program was designed to insure broad distribution across the watershed while maximizing the efficient use of mountain bike transportation. Mountain bikes were chosen because they offer a compromise between accessing roaded and unroaded areas, they are relatively unobtrusive compared to motorized vehicles, they are easy to mount and dismount, and with odometers, they facilitate rapidly locating plots along linear road transects.

Stations were established along roadsides every 0.50 miles. Each station, or plot, consists of four sub-plots. These sub-plots are established on both the left and right-hand sides of the road. All sub-plots are 3-meters in radius, however for each side of the road, there is one plot center at 3 meters distance from the road edge and one plot center at 10 meters from the edge of the road edge. It is important to note that both plots (3 and 10 meters from the road edge) were 3-m in radius. In the case of the road edge being undefined, the measurements are taken from the outer edge of the tread marks. (see below, Diagram A).

Diagram A: Plot and subplot delineation. (Diagram not drawn to scale or proportion). All sub-plots are 3-meters in radius. Plot centers are located every 0.50 miles.



<u>b. Resampled plots</u>. To determine whether populations of the target species were changing over time, a subset of study plots from 2000 was resampled in 2002 using the same sampling methods.

Previously established plots were relocated with the aid of a GPS receiver loaded with the waypoints recorded in the 2000 survey, in conjunction with a printed map of the locations, and the description of the location from the original plot. Although it was impossible to relocate the exact location of the original plot, in most cases, the 2002 plots matched the descriptions of the 2000 plots within about 5 meters.

New GPS waypoints were recorded at the center of each 3-meter plot, and the center of both the 3-meter and 10-meter plots were marked with blue flags. The sampling methods were identical in both years.

<u>c. Off-road plots</u> <u>(“*road-perpendicular plots*”)</u>. To more fully investigate the relationship of road proximity to invasive species’ occurrences, transects were placed perpendicular to roadside plots. This part of the study was designed to examine the decline of abundance beyond the 10-meter distance sampled in the roadside plots. Because invasive species presence rapidly declines within several meters of a roadside, a set of 5 plots 10 meters in diameter, spaced 50 meters apart, was judged to be the most practical compromise between doing rigorous off-road sampling, while still obtaining enough data to give indicate the magnitude of the road’s influence

A variety of habitats were sampled with this protocol, in order to determine if any particular unroaded habitats were prone to invasion.

Sets of 10 plots were established 50 meters apart along two 200-m transects, with the origin of each transect 3 meters from the edge of opposite sides of the road. Sub plots were 10 meters in diameter and were placed along the transects at 50, 100, 150 and 200 meters distance beginning at the road edge. Transects began at previously established 3-m radius roadside plots, unless there were no prior plots at that location, in which case, a 3-m roadside plot was established as described above, with the perimeter along the road edge.

Approximate locations of the off-road transects were determined prior to field work, using a GIS to locate suitable areas where roads had at least 200 meters of unroaded, evenly vegetated terrain on either side. Transects were located by following a perpendicular compass bearing from the road, except in a few cases where cliffs or streams forced a slightly different direction, in which case a note was made on the datasheets.

Off-road plot datasheets:

Datasheets recorded the waypoint location, transect azimuth, photograph number, general vegetation notes, observed disturbances, plot composition percentage cover of bare ground, native vegetation, alien vegetative cover, canopy cover, and target species cover, and notes of whether any additional alien species were observed between plots. Each plot was marked in the center by a flag and the following information was recorded on the datasheets:

- GPS reading taken at the center of the plot. If the accuracy was judged to be unsatisfactory at the center of the plot, a reading was sometimes made at a nearby open area and the distance from that point to the center of the plot recorded.
- A digital photo of the plot, along with a record of the photo number.
- Notes on general vegetation which describe the dominant vegetation type in the plot.
- Notes on history/land use of the plot including:
  - Grazing presence noted by four indicators: presence of dung, trampling of vegetation, browsing activity, and/or live animal presence. For each of these indicators, details on intensity and animal species was provided.
  - Logging activity including apparent logging history, type of logging activity (thinning, clearcuts), presence of skid trails, average stump diameter, and approximate time when logging occurred.
  - Other land use and disturbances noted, including prescribed or natural burns, herbicide use, and other land modifications.
- General plot composition which provides an overview of vegetation cover in the plot, as well as canopy cover.
- Percent cover of target species. For percentages less than 1%, trace amounts were recorded as 0.1% and the number of stems in the plot recorded. Trace amounts of percent cover (<1%) were recorded in 2000 as "1%", and in 2002 as "0.1%", resulting in potential errors in calculations. During analysis, the calculations were made comparable by making the 2002 data conform to the 2000 measurement criteria.
- Aggregate percent cover of native species and of non-target alien species.
- Other alien species observed between the transect points at intervals of 0-50 m, 50-100 m, 100-150 m, and 150-200 m.

3. Recording Waypoints: In order to permanently record plot locations, a GPS (global positioning satellite) unit was used to record latitude and longitude of waypoints along with their corresponding precision. Waypoint readings and identifier numbers were recorded at the center of each 3-meter sub-plot. The ability to obtain an accurate GPS reading depends on canopy cover, cloud cover, time of day, and topography. Desired plot accuracy was <6 meters. If accurate readings could not be fixed from the sub-plot centers, surveyors recorded the waypoint from the closest location in the general plot area that could receive a satellite signal. At the end of each day in the field, these waypoints were downloaded into an Access database.

4. Recording Plot Information: Observations from each set of 4 roadside plots were recorded on one datasheet for the plot number, the date, the observer's initials, the road name, direction of travel, description of road type, general vegetation type, and land use history, including any previous disturbances. An example datasheet is included in Appendix C. Details on datasheet records are as follows:

a. Plot Number: Plot numbers started with #1 each day. To insure plot numbers were unique, plots were renumbered by the person in charge of data entry at the end of the day during the downloading of waypoints into the database. The final plot numbers correspond to a master sequence in an Access database.

b. Date: This is the date in which the survey was performed.

c. Observer: (initials).

d. Location:

i. Direction & Road. This is the name and number of the road and the general direction along that road. In some cases, directions given as up or down are preferable to cardinal directions. Records include the numbers of National Forest roads and the names of familiar creeks or landmarks.

ii. Description: This field describes the road condition, e.g., whether the road is paved, gravel, rocky, dirt, or a combination of these. Records include any location markers observed, and the names of any other adjoining roads.

iii. Elevation, Slope, & Aspect: These fields are derived from GIS queries, and were left blank in the field, unless local topography was variable.

e. General Vegetation Type: This field records the general vegetation of the area immediately adjacent to the plot. Dominant species and their approximate percent cover were recorded, particularly for trees and shrubs. Descriptions attempted to match recognized plant associations (Lillybridge et. al., 1995).

f. History/Comments (General): This field contains any general observations about the area around the plots. Observations included:

- Disturbance – When a disturbance was present, it was **always** recorded, including the type(s), and the estimated duration and intensity of disturbance. Disturbance was noted in the general area as well as in the sub-plots; nothing was recorded if no obvious disturbances were observed.
- Slope – Indicates the slope within a plot
- Erosion & texture – Indicates the soil texture and whether there are signs of erosion.
- Land Use/Management (historic and current) – Notes of whether the area has current or old homesteads, fields, irrigation canals, roads, road maintenance (e.g., cut-and-fill slopes), logging, grazing, past fire, herbicide spraying, or livestock disturbance. Records the type of past logging activities (clear-cuts, partial cutting, selective thinning). Herbicide spraying was noted if obvious.

- Moisture Regime – This field records a coarse estimate of the hydrologic setting, by noting any standing water in the plot, whether the soils were wet, dry or moist, or whether the plot was immediately adjacent to a riparian areas.

5. Recording Sub-plot Information: The following data was recorded for each of the four sub-plots:

a. Left and Right sides (3-m and 10-m sub-plots): This field is used to record more specific information than that given in the general comments. Information typically includes predominant vegetation, slope, types of disturbance, whether there is erosion, soil characteristics (whether the soil is sandy, rocky, duffy, or whether the area is wet or moist) and any other comments that differ from the general comments.

b. Waypoints and Accuracy: The waypoint identification number is recorded for each 3-m plot, along with its corresponding accuracy.

c. Percent Cover: For each of the surveyed 3-m and 10-m sub-plots, the percent cover of the following ground cover types was recorded: 1) the 6 individual target weed species, 2) bare/litter, 3) natural vegetation, and 4) alien vegetation other than the six target species.

The abundance of these four categories is defined to be mutually exclusive and should sum to 100%. This approximation facilitates rapid estimation of the data. Care was taken not to leave any of these four entries blank.

The assumption that these categories are mutually exclusive and non-overlapping may not be valid for plots where native and alien species overlap. When these categories overlap, the abundance of native species is defined to be that remaining after subtraction of any overlapping cover of all alien species; likewise, scores for non-target aliens is that remaining after subtraction of the area of any target aliens which overlap them. The sampling order used was target species > non-target aliens > native species.

Aerial cover was measured for each category of cover type within the area of each sub-plot, estimated as the percent cover from an eye-level perspective (5 feet above the ground).

Percent aerial cover of plant categories was defined in this study as the vertical projection of the outline of the cover type onto an imaginary horizontal surface. The aerial percent cover was estimated for partial outlines of plants regardless of whether the plants were actually rooted within the sub-plot perimeter. For most perennials with a rounded form, holes in the canopy were counted as part of the canopy, but for linear species such as branches hanging into the plot from outside, vines, or annuals, only the actual outline was considered as part of the canopy. Dead plants were counted as part of litter, and dead stems on live plants were also counted as dead plants. If the percent cover was less than 1%, surveyors recorded “T”, for trace, which was converted to 0.1% during data entry into the Access database.

Mutually exclusive percent cover totaling 100% was recorded for the following 4 categories:

i) Percent Cover of the Six Target Weed Species. Within each sub-plot, the percent aerial cover for each of the six target invasive plant species given below was recorded.

Cardaria draba (CARDRA) *Cardaria pubescens* (CARPUB)

Centaurea diffusa (CENDIF) *Centaurea maculosa* (CENMAC)
Centaurea repens (CENREP) *Linaria dalmatica* (LINDAL)

ii) Percent Cover for Bare Ground and Litter (combined). Within each sub-plot, the percent ground cover of exposed bare ground and litter was recorded.

iii) Percent Cover of Other Alien Vegetation. (see Appendix D). Within each sub-plot, the percent aerial cover of all alien species that are not overlapped by the 6 target species was recorded. These species were: *Agropyron repens* (L.) Beauv. (quack grass), *Artemisia absinthium* L. (wormwood), *Bromus tectorum* L. (cheat grass), *Carduus nutans* L. (musk thistle), *Chrysanthemum leucanthemum* L. (oxeye daisy), *Cirsium arvense* (L.) Scop. (Canada thistle), *Cirsium vulgare* (Savi) Tenore (bull thistle), *Cytisus scoparius* (L.) Link (Scot's broom), *Gypsophila paniculata* L. (baby's breath), *Hypericum perforatum* L. (St. Johnswort), *Kochia scoparia* (L.) Schrad. (kochia, red belvedere), *Poa bulbosa* L. (bulbous bluegrass), *Salsola kali* L. (Russian thistle), *Sisymbrium altissimum* L. (tumble mustard), *Tanacetum vulgare* L. (tansy), and *Verbascum thapsus* L. (flannel mullein). Additional introduced species were sometimes also recorded in the notes.

iv) Percent Cover of Native Vegetation. Within each sub-plot, the percent aerial cover of all native vegetation which did not overlap with alien species was recorded.

d. Canopy Cover Density - Within each sub-plot, the combined percent canopy cover of all trees was recorded. Percent canopy cover was measured independently of the above categories, and therefore includes any overlap. A spherical densiometer was used as a training tool to calibrate surveyor estimates. Canopy density includes the canopy outside the plot that intersects a 30-degree angle from a perpendicular drawn at the plot center.

e. Stem frequency: Within each sub-plot, stem frequencies were recorded for the six target species as followed:

1 = 1-100 stems present in the plot
2 = 101-1000 stems
3 = > 1000 stems

<u>6. Alien species observed within ¼ mile of the plot</u>: In addition to the 6 target species, presence or absence was recorded for species on the list in Appendix D which were observed within 0.25 mile of the plot. The list includes target weed species not occurring within the plot. If none of these weeds are observed within 0.25 mile of the plot, the box was marked "NONE".

B. Analytical Methods

Following field data collection, data was entered into Microsoft Access database tables and carefully checked for errors.

A number of analytical procedures were applied to determine range limits, habitat preferences, disturbance response and population trends. Many of these involved

ArcView mapping software by Environmental Systems Research Institute (ESRI), combined with spreadsheets and image analysis software to prepare charts and tables.

Range and distribution of the six target invasive species was determined by mapping all road plots for the years 2000 and 2001

C. Literature review and interviews

As part of this study, we have collected references on the biology and demography of the study species. This study includes interviews taken of long-time residents of the area.

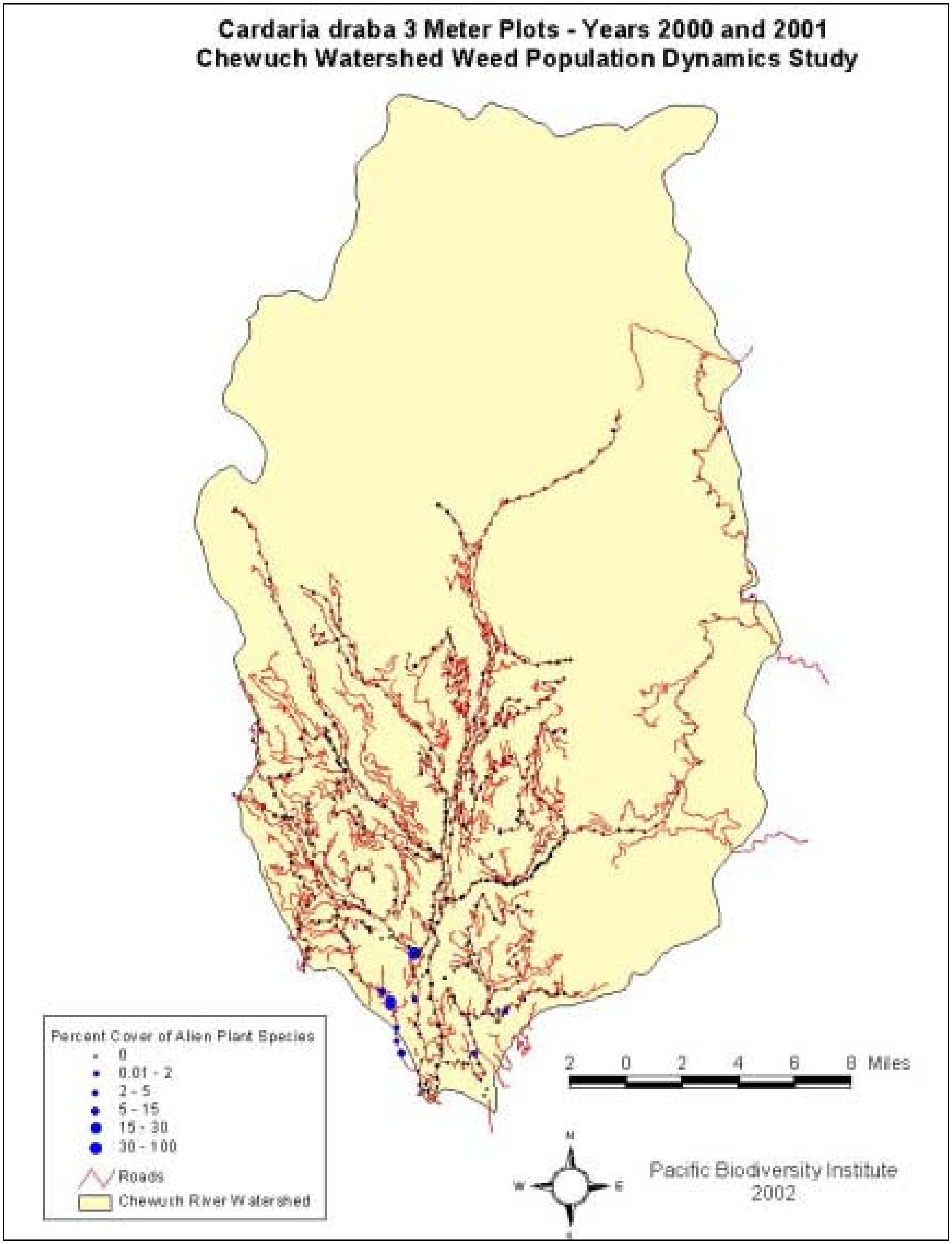
IV. Results & Discussion

A. Numbers of sample stations

In 2000, a total of 317 waypoints were sampled at 3 and 10-meters distances from the road edge for a total of 634 plots taken over a distance of approximately 79 miles, which are referred to in this report as ***road plots***. In 2001, 1122 waypoints were sampled at 3- and 10-meters for a total of 2244 road plots established over a distance of approximately 267 miles. In 2002, resampling was performed on 48 of the waypoints recorded in 2000, for both the 3-m and 10-m plots, giving a total of 92 plots, which are referred to in this report as ***resample plots***. Also in 2002, 30 200-m transects were established perpendicular to roads beginning at 15 road plots. Each transect contained 5 sample plots located 50 m apart, for a total of 150 sub-plots, which are referred to in this report as ***off-road plots***.

B. Distribution maps of target species

Range maps were prepared for the 3 and 10 meter road plots for the six target species.


Cardaria draba 3 Meter Plots - Years 2000 and 2001
Chewuch Watershed Weed Population Dynamics Study
Percent Cover of Alien Plant Species
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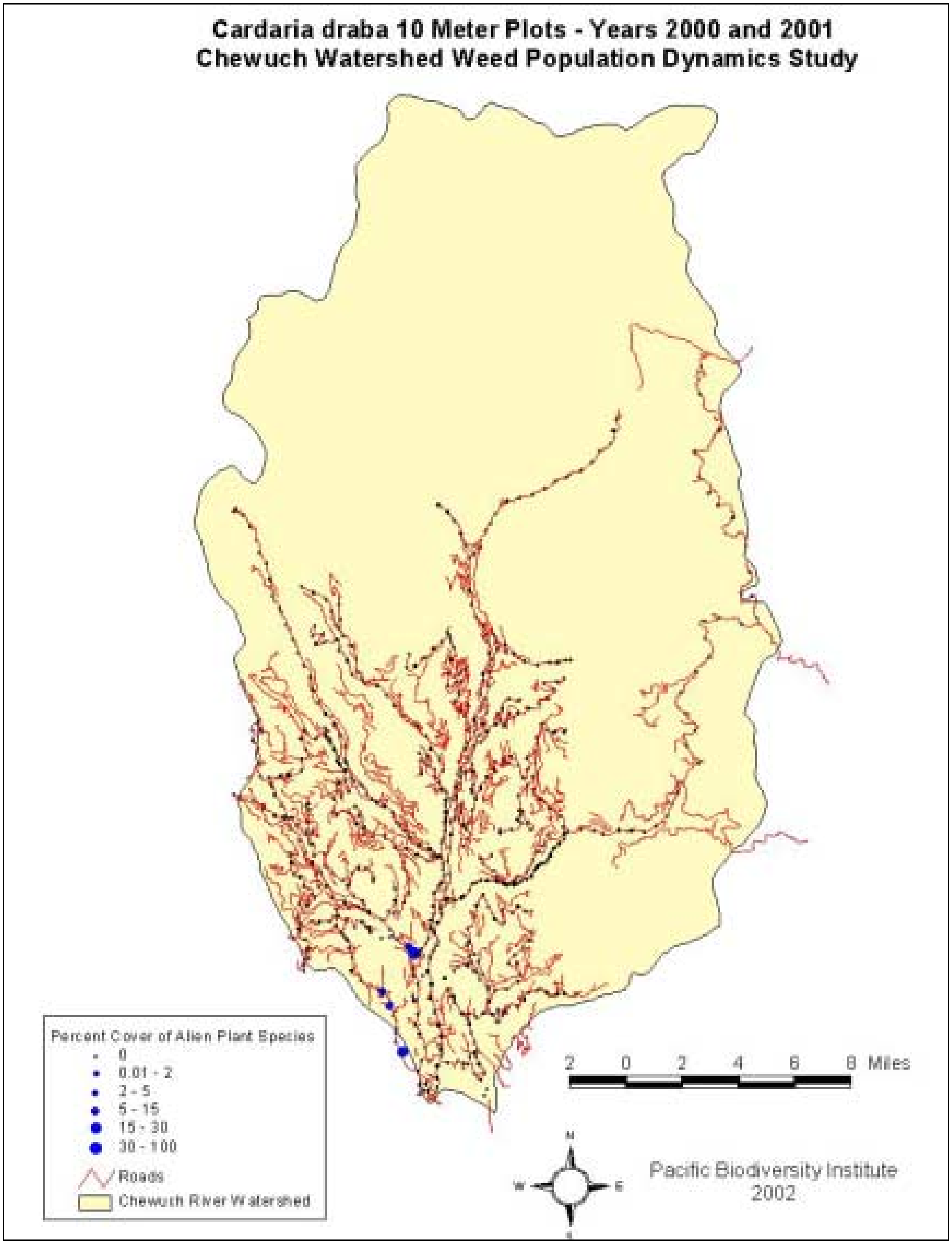
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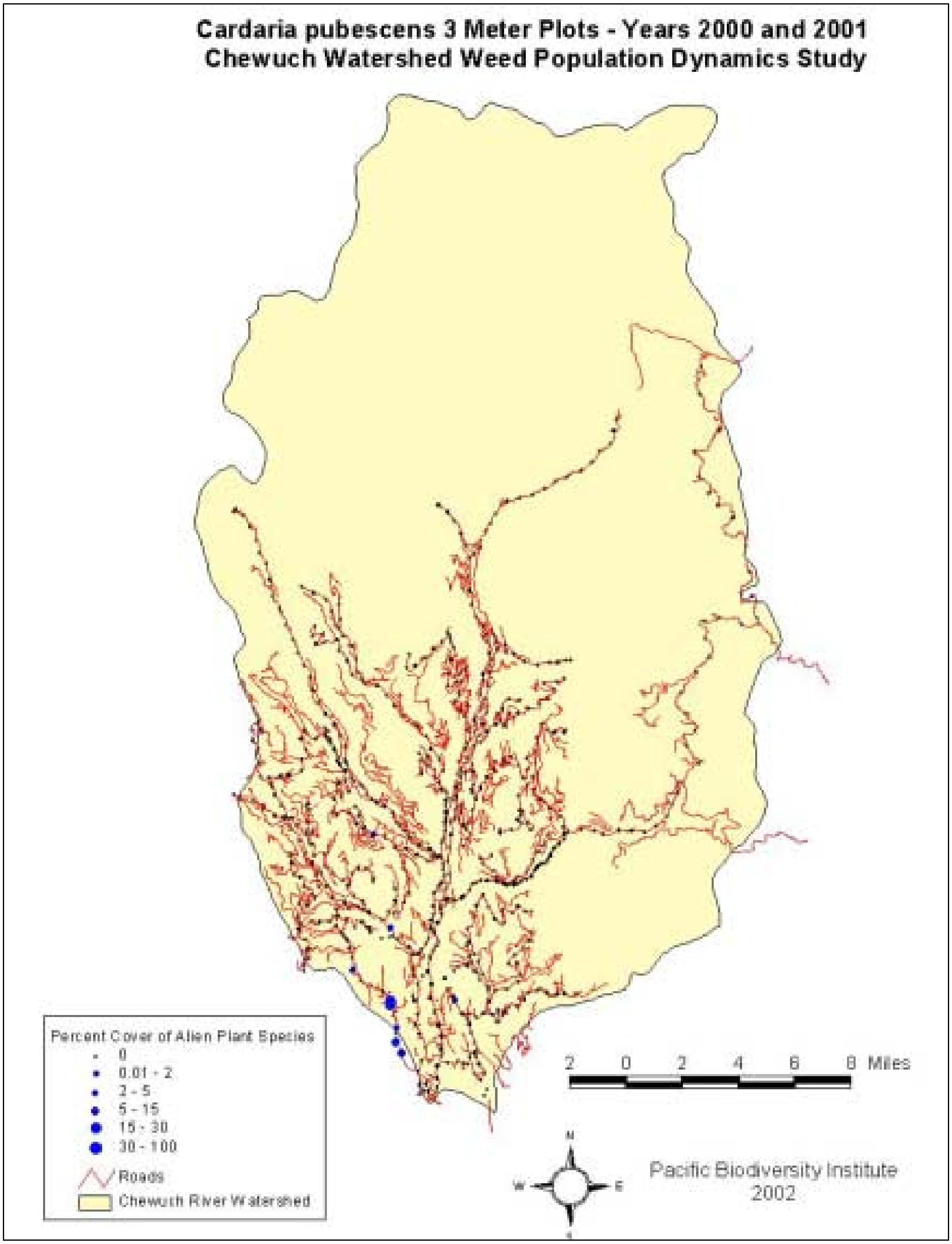
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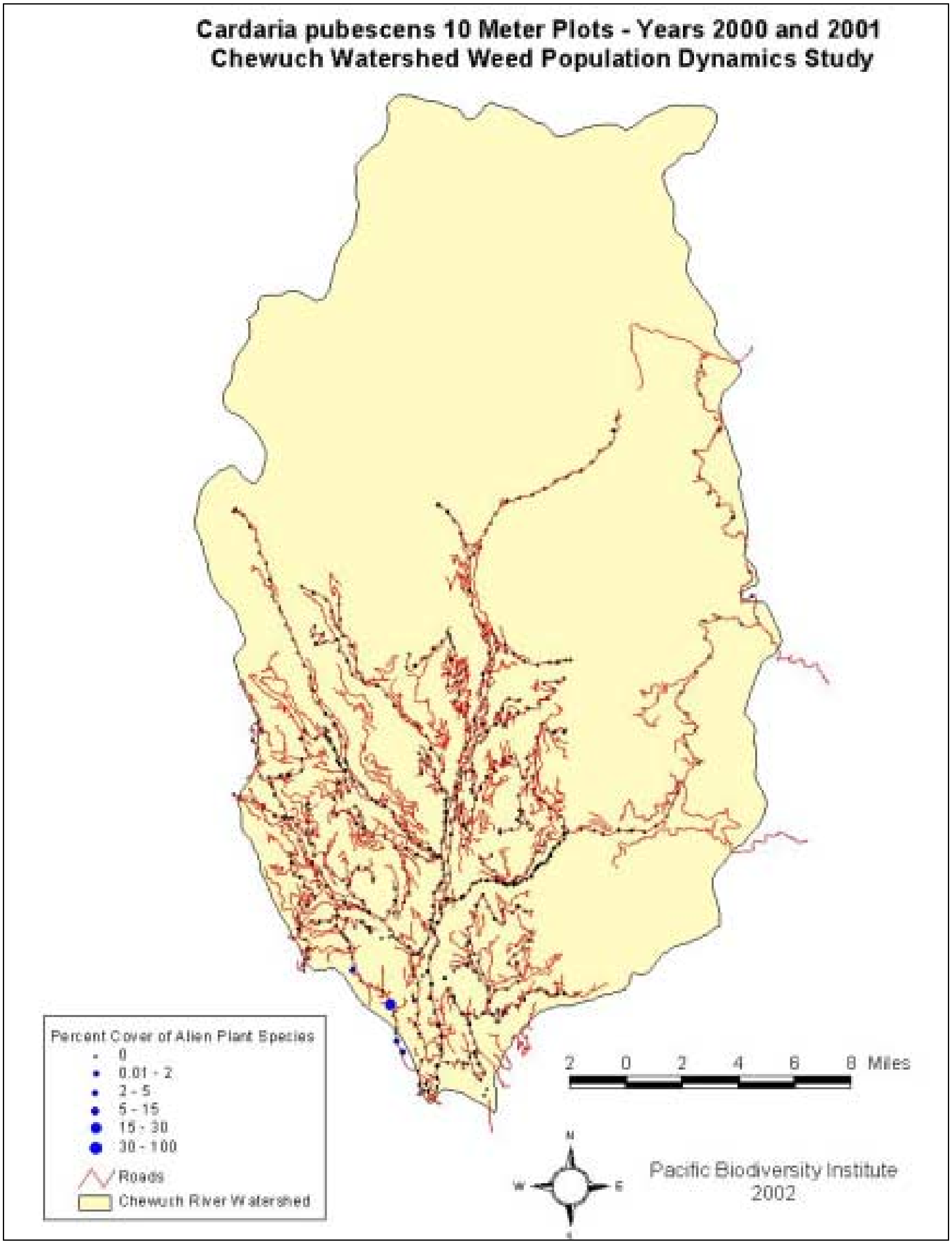
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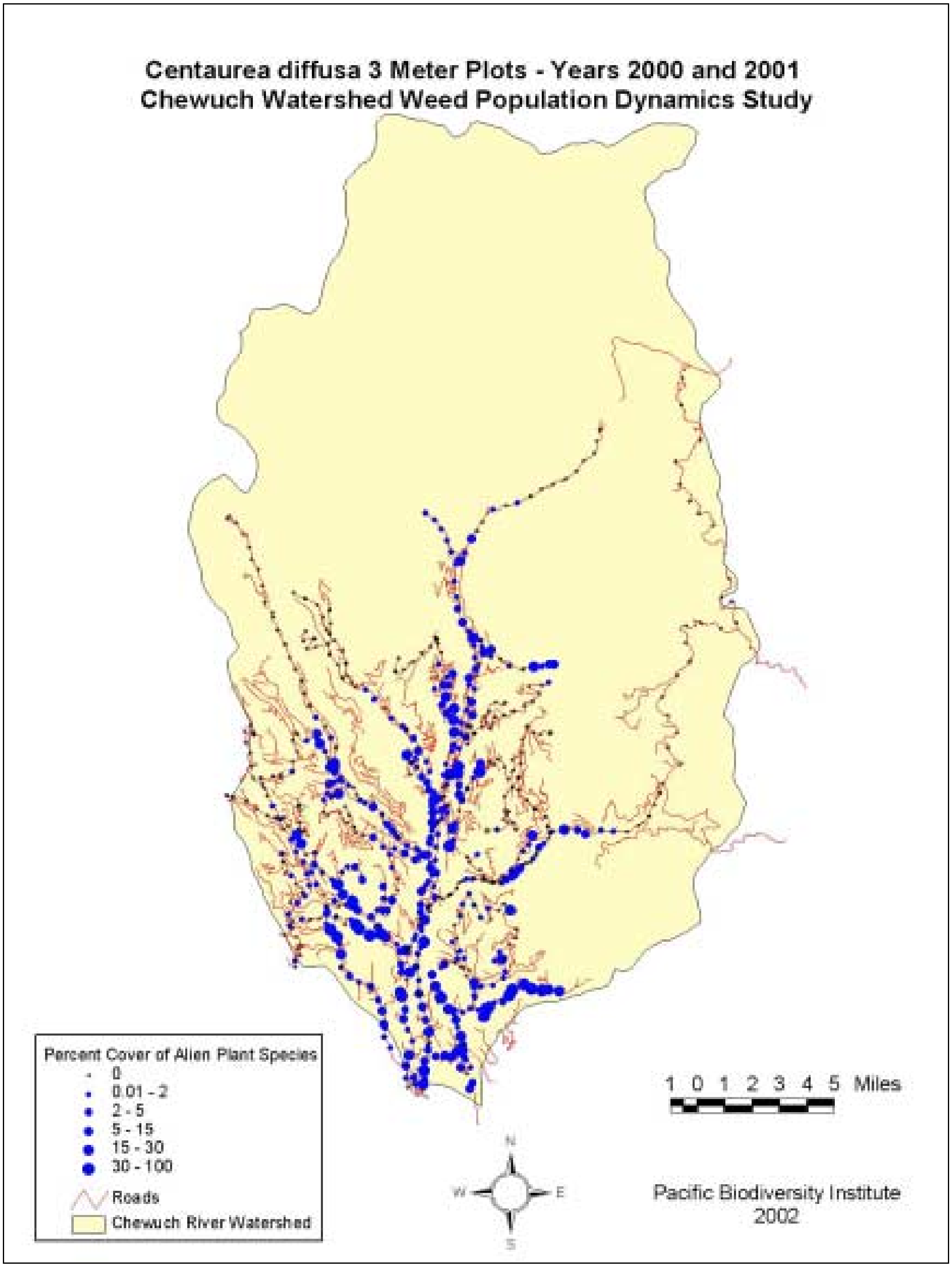
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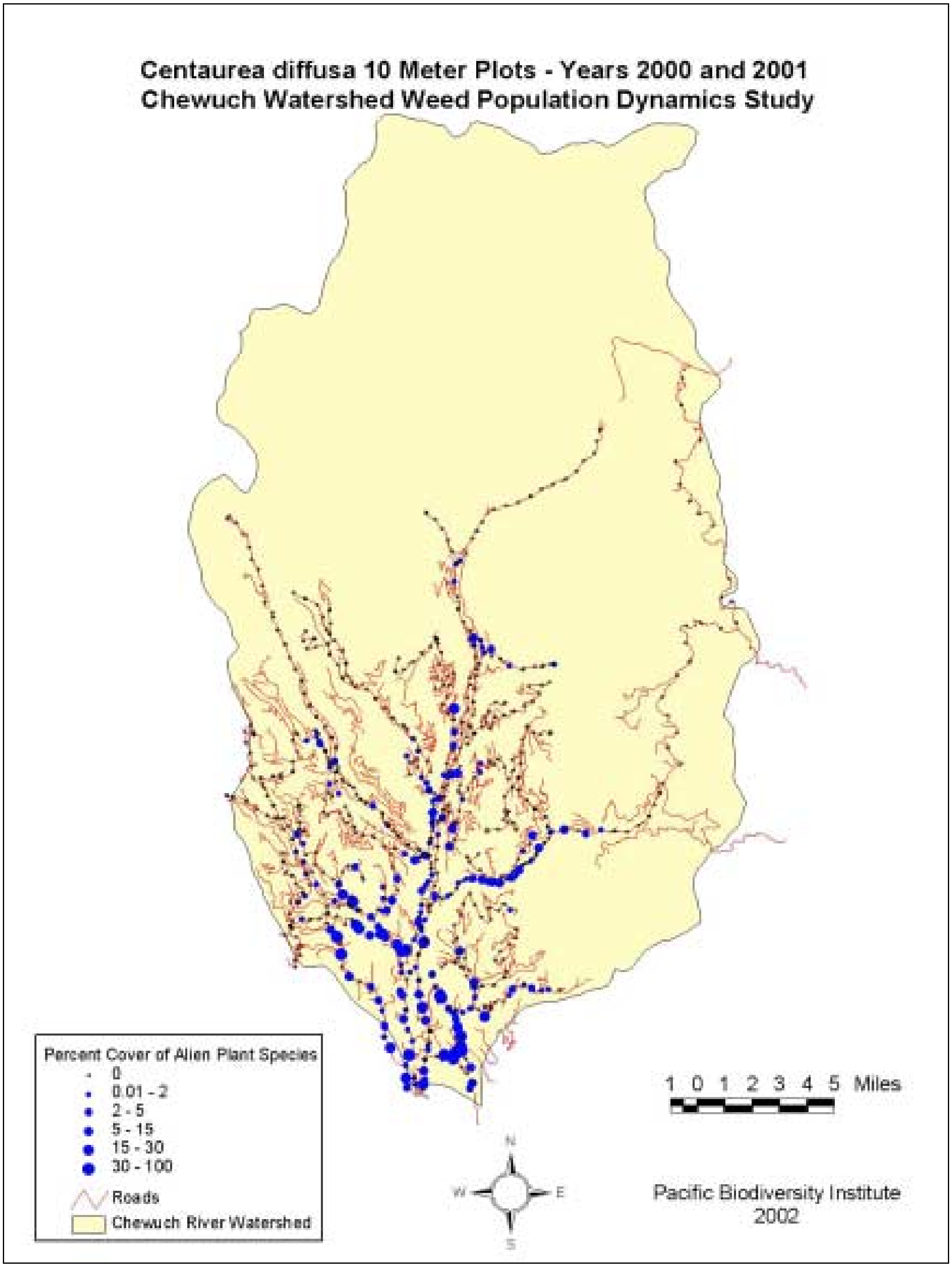
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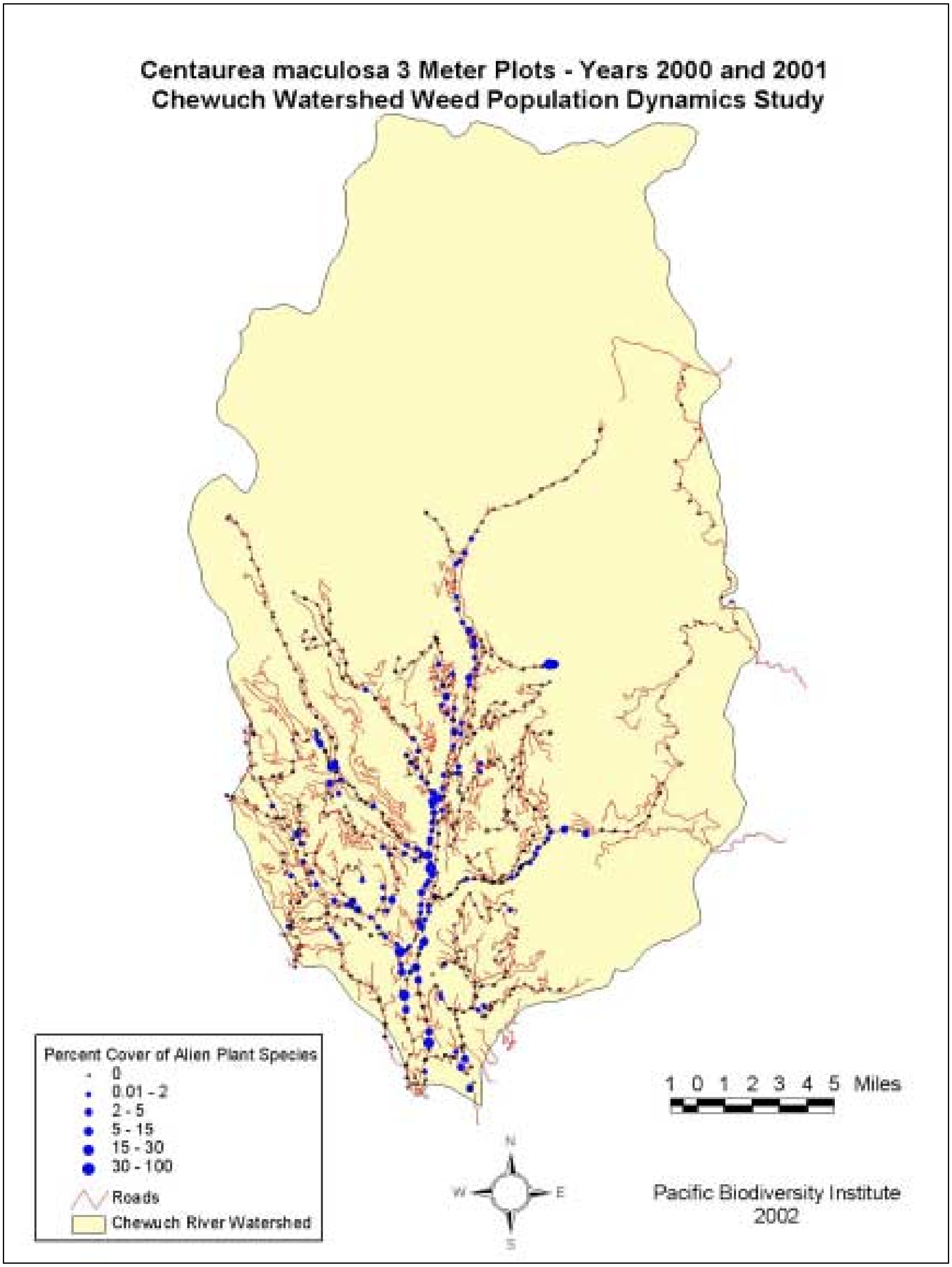

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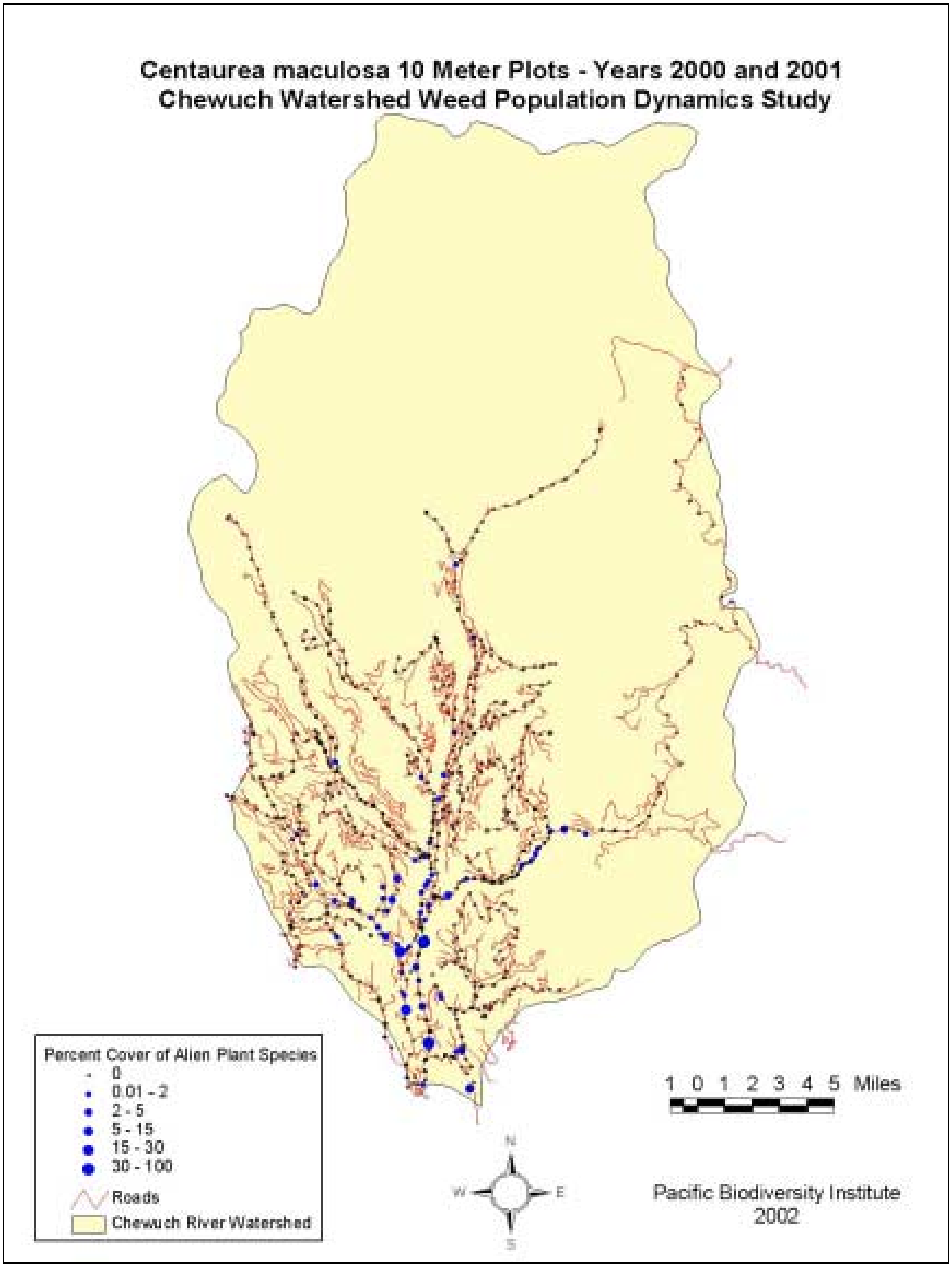
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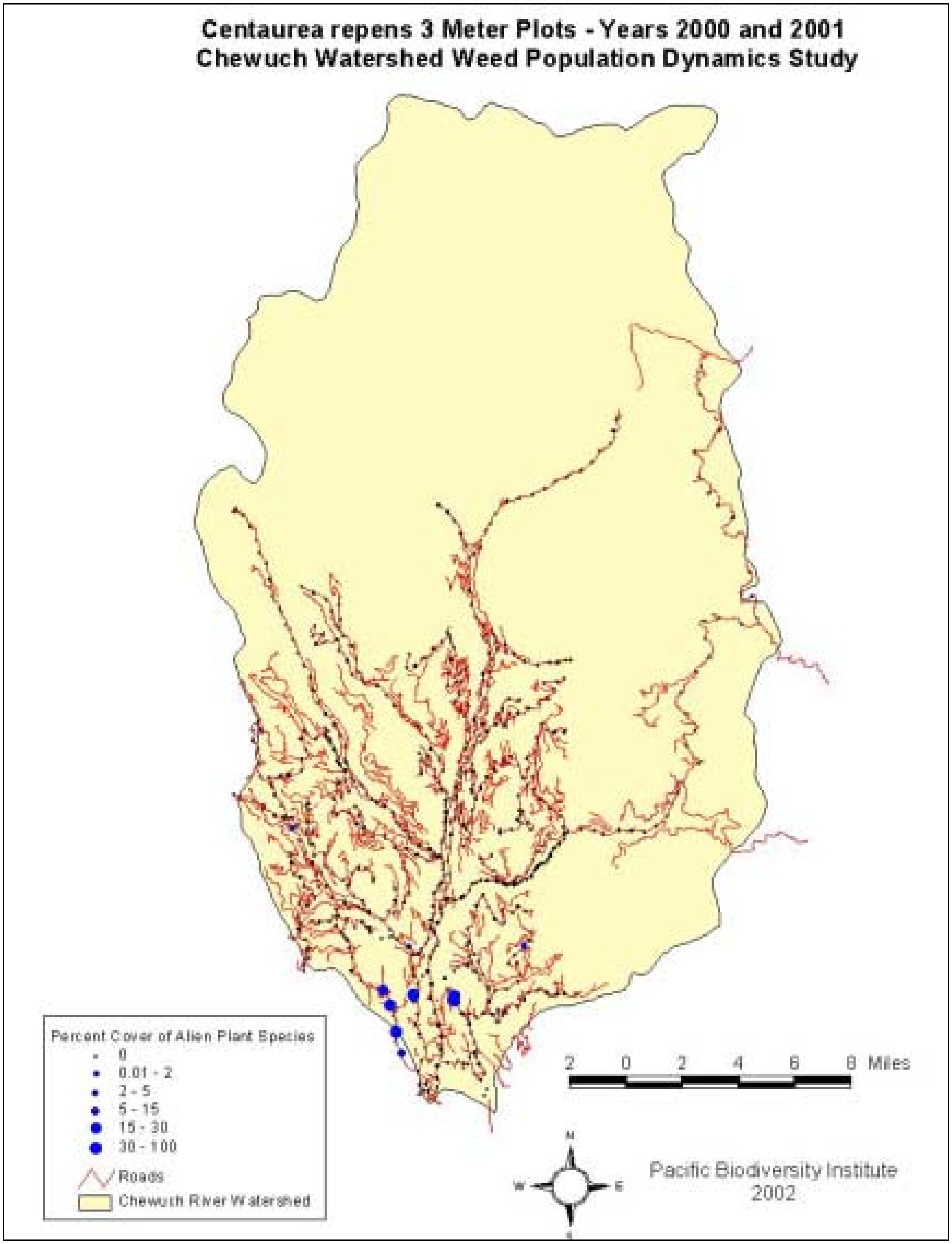
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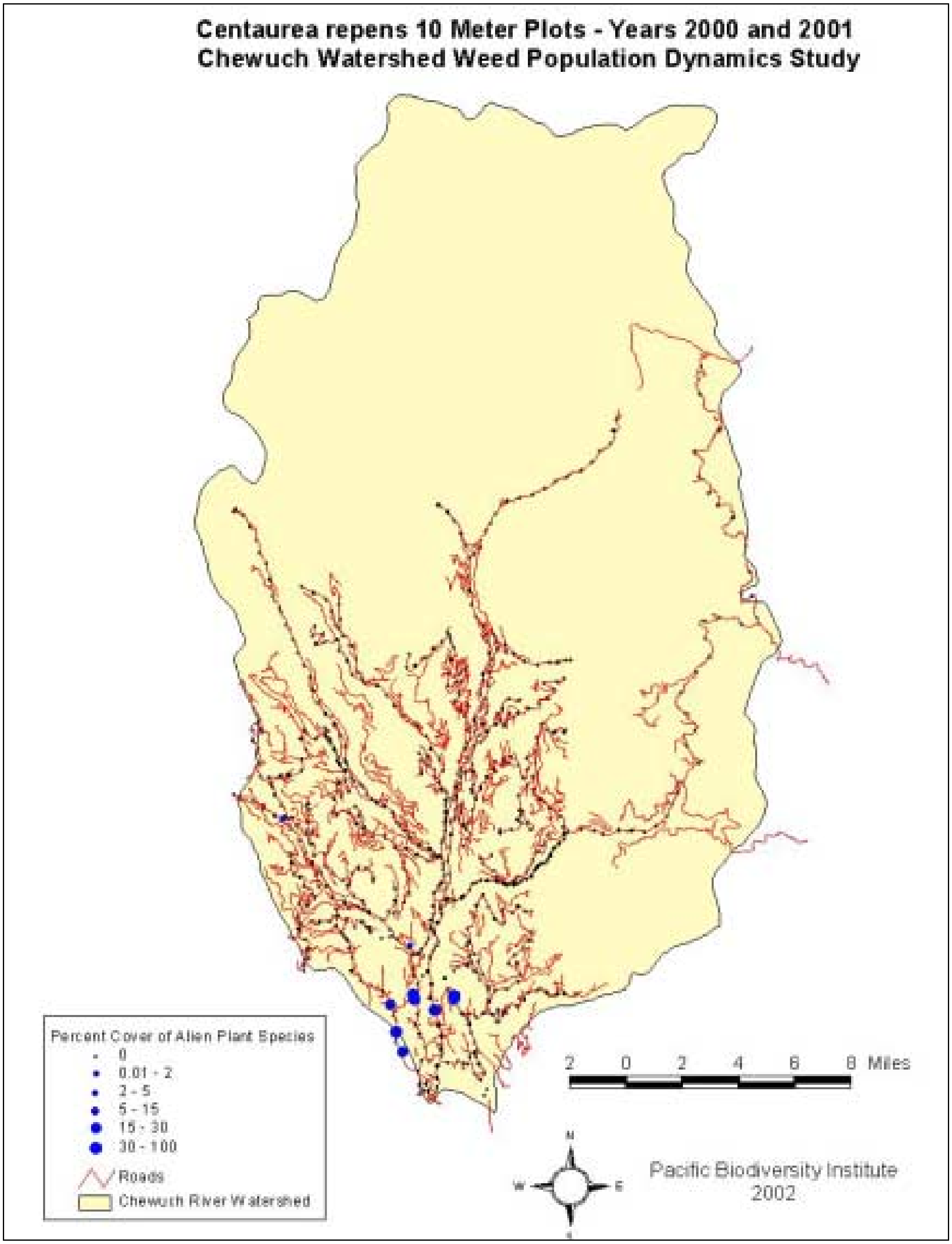
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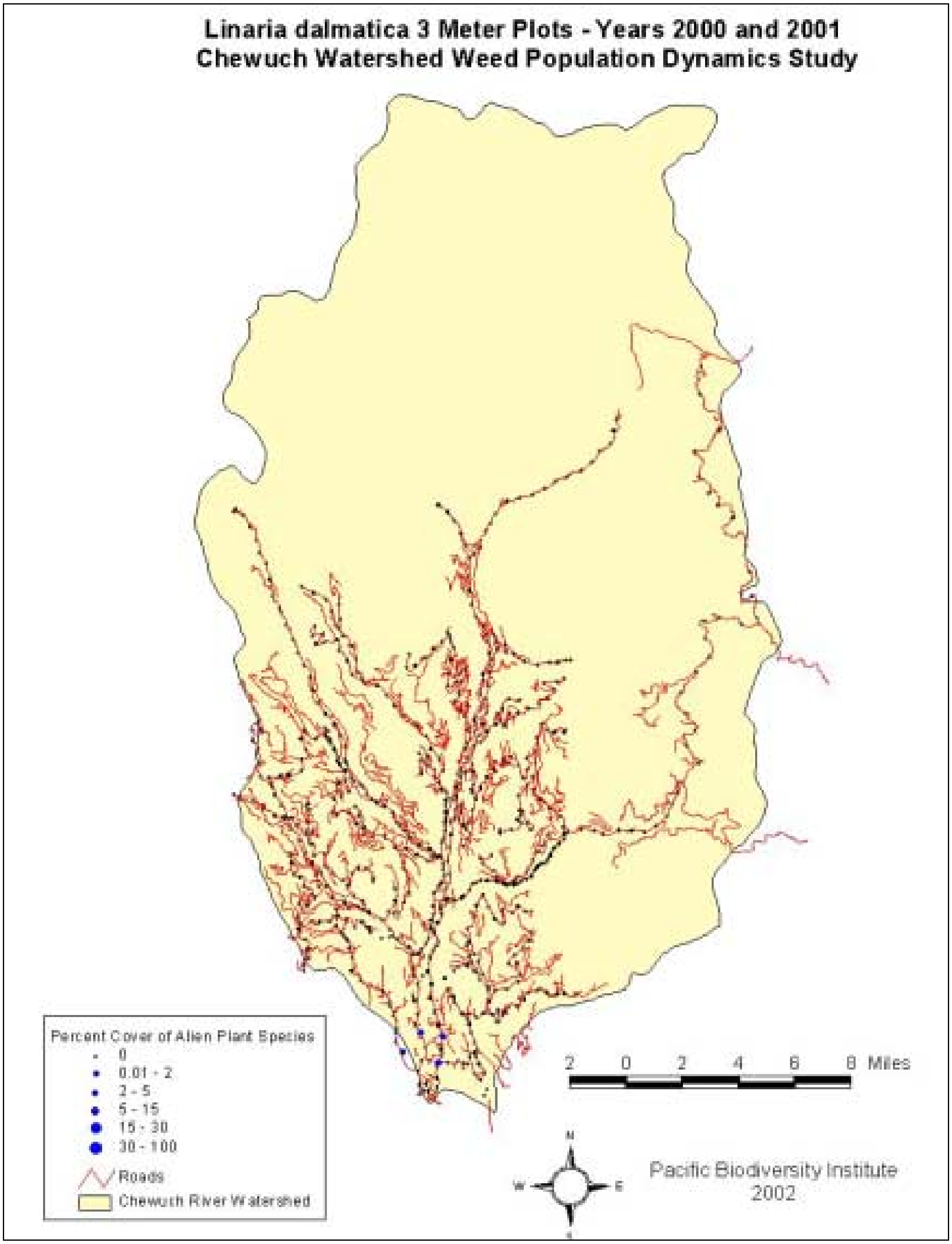
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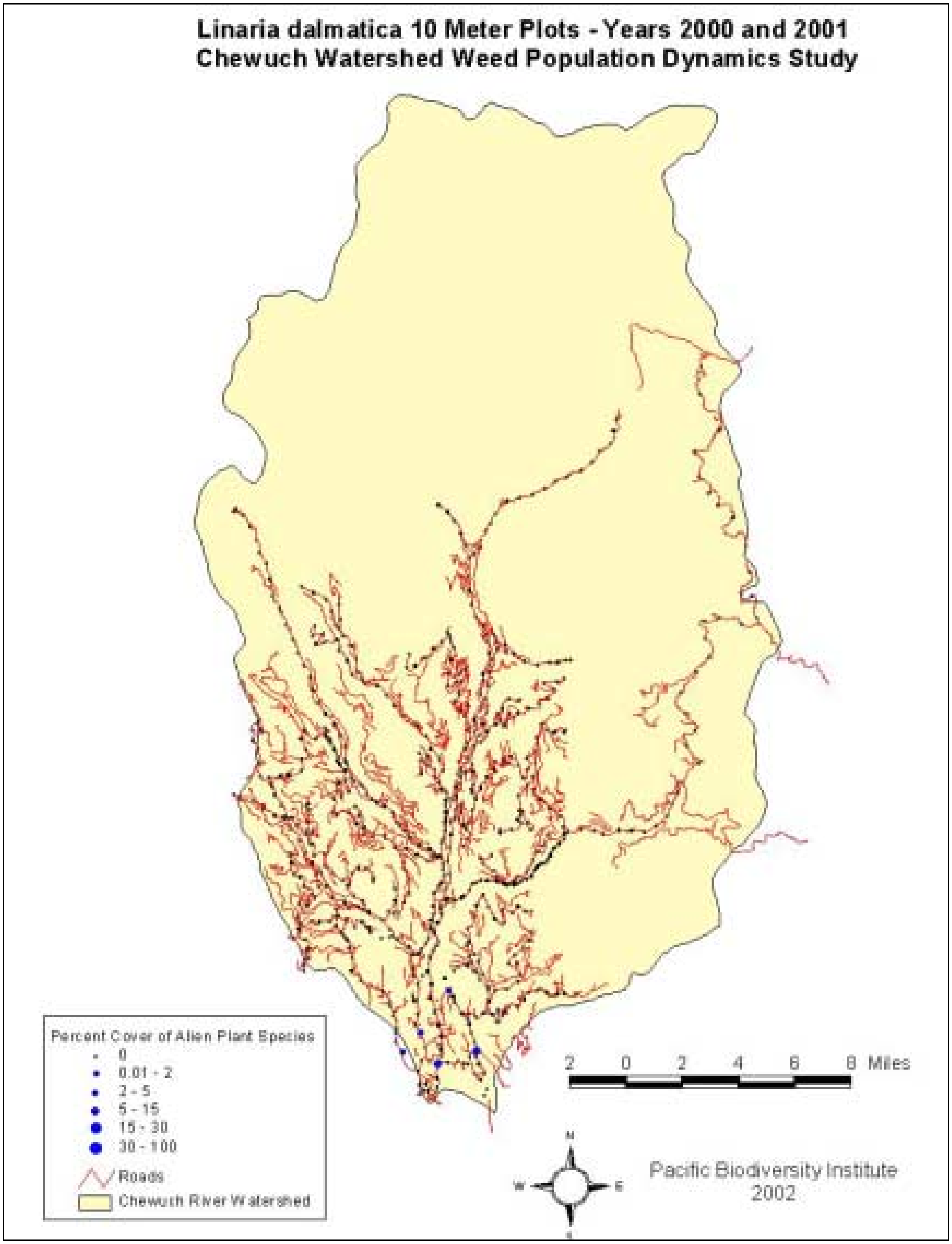
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2002

Discussion of target species distribution

The maps indicate the overall distribution of road plots within the Chewuch watershed. The plot distribution along the road network is broad enough to sample an equitable range of ecological variation in the roaded areas. For practical reasons, the majority of the unroaded areas were not sampled as this part of the study. The rationale for concentrating on roaded areas was supported by the data from the off-road plots, which indicates that the target species occur only at very low frequencies away from roaded areas. The analysis of off-road plots and the measurement of the distributions of invasive species in the unroaded portions of the watershed are planned as a future part of this project.

The maps provide an overall indication of the distribution of the six target species along roads. The species with the widest distribution, *Centaurea diffusa*, is also the species with highest abundances. According to anecdotal accounts, *Centaurea diffusa* experienced its greatest expansion during the 1960s. The abundance of *Centaurea diffusa* is highest immediately adjacent to roads. Its distribution along roads tends to be patchy. Patches are typically densest immediately adjacent to the road edge, where they may cover 100% of a narrow strip about 0.5 meters wide. Many patches drop to less than 1% abundance within 10 meters of the road edge. Factors related to the widespread occurrence of *Centaurea diffusa* along roadsides include road maintenance, soil condition, vehicle traffic, roadside vegetation and roadside herbicide treatments. In understanding more about the biology of *Centaurea diffusa*, it is important to consider specific aspects of its biology, including tolerance of disturbance, tolerance of drought, need for sunlight, seed production and viability, seed transport, pollinators, insect pathogens, and its ability to co-opt nutrients and outcompete other plants.

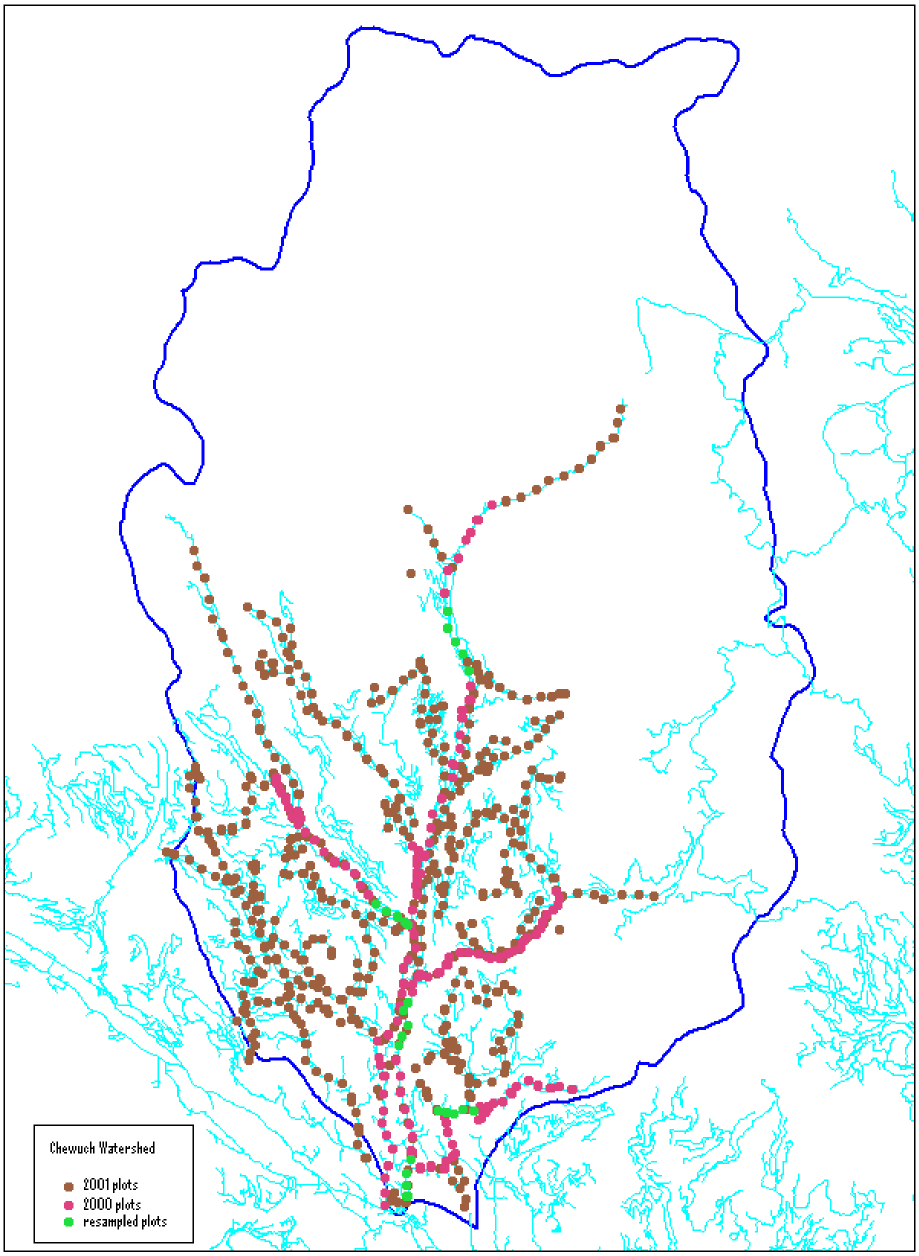
The next most abundant species, *Centaurea maculosa*, has a more limited distribution. Even though this species is morphologically and ecologically similar to *C. diffusa*, it is apparently a more recent introduction into the watershed, and only began spreading in the 1990s from a site near the outlet of Eightmile Creek. In the intervening decade since it first began to undergo rapid expansion, it has moved up to 20 miles in all directions. Like *C. diffusa*, its presence and abundance is strongly correlated with proximity to roads. *C. maculosa* appears to prefer somewhat more mesic habitats than *C. diffusa.*

The remaining species were much more limited in their distribution. These were *Centaurea repens, Linaria dalmatica, Cardaria draba,* and *Cardaria pubescens. Linaria dalmatica* underwent a rapid expansion from what was just a small population near Winthrop in the late 1970s. Because of this, its status as a noxious weed was upgraded to Class B in 1998. *L. dalmatica* was observed invading areas further from the road than the other target species. Despite its limited range at present, it is the only target species with greater abundance in the 10-m plots. It was observed competing successfully with *Centaurea diffusa* and can successfully spread via both rhizomes as well as seeds. The two species of *Cardaria* and *Centaurea repens* reach their greatest abundance in areas that have more surface moisture. Along the drier sites that we sampled, their distribution is more occasional and they are less apt to attain dominance.

C. Trend Analysis for resampled plots

In June 2002, 48 waypoints along five sections of road were selected for resampling the 2000 plots. Each of the 48 waypoints was located on opposite sides of the road, and had both a 3-m and 10-m sub-plot, for a total of 96 sub-plots. The goals of this experiment were to test the reproducibility of the data, and to observe population trends of the target species over two years.

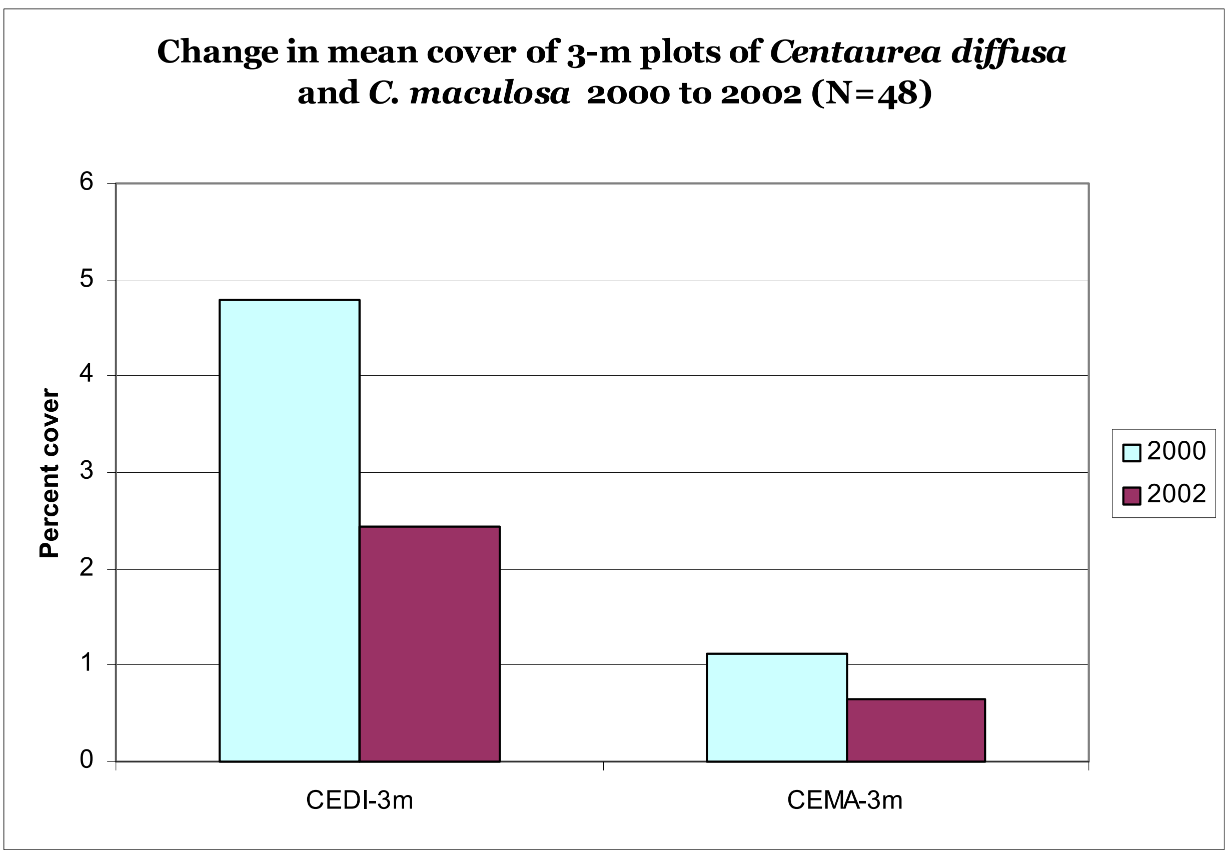
Resample plots. The following map shows resample and road plots established in 2001 and 2002 in the Chewuch Watershed.

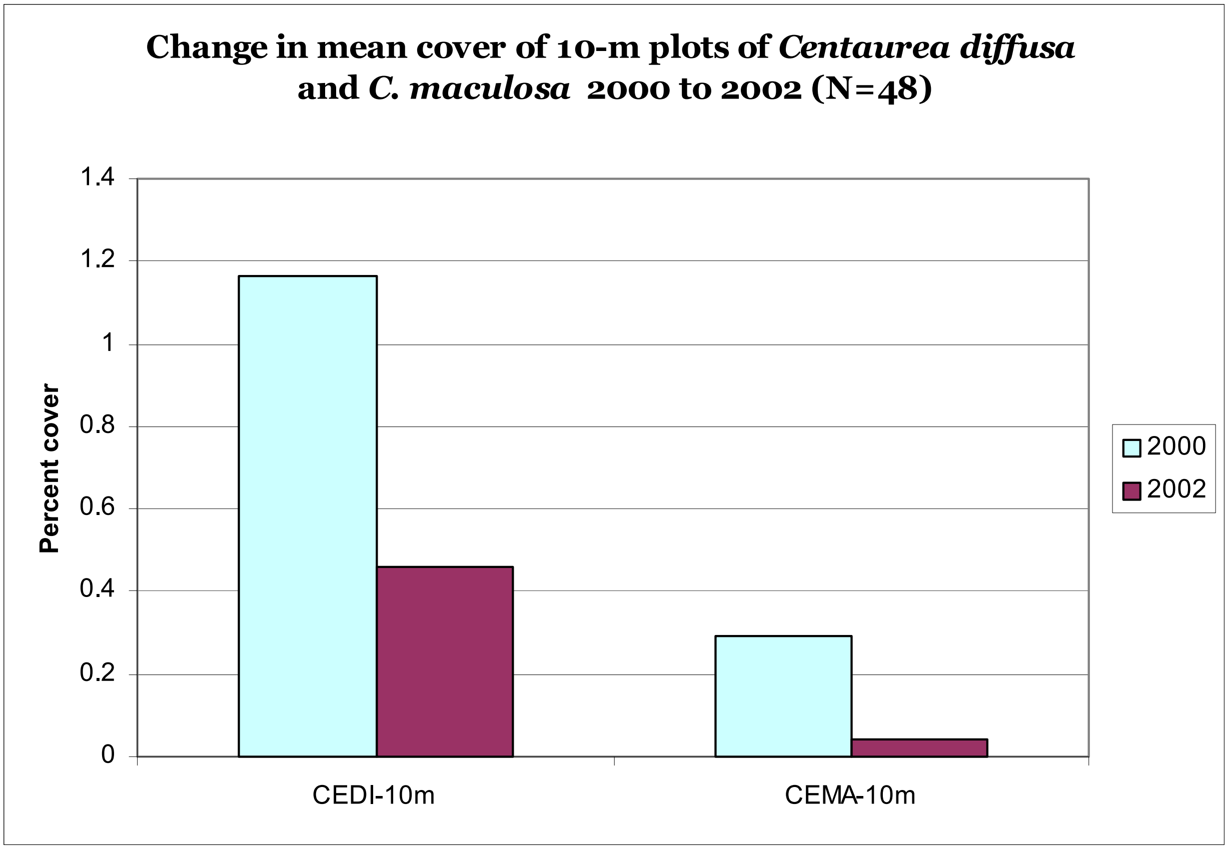


The reliability and precision of the resampled GPS locations was somewhat problematic. The accuracy of waypoint recordings was typically on the order of 5 meters or more. The accuracy was improved by the use of descriptions of the data location, and by the use of printed aerial imagery showing the paired waypoints at each road station. The observers felt that the overall precision of the resampled plot locations was within 5 meters of the original location. Unfortunately, this is about equal to the plot diameter of 6 meters, lowering the confidence in the precision of the resampled locations. In order to accurately resample plots of this size, it will be necessary to physically mark plots on the ground with permanent stakes at the plot centers.

Four of the target weed species were observed in the resampled plots. These were diffuse knapweed (*Centaurea diffusa*), spotted knapweed (*Centaurea maculosa*), Dalmatian toadflax (*Linaria dalmatica*), and whitetop (*Cardaria draba*). Dalmatian toadflax and whitetop were each present in only a single plot, both in 2002; no Russian knapweed (*Centaurea repens*), or hoary whitetop (*Cardaria pubenscens*) was observed in or adjacent to any of the plots resampled in 2002.

The most commonly observed species in both 2000 and 2002 was diffuse knapweed, followed by spotted knapweed. Overall, there was a trend showing decreased target species coverage, as illustrated in these charts for these two species, for both the 3-m and 10-m plots:





It is also apparent from these charts that on both years, the plots with their centers located 10 meters from the road edge have a much lower percent cover.

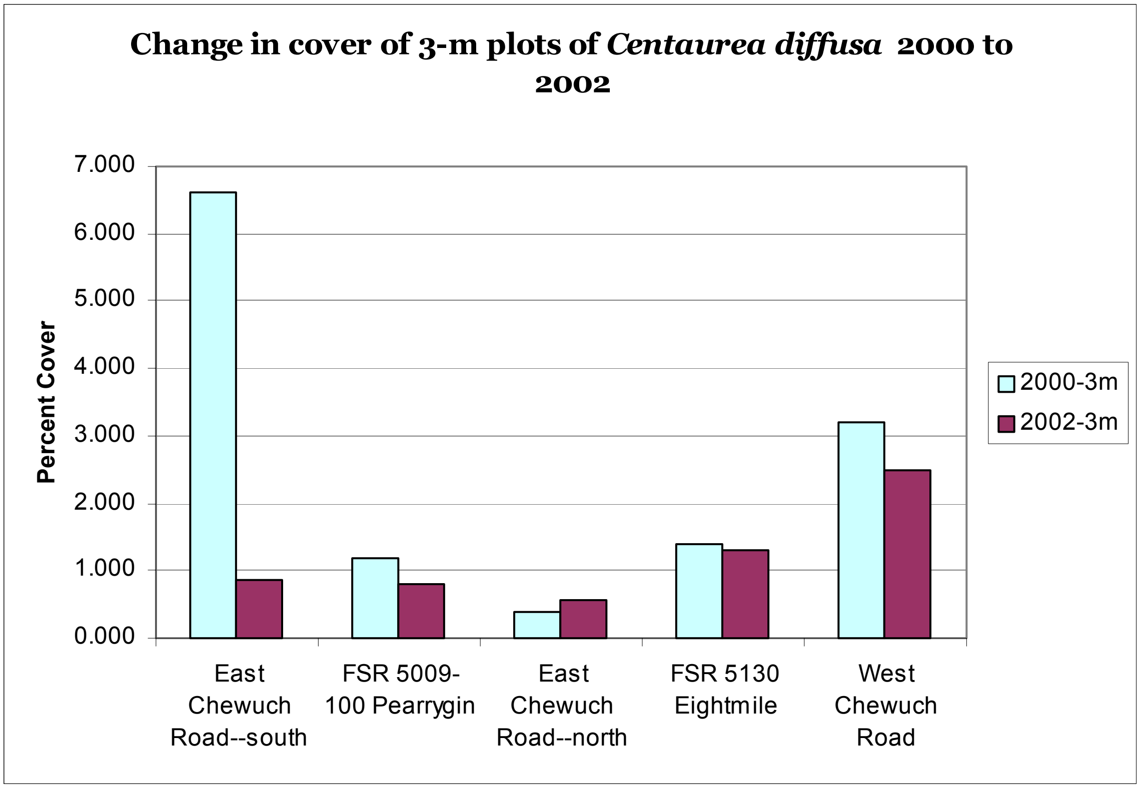
Trends by road segment

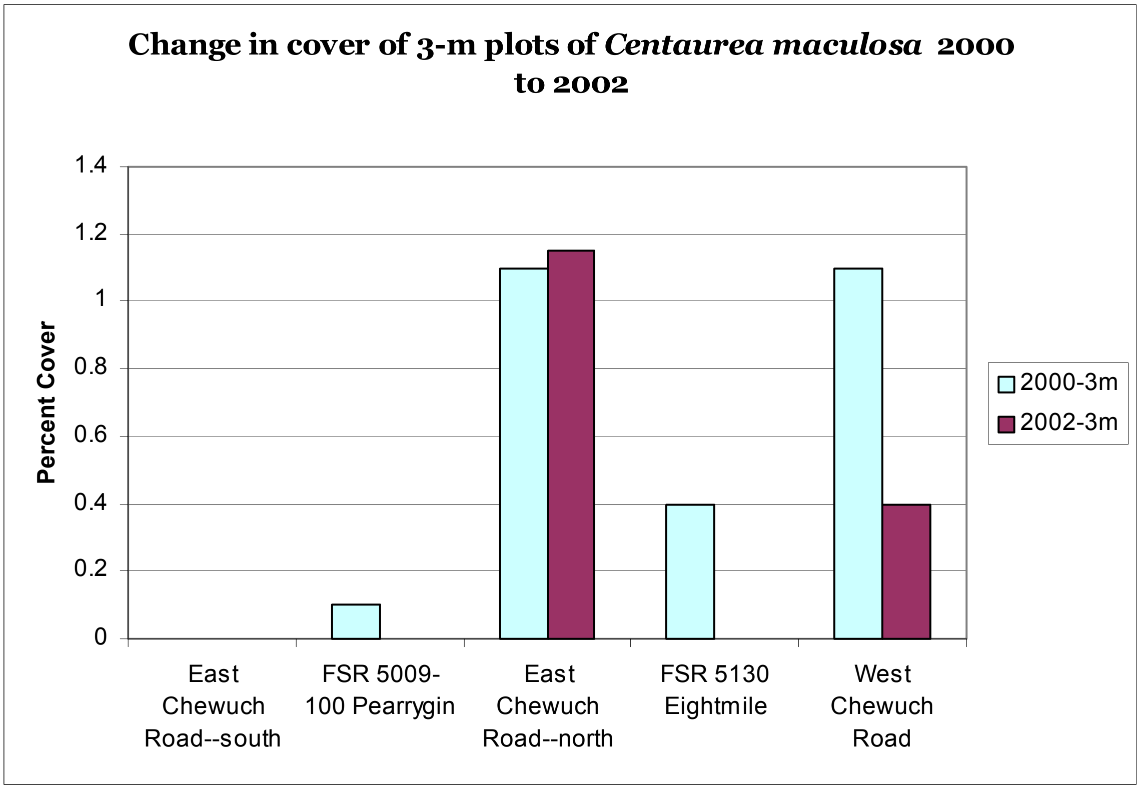
The 96 sub-plots were grouped into 5 stretches of road to compare the response of the target species between areas with different environmental factors such as road disturbance, canopy cover and ownership.

- **East Chewuch Road (1- south end)**: Plots 1-4, going north (6/13/02 to 6/14/02). These four plots are located immediately north of the town of Winthrop adjacent to privately owned lands.
- **Forest Service Road #5009 100 and 300**: Plots 5-8 (6/17/02-6/18/02) and plot 9 (6/18/02). These five plots are on an unimproved road near Pearrygin Lake and Sullivan Pond on state-managed lands.
- **East Chewuch Road (2 – north end) and National Forest Road #37 (Boulder Creek)**: The first three plots (10-12, 6/20/02) are located near the northern end of the East County Road, and the last two plots (13-14, 6/20/02) are on National Forest Road No. 37 on Boulder Creek. The adjacent ownerships are state and federal.
- **Forest Service Road #5130**: These five plots (15-19, 6/21/02) are located along the road on Eightmile Creek, starting approximately 1 mile up the road. The land is National Forest.

- **West Chewuch Road**: These five plots (20-24, 6/27/02) are located about 18 miles north of Winthrop on the West Chewuch Road within National Forest lands.

Because of their small sample size and sampling errors, the data in these smaller sets of plots are not significant, however the trends indicate that the overall decline in the two species of knapweed is occurring at different rates in different areas. The data for *Centaurea diffusa* and *C. maculosa* in the plots located 3 m from the road is illustrated in the following charts:





East Chewuch Road (near Winthrop)
The only target weed species observed in plots along this stretch of road was diffuse knapweed, *Centaurea diffusa*. In 2000, there was a mean of 6.6% cover and 2.9% cover in the 3-m and 10-m plots, respectively. In 2002, the mean cover was 0.9% and 0.3%, respectively, for 3-m and 10-m plots, a decrease of approximately 87% and 91%. A number of other alien species were observed within and between the plots on both years, however large patches of diffuse knapweed which were observed between plots in 2000 had decreased to only scattered individuals in 2002.

Forest Service Road #5009-100 &5009-300 (Pearrygin Lake area):
In 2000, diffuse knapweed was observed at a mean of 1.2% and 0.4% cover in the 3-m and 10-m plots, respectively. In 2002, the mean coverage was 0.8% and 0.2%, respectively. Spotted knapweed, *Centaurea maculosa*, was observed at 1% cover on one 3-m plot along this stretch of road in 2000, but was not seen in any other plots or surrounding areas in 2000 or in 2002. In 2002, whitetop, *Cardaria draba*, was observed as a monoclone patch covering 45% of one 3-m plot and 77% of the nearest 10-m plot (a mean of 4.5% and 7.7%, respectively, for the stretch of road). The only other observation of this species in the 2002 resample survey was in a 25-m radius patch adjacent to these plots. This species was not observed in any of the plots or noted in surrounding areas in 2000. The observation of these two large patches in 2002, but not in 2000, is believed to be due to imprecision in relocating the waypoints, compounded by omission of the observation as an adjacent species in 2000.

East Chewuch Road (2-north end) and Road #37 (Boulder Creek):

Spotted and diffuse knapweed were both observed along this stretch of road. In 2000, diffuse knapweed was present at a mean of 0.4% and 0.1% at the 3-m and 10-m plots, respectively, and in 2002 the mean cover slightly increased to 0.6% and 0.1%. Although there was no record of observed diffuse knapweed outside of the plots in 2000, this may have due to confusion with spotted knapweed on the part of the 2000 observers, as both species were observed between all the plots in 2002. This road segment had the highest cover of spotted knapweed of all the roads resampled. Spotted knapweed covered a mean of 1.1% and 0.6% of the 3-m and 10-m plots, respectively, in 2000. In 2002 its cover was about the same with a mean of 1.1% and 0.1%, respectively.

Forest Service Road #5130 on Eightmile Creek:
Spotted and diffuse knapweed were both observed along this stretch of road in 2000, but in 2002 only diffuse knapweed was observed. In 2000, diffuse knapweed was present at a mean cover of 1.4% cover in the 3-m plots, while it was absent from the 10-m plots. In 2002, its cover was essentially unchanged in the 3-m plots with a mean of 1.3%, while it had increased from 0 to 0.5% in the 10-m plots. Large patches of diffuse knapweed were noted between the plots in 2000, but in 2002 only scattered occurrences were observed. In 2000, spotted knapweed was observed in three of the 3-m plots at a mean of 0.4% cover, as well as being observed between plots. It was absent from the 10-m plots. This species was not observed in any plots along this road segment in 2002, nor between the plots.

West Chewuch Road:
Spotted and diffuse knapweed were both observed along this stretch of road in 2000, but in 2002 spotted knapweed was absent. In 2002, diffuse knapweed covered a mean of 3.2% in the 3-m plots, while in 2002, its mean cover had decreased slightly to 2.5%. There was no diffuse knapweed present in the 10-m plots either year, although it was observed along the roadside for the entire stretch of road on both years. In 2000, spotted knapweed was present at a mean cover of 1.1% and 0.1%, respectively, for the 3-m and 10-m plots, as well as being observed along the entire stretch of road. In 2002 spotted knapweed was present in one 3-m plot, at a mean of 0.4% cover for the road segment; it was only observed adjacent to the plots in one small area.

Discussion of trends

Overall, *Centaurea diffusa* decreased its coverage in the 3-m plots by about 50% in two years, from 4.8% to 1.2%. *Centaurea maculosa* also decreased by about half, although it was initially present at lower coverage. The reason for this decrease may be due to changes in road management, climatic factors, herbicide use, roadside seeding or biological controls.

Centaurea diffusa
The observed coverage of this species decreased dramatically along some stretches of road, while remaining about the same in others. Its abundance only increased in a few instances.

The greatest decrease occurred along the stretch of the East Chewuch Road located just north of Winthrop. Along this stretch of road, four species of knapweed biological control insects are well-established: the gall-flies, *Urophora fasciata* and *U. quadrifasciata,* the root-boring beetle, *Sphenoptera jugoslavica* and the seed-head weevil, *Larinus minutus.* The stunted growth and stocky appearance of much of the diffuse knapweed along this stretch of road indicates presence of *Sphenoptera jugoslavica*, whose root-boring larvae excavate the roots of knapweed species. *Sphenoptera* beetles were first introduced to Okanogan County in the late 1980s. *Larinus minutus,* a seed-head weevil, was introduced in 1999 in Methow Valley, and has only been in the US since 1991. The species feeds on the leaves, seeds, and flowers of both spotted and diffuse knapweed, with a slight preference for diffuse knapweed. It has proven to effectively reduce seed production in both types of knapweed in other studies (Seastedt, 2003).

Another potential cause for knapweed decrease in this area may be the use of herbicides along the East Chewuch road, but this has not been confirmed.

Presence of diffuse knapweed in areas adjacent to the resurveyed plots seemed to be relatively unchanged between the two study years. Small differences in total percent cover could be attributed to individual observer differences, small population fluctuations, differences in plot location between years, and in the differenct notation for trace cover (<1%). *Larinus minutus* was not abundant along 4 of the 5 stretches of road. Since this weevil is a new introduction, its impact on knapweed species is just beginning.

Along FSR #5130, diffuse knapweed is now present in some of the 10-m plots where it was absent in 2000. This indicates that can rapidly invade an area despite its overall decline, or in some areas, relative stability (as in the 3-m plots in this stretch).

It is difficult to make comparisons of between-plot diffuse knapweed presence between years because its presence was noted but not quantified.

Centaurea maculosa
Spotted knapweed was observed along four of five stretches of road in 2000, but on only two of those stretches in 2002. While this limited study suggests it is in decline, there were identification problems in 2002 partly because the initial survey was conducted much earlier in the season than in 2000 and also because many plants did not mature (when they can be identified with confidence) due to a severe drought. The 2000 surveys were performed in August and September. Conversely, some of the 2000 identifications may have been in error due to the lateness of the season.

Cardaria draba
Whitetop was only present in one plot in 2002 and was not noted at all in 2000. Since there is no record of this species along that stretch of road in 2000, the two patches of whitetop that were observed in 2002 either managed to establish two patches over 3 m across in two years or else the patches were simply outside the plot and not noticed in 2000.

Linaria dalmatica
Since Dalmatian toadflax was only present in a single plot in 2002, no conclusions can be drawn about trends from the resampling survey.

Overall observations

The observed decline in the relative abundance of *Centaurea diffusa* may signal the end of 30 years of explosive growth of this species. It is important to identify possible mechanisms responsible for changes in populations as a prerequisite to testing for relationships. Major factors which may be contributing to the relative abundance of *Centaurea diffusa* and *C. maculosa* in this watershed include roadside seeding programs, introduction of biological controls for knapweed, road grading, seed transport, agricultural practices, soil disturbance, cattle grazing and herbicide treatments. The interaction of these factors is complex, and in addition, both 2001 and 2002 were significant drought years.

The effect of herbicide treatments on the decline of the two knapweed species can only be indirectly inferred because the Okanogan National Forest did not treat any of the sampled roads during the time period from 2000 to 2002. An extensive herbicide treatment of some of the sampled roads occurred in 1999, using the herbicides picloram and glyphosate. But the abundance of the two knapweed species after these treatments is possible evidence that the herbicide treatments were not as successful as weed control planners had hoped.

It is possible that the observed decline in abundance of *Centaurea* species is partly due to the presence of residual herbicides from the 1999 treatments. However this does not fit the observance that *Centaurea diffusa* decreased as much in the 10-m plots as in the 3-m plots, since herbicides were primarily used within 10 feet (ca. 3 m) of roadsides. Further review of the herbicide treatment protocol may be able to resolve this.

Roadside revegetation efforts occurred throughout the watershed, primarily through seeding grasses along roadsides. The 1999 herbicide treatments were followed by reseeding grasses along roadsides. In addition, we observed a number of sample stations on private right-of-ways that had recently been replanted. It is reasonable that competition from grasses is helping to reduce *Centaurea* populations, however the extent of the contribution from grass competition is impossible to quantify from this data.

Another factor contributing to the decline of *Centaurea diffusa* is the recent introduction of the seed-head weevil, *Larinus minutus*, into the Chewuch watershed. Since its introduction into the Chewuch Watershed the late 1990s, it has spread throughout all of the lower valleys. In 2000 it was not observed in any of the plots, but by 2002, it was found to be common along the main road near Winthrop. Introduced *Larinus* species have contributed strongly to a decline in *Centaurea* abundance in other studies. In a Colorado study Seastedt et. al. (2003), found that *Larinus minutus* introduction accompanied a decline in well-established *Centaurea* populations from 15% to 2%.

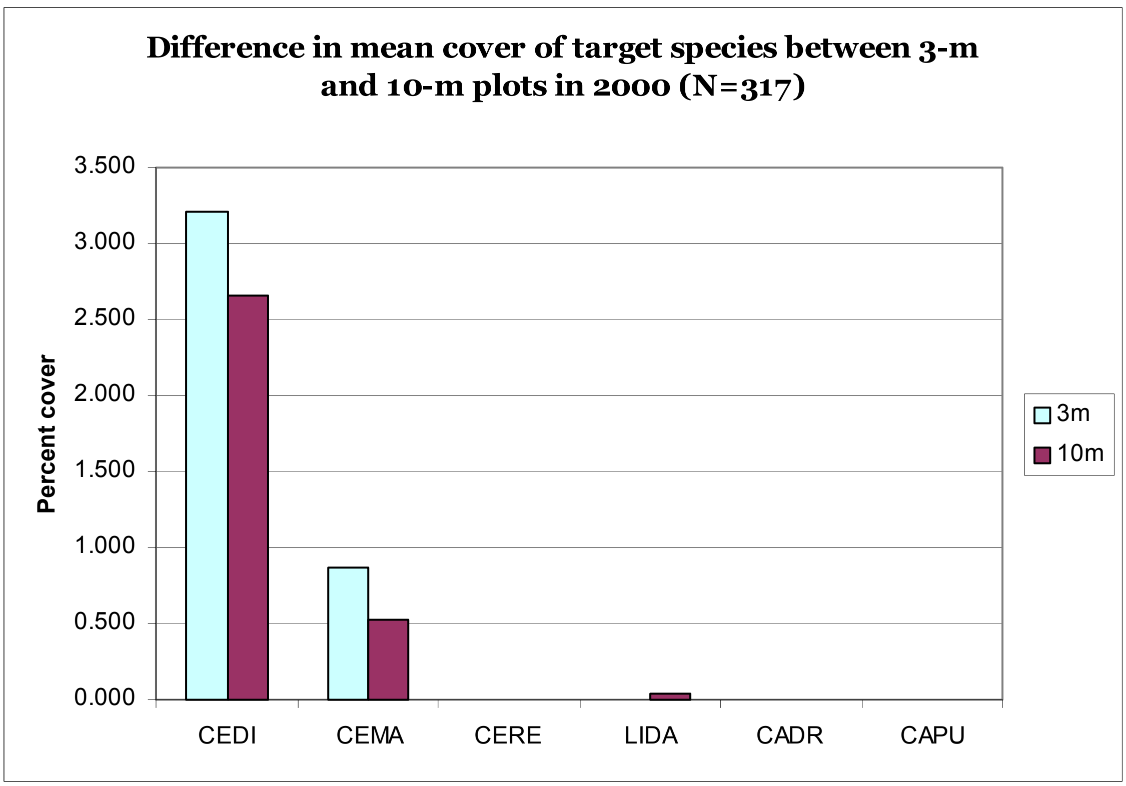
Other factors such as vehicle use and road maintenance are essentially unchanged on the sampled areas, and therefore should not have contributed to the observed decline in abundance of *Centaurea* species. Further study on the relationship to cattle grazing is planned as part of this study.

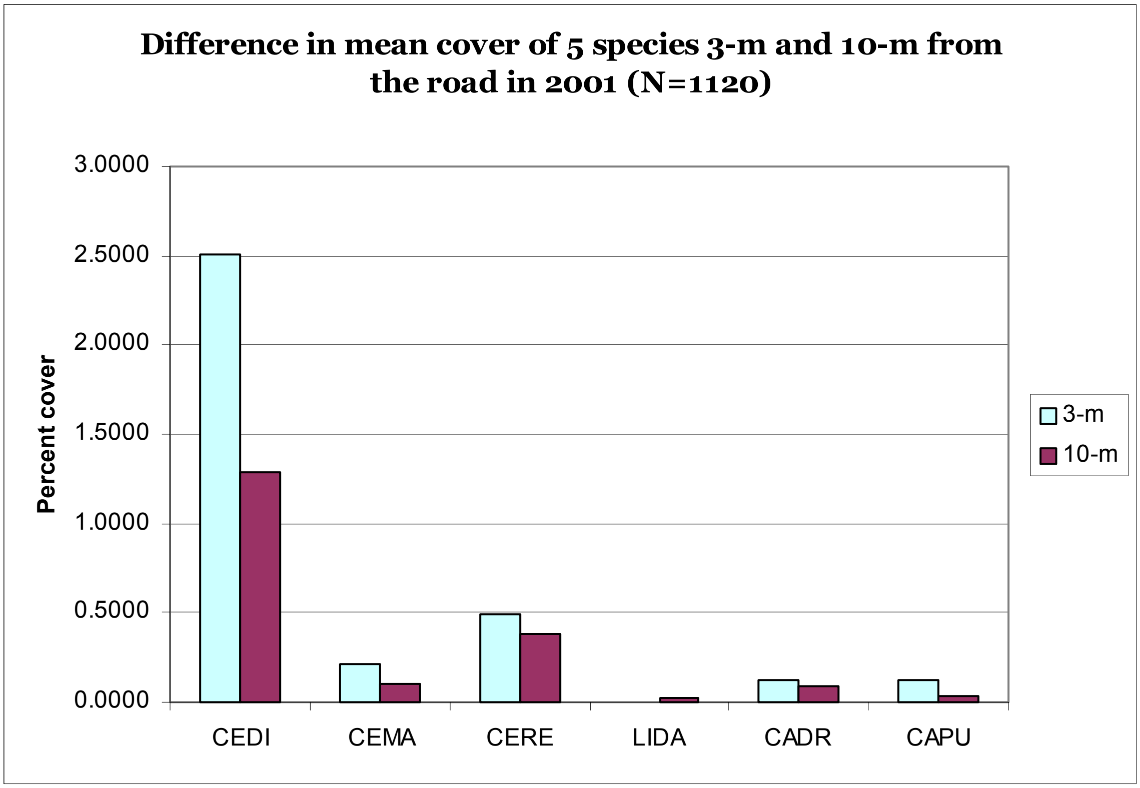
When combined with an analysis of road proximity, the relative importance of these different factors on the overall decline of the two species of *Centaurea* can be inferred.

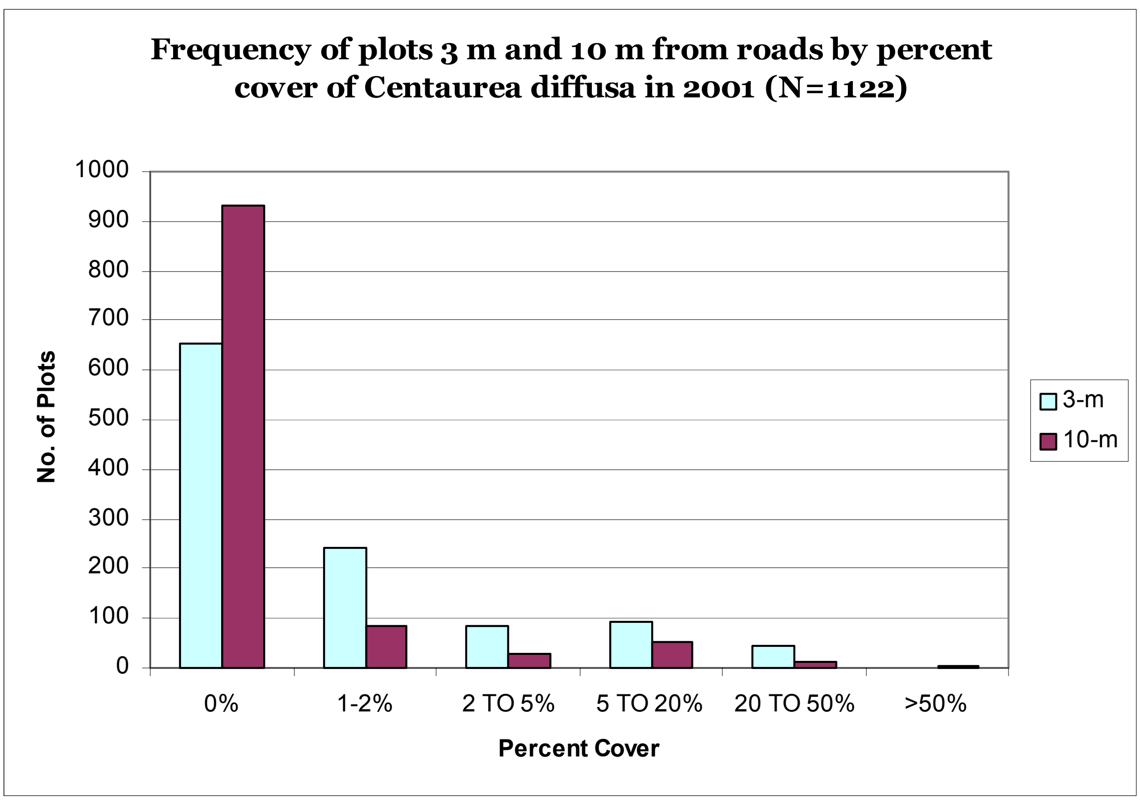
D. Influence of road proximity

The influence of road proximity on the target species was tested by comparing the difference in mean cover between the pair of sub-plots 3 meters and 10 meters from the road. There were 317 pairs of these sub-plots in 2000 and 1122 in 2001. Additional analyses of off-road plots are underway that will add to this study.

The following graphs compare the differences between plots 3 m and 10 m from the road.




Difference in mean cover of 5 species 3-m and 10-m from the road in 2001 (N=1120)
3.0000
2.5000
2.0000
1.5000
1.0000
0.5000
0.0000
Percent cover
CEDI
CEMA
CERE
LIDA
CADR
CAPU
3-m
10-m


Frequency of plots 3 m and 10 m from roads by percent cover of Centaurea diffusa in 2001 (N=1122)
1000
900
800
700
600
500
400
300
200
100
0
No. of Plots
0%
1-2%
2 TO 5%
5 TO 20%
20 TO 50%
>50%
Percent Cover
3-m
10-m

Discussion of influence of road proximity in conjunction with overall trends

In 2001, all of the target species except Dalmatian toadflax (*Linaria dalmatica*) decreased in abundance with increasing distance from the road. In the 2000 data set, this same relative difference was observed for the three species that were observed, i.e., *Centaurea diffusa* and *C. maculosa* cover was lower in the 10-m plots, while *Linaria dalmatica* cover was higher in the 10-m plots.

The frequency of cover classes in the 2001 data indicates that the number of plots with no *Centaurea diffusa* at all is greater for the 10-m plots than the 3-m plots (931 vs. 634). There are consistently half as many 10-meter plots as 3-m plots containing any given abundance of *Centaurea diffusa*.

A number of factors might possibly have influenced the observed lower abundance of *Centaurea diffusa* and *C. maculosa* in the sub-plots further from the road. These include roadside seeding efforts, introduction of the biological control agents, road maintenance, seed transport mechanisms and herbicides.

By considering the results of the trend analysis given in Section C in conjunction with the effects of road proximity, the overall importance of these different factors on the relative decline of the two species of *Centaurea* can be inferred.

Both *Centarea diffusa* and *C. maculosa* decreased in abundance by approximately 50% between 2000 and 2002 for *both* the 3-m as well as the 10-m plots. Therefore, the decline in abundance appears to be independent of the effect of roads, indicating that the major influence is environmental. Two environmental factors changed significantly between 2000 and 2002—climate and the presence of biological controls. After the 2000 data was collected, the subsequent two years suffered a severe drought. Also in 2002, the biological control agent *Larinus minutus* was frequently observed for the first time in the Chewuch watershed on *Centaurea diffusa* and *C. maculosa*.

To determine which of these factors is predominantly responsible for the decline in abundance of in *Centaurea diffusa* and *C. maculosa* will probably become clear over the next few years as the biological control agents become more widespread. The hypothesis that biological controls are responsible for the decline is consistent with the observation that *Linaria dalmatica* abundance is slightly higher in the 10-m plots. However, it is difficult to explain how *Larinus* could have become so effective in such a short time since its introduction in 1999.

Surveyors first noticed *Larinus minutus* along the main roads of the Chewuch bottomlands in 2002. Ann George, a resident of the Chewuch Valley, first introduced *Larinus minutus* into the drainage at several sites near her Winthrop property in 1999. It is possible that the insects were present in our plots in 2000 or 2001, but were simply not noticed by the surveyors. If *Larinus minutus* was present in the study area in 2001, then the observed reduction is consistent with the findings of Seastedt et. al. (2003).

In Colorado, Seastedt et. al. (2003) observed a decline of *Centaurea diffusa* from 8% to 2% between 2000 and 2001. *Larinus minutus* was released at their study site in 1997, along with 3 other insect predators, and two gall-head flies (*Urophora* spp.) that were already established. Four of the biological insect controls present in the Chewuch watershed are the same as those in the Colorado study. Both gall-head flies have been well-established for years, and in addition, the root-boring beetle, *Sphenoptera jugoslavica*, was established near the Chewuch in the early 1990s. *Sphenoptera jugoslavica* does not kill its host, however its infection rate is close to 100% in the Chewuch watershed and infected plants are noticeably shorter in stature. It is possible that *Sphenoptera* populations had just begun to exert a significant influence on *Centaurea* spp. in the Chewuch watershed, or that its impact was compounded by the presence of *Larinus minutus*.

V. Ongoing plans for further research

We intend to continue this project over at least a ten-year time frame. To determine the population trends of the target weed populations, repeated sampling of the study area will be needed. Preliminary results from the first few years indicate that some fairly dramatic weed population changes are to be expected.

A more detailed analysis is planned to probe the factors that relate to the differences in the range, distribution and abundance of these invasive species. Significance tests need to performed on the data, and amended with additional information where possible. Studies of the relationship to variables such as road disturbance and proximity, herbicide treatment, reseeding, grazing, burning, and logging are underway. Locations of herbicide treatments are being input into ArcView for correlation with the sampled locations. Climate and road treatment data is being gathered for inclusion in the analyses.

We also hope to do more sampling in the unroaded portions of the watershed in the next two years to determine how far the target weed species have invaded these more pristine areas.

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VII. APPENDICES

Appendix A: Quality Control

- Locating Plots/sub-plots: The use of an odometer ensures that distances between plots are accurate and eliminates distance guesswork. Make sure that the odometer is well calibrated and installed correctly on the bicycle.
- GPS Waypoints: This involves setting up a system for recording plot numbers, daily field transects, and naming individual GPS way-points.
- Percent Cover: There are limitations to assuming percent cover totals should approximate 100%. It allows for non-overlapping data points (i.e. Individual percent cover estimates will also depend on which subcategory (i.e. percent aerial cover of target weed species) is estimated first. By measuring percent cover, both aerial and ground, from a five-foot approach, the estimate of bare ground/litter cover estimates may also be under-estimated. Thus, there is the potential for lost information in field data collection. Overall percent cover estimates may also vary with individual observer. Although it is important to recognize the potential for error in data collection, to obtain precision (i.e. repeatability) in sample estimates it is better to sacrifice some accuracy of measurement on each sampling unit in order to increase the total number of sampling units that can be observed with the time available. Repeatability is important in monitoring because it establishes the ability of a method to measure change over time. This is the reason for using stem frequency and percent cover estimates.
- Data Entry: This should be completed directly after fieldwork is completed. It Data cannot be entered the same day as it was collected in the field (i.e. because you are located in a remote setting or time constraints are too great) at least the GPS data points should be downloaded and placed in their appropriate waypoint folder.

Appendix B: Field Materials and Equipment:

Please become familiar with this list of field study materials and equipment. This will save time in the field. You may use this list as a check-off sheet before heading out to conduct fieldwork.

- Bicycle
- Bicycle odometer
- Plant field books
- Spherical densiometer
- Hand lense
- Geographic Poistioning System (GPS)
- Datasheets, pencils/pens
- Digital camera
- Notebook
- Compass
- Tape measure (meters)
- Map(s)

Appendix C: Example Datasheet

Overview Weed Survey
Data Sheet A

Plot Number ________
Date ____________
Observer ________

LOCATION: Direction & Road ______________________
Description ______________________
Elevation ____________ Slope ____________ Aspect ____________

General Vegetation Type ______________________

History/Comments (General) ______________________

Left side **(3 m. plot)** ____________
Steepness: ____________
Erosion: ____________
Disturbance: ____________
Vegetation: ____________
(10 m. plot) ____________
Steepness: ____________
Erosion: ____________
Disturbance: ____________
Vegetation: ____________

Right side **(3 m. plot)** ____________
Steepness: ____________
Erosion: ____________
Disturbance: ____________
Vegetation: ____________
(10 m. plot) ____________
Steepness: ____________
Erosion: ____________
Disturbance: ____________
Vegetation: ____________

	Left Side of Road Waypoint _____ Accuracy_____				Right Side of Road Waypoint _____ Accuracy_____			
	Percent Cover		Stem Frequency		Percent Cover		Stem Frequency	
	3 m	10 m	3 m	10 m	3 m	10 m	3 m	10 m
Cardaria draba								
Cardaria pubescens								
Centaurea diffusa								
Centaurea maculosa								
Centaurea repens								
Linaria dalmatica								
% bare/litter								
% native vegetation								
% other alien veg.								
% canopy cover								
photo numbers								

Weeds seen outside plot ____________none______________________

___ Agropyron repens
___ Artemisia absinthium
___ Bromus tectorum
___ Cardaria draba
___ Cardaria pubescens
___ Carduus nutans
___ Centaurea diffusa
___ Centaurea maculosa
___ Centaurea repens
___ Chrysanthemum leucanthemum
___ Cirsium arvense
___ Cirsium vulgare
___ Cytisus scoparius
___ Gypsophila paniculata
___ Hypericum perforatum
___ Kochia scoparia
___ Linaria dalmatica
___ Poa bulbosa
___ Salsola kali
___ Sisymbrium altissimum
___ Tanacetum vulgare
___ Verbascum thapsus

Appendix D: List of Plant Species observed in the Chewuch Watershed (during 2001 invasive plant studies)

The following lists contain the names of plant species observed in the Chewuch Watershed during invasive species research in 2001. The lists include the plant code, scientific name, common native and whether the plant is native.

Trees
ABILAS – *Abies lasiocarpa* – subalpine fir (native)
ALIN – *Alnus incana*- mountain alder (native)
BETOCC - *Betula occidentalis* – water birch, spring birch, red birch (native)
LAROCC – *Larix occidentalis* – western tamarack/larch (native)
PICENG - *Picea engelmannii* – Engelmann spruce (native)
PINALB – *Pinus albicaulis* – white-bark pine (native)
PINCON - *Pinus contorta var. latifolia* – lodgepole pine (native)
PINPON - *Pinus ponderosa* – ponderosa pine (native)
POPTRE - *Populus tremuloides* – trembling/quaking aspen (native)
POPTRI - *Populus trichocarpa* – black cottonwood (native)
PSEMEN - *Pseudotsuga menziesii* – Douglas fir (native)
ROBPSU – *Robinia pseudoacacia* – robinia (introduced)
SALBEB - *Salix bebbiana* – Bebb willow (native)
SALSCO - *Salix scouleriana* – scouler willow (native)
SALSP - *Salix* sp. - willow
THUPLI – *Thuja plicata* – western red cedar/pacific red cedar (native)
ULMSIB - *Ulmus siberica* – Siberian Elm (native)

Shrubs
ACEGLADOU - *Acer glabrum var. douglasii* – Douglas' maple (native)
AMEALN - *Amelanchier alnifolia* – serviceberry (native)
AMECOL - *Amelanchier columbiana* – (native)
AMESP - *Amelanchier* sp. – serviceberry, shadbush (native)
ARCUVA - *Arctostaphylos uva-ursi* – kinnikinnick, bear berry (native)
ARTABS - *Artemisia absinthium* - wormwood/absinthium (introduced)
ARTTRID - *Artemisia tridentata* – big sagebrush, prairie sage (native)
ARTTRIP - *Artemisia tripartita* – three-tip sagebrush (native)
CEASP - *Ceanothus* sp. – mountain lilac (native)
CORSTO – *Cornus stolonifera* – red-osier dogwood (native)
HOLDIS – *Holodiscus discolor* – oceanspray (native)
JUNCOM - *Juniperus communis* – common juniper (native)
LINBOR - *Linnaea borealis* – twinflower (native)
LONINV - *Lonicera involucrata* – bush honeysuckle, black twin-berry (native)
MAHAQU - *Berberis/Mahonia aquifolium* – shining/tall Oregon grape (native)
PACMYR - *Pachistima myrsinites* – Oregon boxwood (native)
PRUVIR - *Prunus virginiana* – common chokecherry (native)
PUTR - *Purshia tridentata* – bitterbrush (native)
RIBCER – *Ribes cereum* – wax currant (native)

RIBLAC - *Ribes lacustre* – swamp currant/prickly currant (native)
RIBSP – *Ribes sp.* – currant, gooseberries (native)
ROSNUT - *Rosa nutkana* – nootka rose (native)
ROSWOO - *Rosa woodsii* – wild rose, more common (native)
RUBIDA - *Rubus idaeus* - raspberry (native)
RUBPAR - *Rubus parviflorus* – thimbleberry (native)
SHECAN –*Shepherdia canadensis* – russett buffalo-berry (native)
SORSCO - *Sorbus scopulina* – Cascade mountain ash (native)
SPIBET - *Spiraea betulifolia*– birch-leaved spiraea, shiny-leaved spiraea (native)
SYMALB - *Symphoricarpos albus* – common snowberry (native)

Herbaceous species
ACHMIL - *Achillea millefolium* – common yarrow (native)
ADEBIC - *Adenocaulon bicolor* – trail plant, pathfinder (native)
AMARET - *Amaranthus retroflexus* – red root pigweed (introduced)
AMSSP - *Amsinckia spp.* – fiddleneck (native)
ANAMAR - *Anaphalis margaritacea* – pearly everlasting (native)
ANGARG - *Angelica arguta* – tall angelica, sharptooth angelica (native)
ANTMIC - *Antennaria microphylla* – rosy pussy-toes (native)
ANTNEG - *Antennaria neglecta* – field pussy-toes (native)
ANTRAC - *Antennaria racemosa* – raceme pussy-toes (native)
ANTSP – *Antennaria sp.* – pussy-toes (native)
APOAND - *Apocynum androsaemifolium* – Spreading dogbane (native)
ARASP - *Arabis* sp. – rockcress (native)
ASPPRO - *Asperugo procumbens* – madwort (introduced)
ASTMIS - *Astragalus miser* – poverty vetch, weedy milkvetch (native)
BALSAG - *Balsamorhiza sagittata* – arrowleaf balsamroot (native)
BRODOU - *Brodiea douglasii* – wild hyacinth (native)
CALMAC - *Calochortus macrocarpus* – desert tulip, sagebrush mariposa (native)
CAMSP – *Camelina sp.* – mustardweed (Eurasian)
CAPBUR - *Capsella bursa-pastoris* – sheperds purse (introduced)
CARDRA - *Cardaria draba* – hoary cress (non-native)
CARPUB - *Cardaria pubescens* – hairy whitetop (non-native)
CASSP - *Castilleja* sp. – paintbrush (most are native)
CENDIF - *Centaurea diffusa* – diffuse knapweed (non-native)
CENMAC - *Centaurea maculosa* – spotted knapweed (non-native)
CENREP - *Centaurea repens* – Russian knapweed (introduced)
CHADOU - *Chaenactis douglasii* – hoary chaenactis (native)
CHEALB - *Chenopodium album* – lambsquarters (native)
CHEBOT - *Chenopodium botrys* – Jerusalem oak (introduced)
CHEFRE – *Chenopodium fremontii var. atrovirens* – Fremont's goosefoot (native)
CHIUMB – *Chimaphila umbellata* – pipsissewa (native)
CHRLEU - *Chrysanthemum leucanthemum* – oxeye daisy (introduced)
CIRARV - *Cirsium arvense* – Canadian thistle (introduced)
CIRVUL - *Cirsium vulgare* – bull thistle (introduced)
CLELIG - *Clematis ligusticifolia* – western clematis (native)

COLGRA - *Collomia grandiflora* – large flowered collomia – (native)
COLLIN - *Collomia linearis* – narrow-leaf collomia (native)
COLSPA - *Collinsia sparsiflora* – Blue-eyed mary (native)
COLTEN - *Collomia tenella* – Chinese pagodas (native)
CONCAN - *Conyza canadensis* – horsetail (native)
CORCAN – *Cornus canadensis* – bunchberry, dwarf cornel (native)
CORSTO - *Cornus stolonifera* – red-osier dogwood (native)
CRYSP - *Cryptantha* sp. – cryptantha, white forget-me-not (native)
CRYTOR - *Cryptantha torreyana* – torrey's cryptantha (native)
CYTSCO - *Cytisus scoparius* – scot's broom (introduced)
DELNUT - *Delphinium nuttallianum* – larkspur (native)
DESPIN - *Descurainia pinnata* – tansy-mustard (native)
DRASP - *Draba sp.* – draba (native)
EPIANG - *Epilobium angustifolium* – fireweed (native)
EPIGLA - *Epilobium glandulosum* – common willow-nerb (native)
EPIMIN - *Epilobium minutum* – small-flowered willow-weed (native)
EPIPAN - *Epilobium paniculatum* – autumn willow-weed (native)
EPISP - *Epilobium sp.* – willow-herb (native)
EQUARV - *Equisetum arvense* – common horsetail (native)
ERICOR - *Erigeron corymbosus* – three-nerved daisy (native)
ERIELA - *Eriogonum elatum* – Tall buckwheat (native)
ERIFIL - *Erigeron filifolius* – threadleaved daisy/fleabane (native)
ERIHER - *Eriogonum heracliodes* – wyeth buckwheat (native)
ERILIN - *Erigeron linearis* – line-leaf fleabane (native)
ERINIV - *Eriogonum niveum* – snow buckwheat (native)
ERISUB - *Erigeron subtrinervis* – three-veined fleabane (native)
EUPGLY - *Euphorbia glyptosperma* – corregated-seeded spurge (introduced)
FRASP – *Fragaria sp.*- wild strawberry (native)
GAYSP - *Gayophytum* sp. – Ground smoke
GNEMIC – *Gnephalium microcephalum* – white cudweed (introduced)
GRISQU – *Grindellia squarrosa* – curly-cup, gumweed, resinweed (native)
GYPPAN - *Gypsophila paniculata* – baby's breath (introduced)
HABSP - *Habenaria sp.* – bog orchid (native)
HELDOU - *Helianthella douglasii* – sunflower (native)
HIEALB - *Hieracium albertinum* – hairy hawkweed (native)
HIECYN – *Hieracium cynoglossoides* – hound's tongue hawkweed (native)
HIESP - *Hieracium* sp. – hawkweed (native and non-native)
HOLDIS *Holodiscus discolor* – oceanspray (native)
HYPPER - *Hypericum perforatum* – St. Johnsworte (non-native)
IVAXAN - *Iva xanthifolia* – tall marsh-elder (introduced)
KOCSCO - *Kochia scoparia* – red belvedere (introduced)
LACSER - *Lactuca serriola* – wild lettuce/prickly lettuce (introduced)
LEPVIR - *Lepidium virginicum* – tall peppergrass (introduced)
LITARV - *Lithospermum arvense* – corn gromwell (introduced)
LITRUD - *Lithospermum ruderale* – western gromwell, stone seed (native)
LOMAMB - *Lomatium ambiguum* – difficult nine-leaf biscuit root (native)

LOMDIS - *Lomatium dissectum* – chocolate tips (native)
LOMNUD – *Lomatium nudicauli* – naked-stemmed lomatium (native)
LUINAR - *Luina nardosmia* – silvercrown luina (native)
LUPLAT - *Lupinus latifolius* – broadleaf lupine (native)
LUPSER - *Lupinus sericeus* – silky lupine (native)
LUPSP – *Lupinus sp.* – lupine (native)
LUPWYE - *Lupinus wyethii* – Wyeth's lupine (native)
LYCALB - *Lychnis alba* – white campion (introduced)
MADSAT - *Madia sativa* – Chilean tarweed (native)
MALNEG - *Malva neglecta* – dwarf mallow (introduced)
MATMAT - *Matricaria matricarioides* – pineapple weed (native)
MEDLUP - *Medicago lupulina* – black medic (introduced)
MEDSAT - *Medicago sativa* – alfalfa (introduced)
MELALB - *Melilotus alba* – white sweet-clover (introduced)
MELOFF - *Melilotus officinalis* – yellow sweet-clover (introduced)
MELSP - *Melilotus sp.* – sweet-clover (introduced)
MENALB - *Mentzelia albicaulis* – white-stemmed mentzelia (native)
MENDIS - *Mentzelia dispersa/laevicanlis* – bush mentzelia (native)
MENSP - *Mentzelia* spp. – Velcro plant (native)
MICGRA - *Microsteris gracilis* – pink microsteris (native)
NEPCAT - *Nepeta cataria* – Catnip (introduced)
OSMCHI - *Osmorhiza chilensis* – sweet cicely (native)
PENFRU – *Penstemon fruticosa* – showy penstemon (native)
PENPRU - *Penstemon pruinosis* – Chelan penstemon (native)
PHAHAS - *Phacelia hastata* – silverleaf phacelia, silverweed (native)
PHALIN - *Phacelia linearis* – threadleaf phacelia (native)
PLALAN - *Plantago lanceolata* – lanceleaf plantain (introduced)
PLAMAJ - *Plantago major* – common plantain (European)
POLCON - *Polygonum convolvulus* – knot bindweed (introduced)
POLDOU - *Polygonum douglasii* – douglas' knotweed (native)
POLMIN - *Polgonum minimum* – dwarf knotweed (native)
POTREC - *Potentilla recta* – erect cinquefoil (introduced)
POTSP - *Potentilla* sp. – silverweed (native)
PTEAQU – *Pteridium aquilinum* – bracken fern
PYRDEN - *Pyrola dentata* – white-vein pyrola (native)
RANREP - *Ranunculus repens* – creeping buttercup (introduced)
RUMCRI - *Rumex crispus* – curly/yellow dock (Polygonaceae) (introduced)
SALKAL - *Salsola kali* – Russian thistle (introduced)
SILALB - *Silene alba* – white catchfly (introduced)
SILSP - *Silene* sp. – Silene, campion (native and non-native)
SISALT - *Sisymbrium altissimum* – tumblemustard (introduced)
SISLOE - *Sisymbrium loeselii* – Loesel tumblemustard (introduced)
SMIRAC – *Smilacina racemosa* – false solomon's seal (native)
SMISTE - *Smilacina stellata* – false solomon's seal (native)
SOLCAN - Solidago *canadensis* – Canada goldenrod (native)
SOLDUL - *Solanum dulcamara* – climbing/bittersweet nightshade (introduced)

TAROFF - *Taraxacum officinale* – dandelion (introduced)
THLARV - *Thlapsi arvense* – field pennycress (introduced)
TRADUB - *Tragopogon dubius* – Yellow salsify (introduced)
TRIDUB - *Trifolium dubium* – yellow hop clover (introduced)
TRIPRA - *Trifolium pratense* – red clover (introduced)
TRIREP - *Trifolium repens* – white clover, dutch clover (introduced)
VACMEM - *Vaccinium membranaceum* – big huckleberry (native)
VACMYR - *Vaccinium myrtillus* – myrtle leaved blueberry (native)
VACSCO - *Vaccinium scoparium* – whortleberry/grouseberry (native)
VERTHA - *Verbascum thapsus* – flannel mullein (non-native)
VICAME - *Vicia americana/villosa* – wooly vetch (native)
WOOSP - *Woodsia sp*. – Woodsia (native)

Graminoids
AGRCRI - *Agropyron cristatum* – crested wheatgrass (introduced)
AGRDAS - *Agropyron dasytachyum* – downy wheatgrass (introduced)
AGRINT - *Agropyron intermedium* – intermediate wheatgrass (introduced)
AGROSP - *Agrostis sp.* – red top, bent grass (native and non-native)
AGROSTO - *Agrostis stolonifera* – fiorin (introduced)
AGRREP - *Agropyron repens* – quack grass, couch grass (introduced)
AGRSPI - *Agropyron/ Pseudoroegneria spicatum*-bluebunch wheatgrass (native)
AVEFAT - *Avena fatua* – oats (introduced)
BROCAR - *Bromus carinatus* – California brome (native)
BROINE - *Bromus inermis* – smooth brome (introduced)
BROJAP - *Bromus japonicus* – Japanese brome (introduced)
BROSP - *Bromus* sp. – bromes (native and non-native)
BROTEC - *Bromus tectorum* – downy cheat grass (introduced)
CALCAN - *Calamagrostis canadensis* – blue reed (native)
CALRUB - *Calamagrostis rubescens* – pine grass (native)
CARCON - *Carex concinnoides* – low northern sedge (native)
DACGLO - *Dactylis glomerata* – Orchard grass (introduced)
ELYCIN - *Elymus cinereus* – Basin wild rye (native)
ELYGLA - *Elymus glaucous* –western rye grass, blue wildrye (native)
ELYSP - *Elymus* sp. – wild rye
FESIDA - *Festuca idahoensis* – idaho fescue (native)
FESOVI - *Festuca ovina* – sheep fescue (introduced)
FESRUB - *Festuca rubra* – red fescue (introduced)
FESSP - *Festuca* sp. – fescues (native and non-native)
HORSP - *Hordeum* sp. – squirrel tail (native and non-native)
JUNENS - *Juncus ensifolius* – dagger-leaf rush (native)
JUNMYR - *Juncus myrtensianis* – Merten's rush (native)
PHAARU - *Phalaris arundiaceae* – reed canary grass (native)
PHLPRA – *Phleum pratense* – common timothy (introduced)
POABUL - *Poa bulbosa* – bulbous bluegrass (introduced)
POAPRA - *Poa pratensis* – Kentucky bluegrass (introduced)
POASP – *Poa sp.* – blue grasses

SCIVAL - *Scirpus validus* – tule (native)
SECCER - *Secale cereale* – Annual rye, cereal rye (introduced)
SETSP - *Setaria* sp. – bristle grasses (introduced)
SETVIR - *Setaria viridis* – green bristlegrass (introduced)
SPOCRY - *Sporobolus cryptandrus* – sand dropseed (native)
STICAL - *Stipa calmata* – very long awns (native)
STIOCC - *Stipa occidentalis* – Western N & T (native)
STISP - *Stipa* sp. – needle and thread (native)
STITHU - *Stipa thurberiana* – thurbers needlegrass (native)

List of alien species recorded for presence/absence when occurring within 0.25 mi of roadside plots or in between off-road plots
Agropyron repens (quack grass)
Artemisia absinthium (wormwood)
Bromus tectorum (cheat grass)
Cardaria draba (whitetop)
Cardaria pubescens (hairy whitetop)
Carduus nutans (musk thistle)
Centaurea diffusa (diffuse knapweed)
Centaurea maculosa (spotted knapweed)
Centaurea repens (Russian knapweed)
Chrysanthemum leucanthemum (oxeye daisy)
Cirsium arvense (Canada thistle)
Cirsium vulgare (bull thistle)
Cytisus scoparius (Scot's broom)
Gypsophila paniculata (baby's breath)
Hypericum perforatum (St. Johns wort)
Kochia scoparia (kochia, red belvedere)
Linaria dalmatica (Dalmatian toadflax)
Poa bulbosa (bulbous bluegrass)
Salsola kali (russian thistle)
Sisymbrium altissimum (tumble mustard)
Sisymbrium loeselii (Loesel's tumble mustard)
Tanacetum vulgare (tansy)
Verbascum thapsus (flannel mullein)