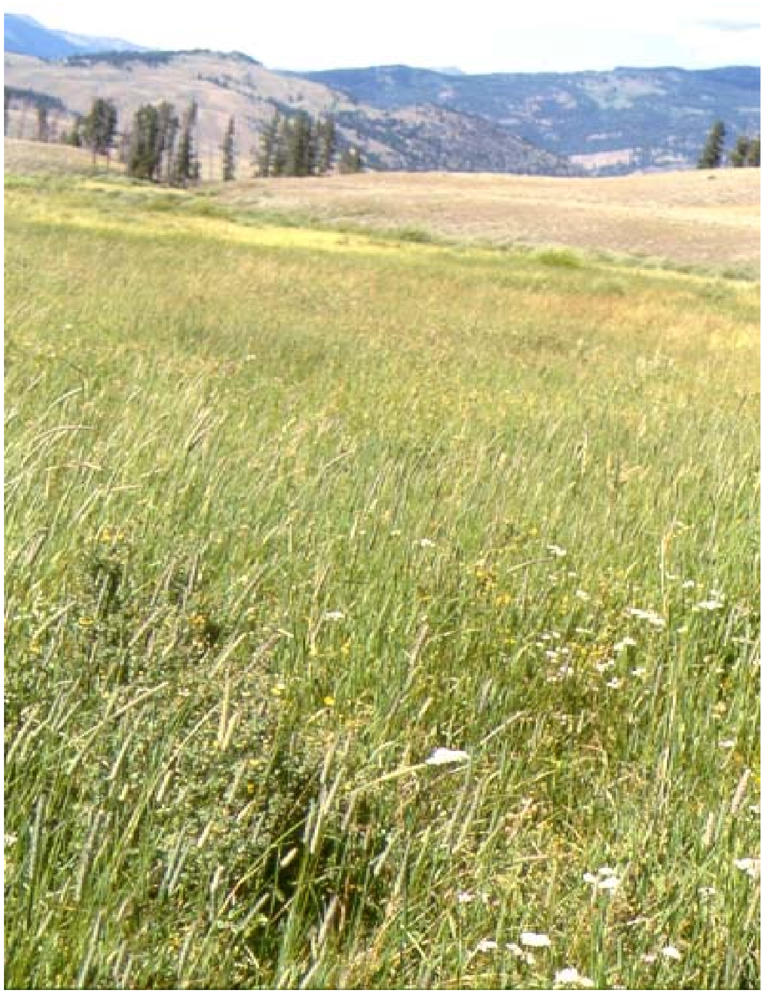
2002 Annual Report

A survey of non-indigenous plant species in the northern range of Yellowstone National Park.



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Project Summary

An inventory/survey is seen as the first of three phases in the management of non-indigenous species (NIS). An inventory or survey needs to be designed to obtain an unbiased assessment of NIS extent. These data can then be used as baseline data to select sites for monitoring of metapopulations, to evaluate changes in spatial and temporal extent, impacts on the ecosystem and impacts of management. Only after following these steps to estimating non-indigenous plant occurrence, extent and dynamics, can effective management strategies be developed for the currently occurring species as well as new species that may invade National Parks and other wilderness/natural areas.

The overall aim of this project (2001-2004) is to survey the occurrence (presence/absence) of non-indigenous species of plants within the northern elk winter range of the Park. From the field data we will create maps of observed NIS occurrence. Analyze the data for correlations of NIS occurrence with human activities (roads and trails) and environmental variables to aid in the prediction of NIS occurrence in areas not sampled. Thus, our maps will have observed and predicted locations of non-indigenous species. The study is not intended to estimate the extent of populations (density or ha infested).

The northern range covers an area of 152,785 ha which is too large to look for NIS species over the entirety so, in 2001 we focused on identifying which sampling methods provide the highest probability of locating even the rarest plant species. This objective was achieved through computer simulation and field sampling. We have adopted a stratified and adaptive sampling methodology that will maximize the ability to predict occurrence of the NIS and quantify the degree of uncertainty in our predictions. In 2002, two crews sampled 133 transects in the area between Gardiner and Tower Falls. These data are now collated, preliminary analysis and logistic and Bayesian modeling performed and some NIS probability maps generated. Next season more transects will be collected in the Lamar valley area which has received little attention to date, plus additional sampling will be performed to test the accuracy of the predictive model. After evaluating the model improvements will be made and the same process repeated during 2004.

Project description

Introduction

The United States Department of Interior National Park Service is required by law to keep the 34 million ha designated as National Parks classified as "natural areas". Natural areas must be "unaltered by human activities" as much as possible (U.S. National Park Service, 1996). Maintaining the Parks as "natural areas" includes removal of non-native species. The definition of non-native is "any animal or plant species that occurs in a given location as a result of direct, indirect, deliberate or accidental actions by humans" (U.S. National Park Service, 1996). This definition permits the user to recognize and distinguish between changes to animal and plant distributions caused by natural processes and human influences.   In reality this statement needs some further clarification. "Human influence" really refers to disturbance by white settlers, more so in the past century and most specifically in the last 50 years.

Many countries have designated specific areas as "wilderness" or "natural ecosystems" and seek to preserve these in their "pristine" state, however pristine is defined. Taking this desire to "protect and retain" such areas, one can argue from the ecological purist point of view, that all non-indigenous species should be removed. However, this is currently impossible from a practical standpoint. In most cases we do not know which non-indigenous species are present within an ecosystem, their frequency or their distribution pattern; how much their distribution is changing and finally what impact they are having on the endemic ecosystem. It is only armed with all of this information that land managers can effectively target and manage non-indigenous species populations.

The language used to describe the presence and impact of non-indigenous species is often very emotive: "aggressive non-indigenous plants, which spread quickly into natural areas replacing native flora and reducing habitat for native flora and fauna". Often the simple presence of a non-indigenous species is stated as proof enough of present or future environmental damage, particularly if it is a highly competitive species and/or if the increase in the non-indigenous species is associated with the decline of native species. However, Weaver *et al.,* (2001) in a study of the northern Rocky Mountains found that of the 29 most commonly found exotic species the majority were intentionally introduced (e.g. *Phleum pratense* and *Poa pratensis*) and none of the most common were generally considered a noxious weeds.

A number of studies have shown that when non-indigenous species are introduced to environments and ecosystems different from those in which they evolved, they may disrupt the ecosystem processes and alter biological diversity (e.g. Braithwaite & Lonsdale, 1989; Hobbs & Mooney, 1991; see Davis *et al*., 2000 and Mack *et al*., 2000 for reviews). Invasion by a new species is influenced by three factors:

1. ecosystem properties, which could be related to the level or frequency of disturbance;
2. number of propagules entering a new environment (propagule pressure); and,
3. the properties of the invading species (Lonsdale, 1999).

Davis *et al.* (2000) and Davis and Pelsor (2001) offer a new theory, that the fluctuation of resource availability is a key factor in controlling invasion. This theory allows for the integration of resource availability with disturbance and fluctuating environmental conditions.

Disturbance is often suggested as a key factor in enhancing the probability of non-indigenous plant establishment in native plant communities. Natural disturbance has a variety of biotic and geomorphic causes including soil disturbance by fauna, weather related events such as mudflows, floods, wind, fire and geological events such as landslides. Fire is sometimes a quasi-human disturbance if management practices suppress, contain or intentionally ignite them, or if fires are ignited accidentally or intentionally by vandals, whichever way, the natural occurrence of fires has usually been altered. Human disturbance includes construction and use of roads and trails, buildings, utility corridors and campgrounds.

As stated above, the National Park Service has a mandate to preserve the natural systems under their control (National Park Service Organic Act of 1916). There are several phases necessary to achieve this objective:

Phase 1 creating an survey/survey (documenting occurrence);
Phase 2 monitoring (quantifying changes in distribution or abundance); and,
Phase 3 control or management of non-indigenous species.

To a certain extent these phases can be performed concurrently (Fig. 1). The aim of the current project is Phase 1, development of an inventory/survey program.

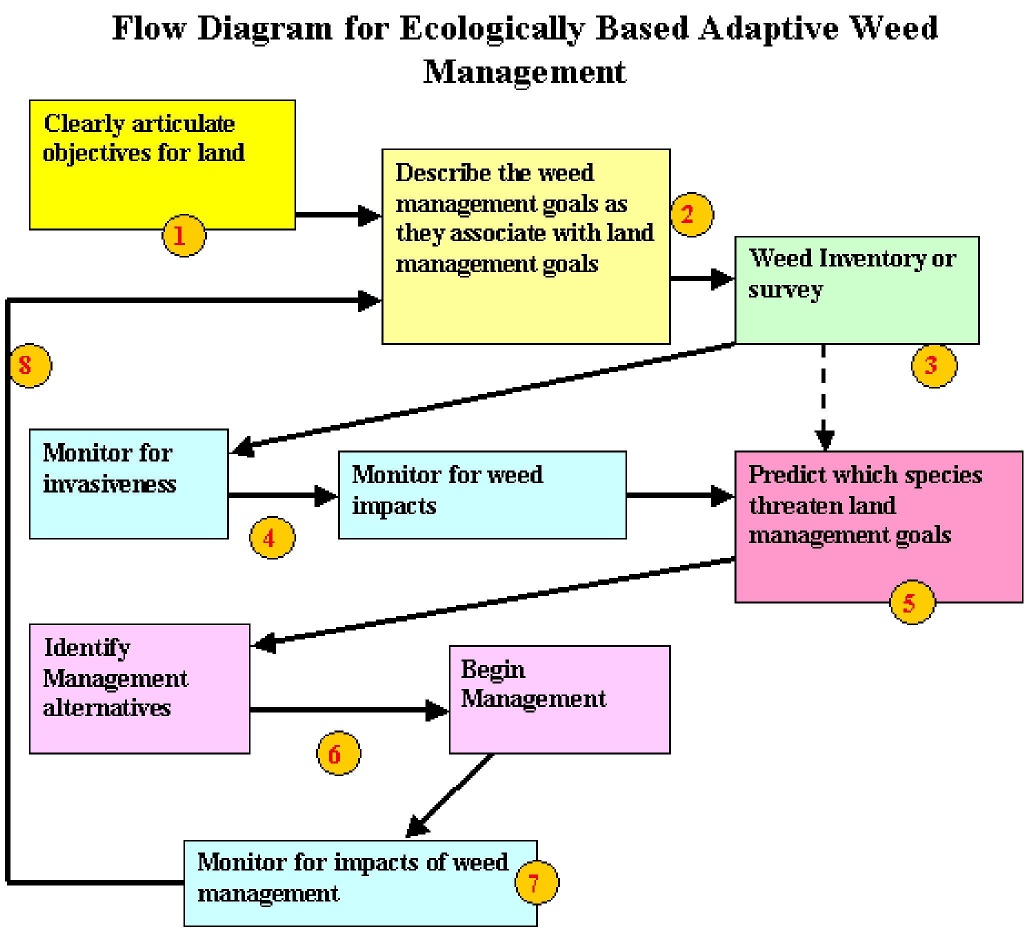

Fig 1 Flow diagram for ecologically based adaptive weed management.

The problem with developing an inventory/survey

Conducting an inventory/survey of non-indigenous plants in a large region where many of the non-indigenous species have infrequent occurrence is a difficult task. The definition of a inventory is a list of all NIS species and their locations in a delineated management area when the entire area can be observed. A survey is defined as a list of NIS species and their locations in a delineated management area when all of the area cannot be observed. A survey requires careful consideration of sampling methods. As the area of the northern range if so large and we cannot sample the entire area we are by definition completing a survey. This term will be used from now on.

Considering the ultimate use of the survey is essential in the design. In the case of the National Park Service, management of NIS is the objective, but because the NIS are relatively infrequent and spread over large areas, it will never be possible to manage all NIS or all their occurrences. Thus, a survey of the NIS and the subsequent assessment of population and metapopulation dynamics must have the objective of creating an unbiased sample in order to prioritize management of those metapopulations that pose the greatest threat to the ecosystem. An unbiased sample requires locating populations or metapopulation over the extent of the environments where they may exist. Therefore, we are reliant upon a survey that maximizes the probability of finding the NIS and simultaneously builds a data set from which models that predict NIS occurrence can be developed to ensure that we represent, through observation or prediction, all environments where the NIS may be found. It is tempting to combine survey and population assessments. If the survey is strictly a means of finding the NIS so that they can be killed, then an estimate of each metapopulation extent in the survey could serve the purpose of knowing approximately how much herbicide/hand-weeding will be required to control the observed metapopulations. However, if the intent of the survey is to maximize the potential of knowing where all of the NIS are located and subsequently using the survey to select a random sample of metapopulations to monitor for an unbiased determination of population dynamics and prioritization of management, then the survey approach that we are suggesting is most appropriate.

Study area

Yellowstone National Park (YELL) covers an area of 899,121 ha (2,220,829 ac). Approximately 1265 plant species have been recorded in YELL of which 187 (15%) are non-indigenous plant species (Whipple, 2001). The proposed study will concentrate on the area within the northern elk winter range of the Park (152,785 ha, 377,379 ac).

Current knowledge of non-indigenous species occurrence

The relative proportional importance of the different forms of disturbance and environmental factors on non-indigenous species establishment and survival has not been quantified. The general perception from the National Park staff involved with NIS surveys and members of this research group was that most infestations occur close to roads, trails and human habitation. From the data collected by YELL park staff in 1998, it was calculated that 278 of 422 (66%) NIS occurrences were less than 100 m from roads or trails, and all observations were made less than 500 m from roads or trails. These data were not collected using a formal sampling strategy and the sites searched were biased by their proximity to roads and trails. Therefore, this information was treated as anecdotal and although considered, the data were not used for any subsequent analysis.

In order to provide a more quantitative understanding of potential factors that influence the occurrence of non-indigenous species a pilot study was performed during the summer of 2001. Initially a computer simulation was performed to evaluate the best sampling methodology. The chosen methodology was then applied in the northern range of Yellowstone and valley floor of Grand Teton National Parks.

To ensure the best use of the limited funds and time available in the field, a desktop study was conducted to develop the most effective sampling regime. This was performed in ESRI ArcView© GIS using routines developed by Aspinall and Dougher. This implemented several different sampling strategies including simple random sample, random walk, random transects, transects normal to specified linear features, stratified random sampling and regular grid sampling. Additionally, different sampling intensities were evaluated for different infestation levels (frequencies) of non-indigenous plants.

It is assumed that most of the species we are targeting are at a low frequency within the landscape and therefore collecting large numbers of observations is important to provide a reliable estimate of the species occurrence. A large sample combined with an appropriate strategy for estimating geographic distribution is also necessary if the goal is to estimate the distribution of the non-indigenous plant in the landscape. Survey design is, therefore, a tradeoff between collecting a sufficiently large sample to provide reliable estimates of occurrence, and using a sampling strategy that is efficient for both a) field work and b) estimating the geographic distribution of the species.

The simulations and sampling strategies implemented within the GIS allowed us to evaluate which sampling strategy provides the highest number of sample points for the shortest time in the field and, also provides geographic coverage necessary for estimating distribution of the non-indigenous species. Random points or grid intersections for example, are not as efficient for collecting data as random walks or transects since time used moving from one survey location to another location is not used for data collection. Surveying along transects allows data to be collected continuously and a large sample size be generated. Additionally, surveying along transects allows changes in underlying environmental variables to be recorded. This is important for estimating the geographic distribution of the species from the sample data.

If the occurrence of a target species is known to be correlated with an environmental variable, we could stratify the sampling scheme on that variable and improve our probabilities of finding the target (Hirzel and Guisan, in press). We accepted the assumption that human disturbance in the form of roads and trails increases the chance of finding non-indigenous species, and stratified our sampling using this variable. However, to test this hypothesis we also needed to sample away from roads and trails. Therefore, transects established perpendicular to roads and trails were accepted as the most effective sampling methodology. The use of 2000 m transects allows the importance of other factors to be evaluated, since each transect is sufficiently long to cross a number of cover or habitat types and other environmental transitions.

Collection of field data

In 2001, the position of each transect was randomly selected, prior to arrival in the field, and ran perpendicular to roads or trails. This approach needed to be partially modified. Two kilometer buffers were established around roads, and trails (Fig. 2). The location of transects was still randomly generated but within a set of confines:

- Starting on a road and finishing 2000 m from all roads but at all times the transect runs more than 2000 m from any known trail
- Starting on a trail and finishing 2000 m from all trails but at all times the transect runs more than 2000 m from any known road
- Starting on a road or trail and finishing 2000 m from all roads and trails.

Transects were walked and locations recorded with a GPS (Global Positioning System), by two person teams. Transects were 10 m wide. Trimble Pro XR receivers and GeoExplorer® 3 units were used and the data post-processed to improve accuracy. The coordinate system and projection used was Universal Transverse Mercator (UTM) Zone 12N, WGS 1984 Datum. This projection and datum is the same as used for GIS data maintained by YELL Center for Resources, and the Greater Yellowstone Area Spatial Data Clearinghouse managed and maintained by the Geographic Information and Analysis Center (GIAC) at Montana State University. Transects were walked and information gathered when a target non-indigenous species was located, the habitat type changed or a disturbance feature was reached. The habitat classifications were based on the classifications devised by D. Despain and incorporated into the YELL GIS layers.

In 2002, all data were collected directly into a data dictionary on a GeoExplorer® 3 unit that contained the same data fields as used in 2001, plus additional information on patch parameters and fields required by North American Weed Mapping Association (NAWMA). These included the location of target species, with additional information on density (in predefined classes of 0, 0-1, 1-11, 12-32, 33-100, 101-316, 317-1000 and >1000 m^{-2}), percentage cover m^{-2}, length (m) and width (m) of infestation, and spatial pattern type. Percent cover estimates was collected in accordance with NAWMA. Environmental variables included; climax habitat type, dominant vegetation cover species (four species), aspect, topography and disturbance. Additional data fields included NAWMA's "Values at risk" and "Ecological status of site/survey unit" and, time and date.

Fields that were not collected but could be added to the database at a later stage include information about the site/region, I&M network, park unit, state, county, ownership, type of survey, and non-indigenous NIS plant and ITIS code all of which can be added to the database in the office.

The National Park Service has historically recorded habitat types rather than dominant vegetation/cover types. For the purpose of evaluating the environment where non-indigenous species are more likely to invade it is necessary to know the current dominant species or successional stage, as well as the climax vegetation (habitat type). Information will continue to be recorded on both the dominant cover and climax vegetation. Classification already developed and used by park staff will be used.

Results of field work
During 2001, 42 transects were walked in the northern range with an overall sampled length of 86 053 m x 10 m wide (Fig. 2). Nine species were targeted; *Bromus inermus, Bromus tectorum, Centaurea maculosa, Cirsium arvense, Chrysanthemum leucantheum, Cynoglossum officinale*, *Linaria dalmatica, Melilotus officinalis* and, *Phleum pretense.*

In 2002, with extended time in the field 116 transects were completed that covered 196 189 m x 10 m. An additional 17 * 2000 m long transects were completed along trails and rivers (Fig. 2). Sixty-two species are listed on the YELL priority list (Appendix 1), all of these were targeted but only 23 of these species were recorded in the transects (Table 2). Six of these species were recorded as present over more than 1% over the study area. *Phleum pratense* (Fig. 3) had a percentage occurrence of 6.5%, which was more than any other species which is not surprising considering that it was intentionally introduced to the park in the early 1900's. *Bromus tectorum* (Fig. 4)*, Cirsium arvense* (Fig. 5), and *Poa pratensis* had occurrences just over 2%, *Bromus inermis* (Fig. 6) and *Linaria dalmatica* (Fig. 7) had occurrences of 1.6 and 1.3% respectively all other species were less, generally considerably than 1% (Table 2).

Infestation length and width measures were estimated by pacing or visually estimating and are therefore not precise. However, they do provide an indication of size of infestations that are present. *Phleum pratense* has the largest average infestations dimensions, which again probably demonstrates that this species was sown in the park and therefore the infestations are less defined. The percentage cover estimates were generally below 15%, with the exception of *Cirsium vulgaris* though only two observations were made of this species so the data should be treated with caution. Density was estimated into eight different classes (0, 0-1, 1-11, 12-32, 33-100, 101-316, 317-1000 and >1000 m^{-2}). The mean class values are provided and show densities were generally low.

Transects were allocated to ensure that each ended 2000 m from a road, trail or road and trail. In reality some service roads and trails were observed that were not on the GIS layer. Therefore, distance from road and trails was re-calculated for each transect and the distance partitioned into 10 m intervals from both roads and trails for further analysis. The patterns observed for those species with more than 50 observations have been plotted and all show a general decline with distance from road/trail. The presence of *C. arvense, L. dalmatica, B. tectorum* and *P. pratense* are shown in Fig. 8, the decline is more rapid for *B. inermis* than other species, this pattern probably reflects that this species has been sown along the roadside.

Table 2. Information on average patch length, width, percentage cover, density (using 8 classes) and percentage occurrence within the area studied.

Species	Number of observations	Average infestation, when present				% occurrence
		Length (m)	Width (m)	% cover	Density (m)	
Phleum pratense	137	93	73	5	20	6.475
Bromus tectorum	134	35	18	11	20	2.393
Cirsium arvense	142	33	32	6	6	2.380
Poa pratensis	98	45	37	2	6	2.234
Linaria dalmatica	116	28	15	5	6	1.643
Bromus inermis	89	28	33	15	20	1.285
Alyssum desertorum	55	25	21	10	20	0.713
Poa palustris	13	49	41	2	6	0.323
Cardaria chalapensis	48	12	10	3	20	0.293
Cardaria draba	31	13	10	6	20	0.213
Poa bulbosa	10	18	6	5	66	0.090
Cynoglossum officinale	22	8	7	8	6	0.084
Poa annua	8	20	15	1	6	0.083
Hieracium caespitosum	6	19	61	1	6	0.058
Cardaria species	17	7	12	5	20	0.056
Melilotus officinalis	17	6	4	4	6	0.055
Trifolium hybridum	10	10	12	15	6	0.051
Verbascum thapsus	2	21	7	1	<1	0.021
Trifolium repens	7	6	11	9	6	0.021
Chrysanthemum leucanthemum	1	40	5	1	<1	0.020
Cirsium vulgaris	2	4	5	28	6	0.004
Carduus nutans	1	6	3	1	<1	0.003
Hieracium floribundum	1	3	30	1	6	0.002
Poa compressa	2	2	1	11	6	0.002
Cardaria pubescens	1	1	1	1	6	0.001

* used when specific *Cardaria* spp. could not be determined.

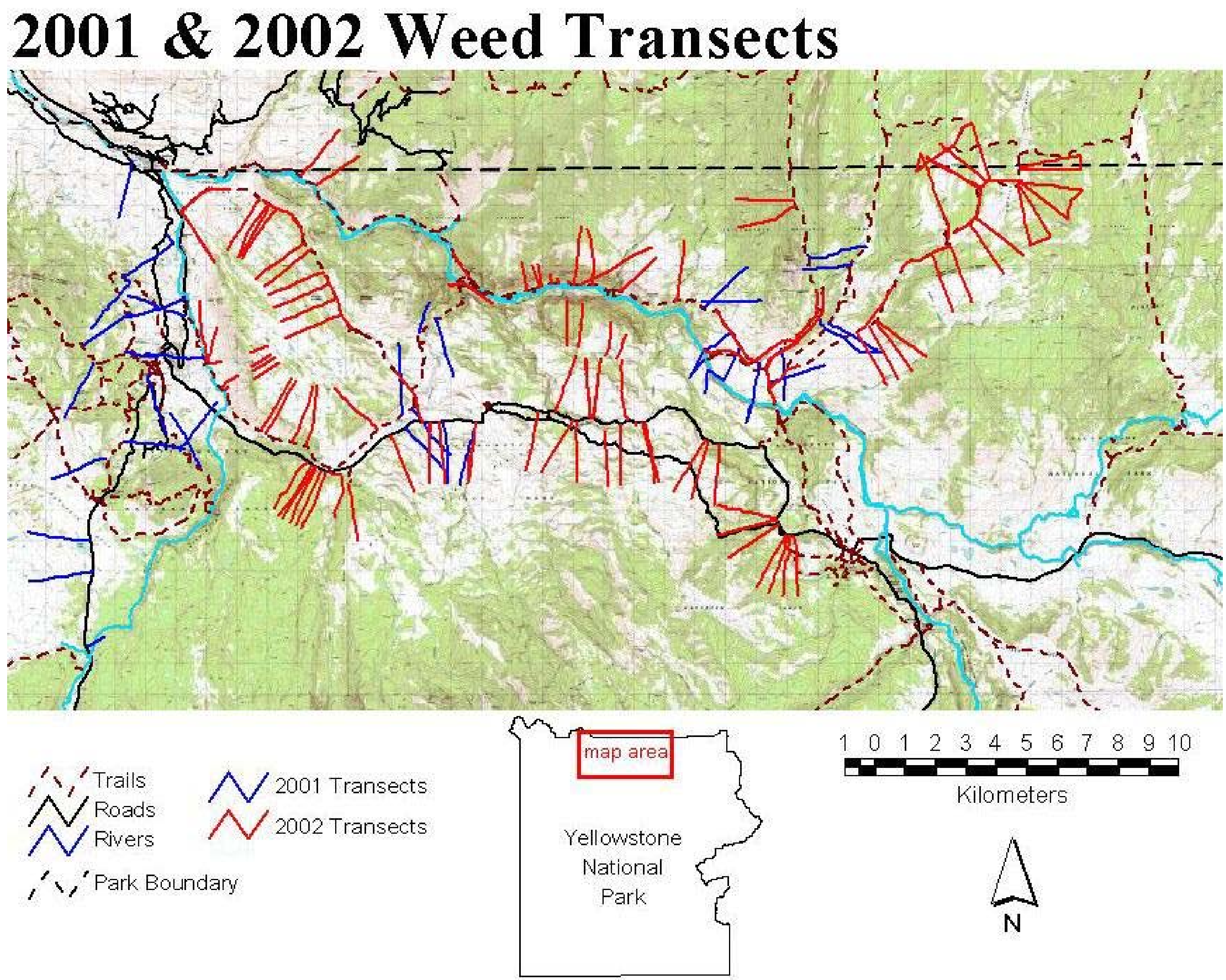

Fig. 2. Locations of all transects walked in 2001 and 2002 in the northern range of

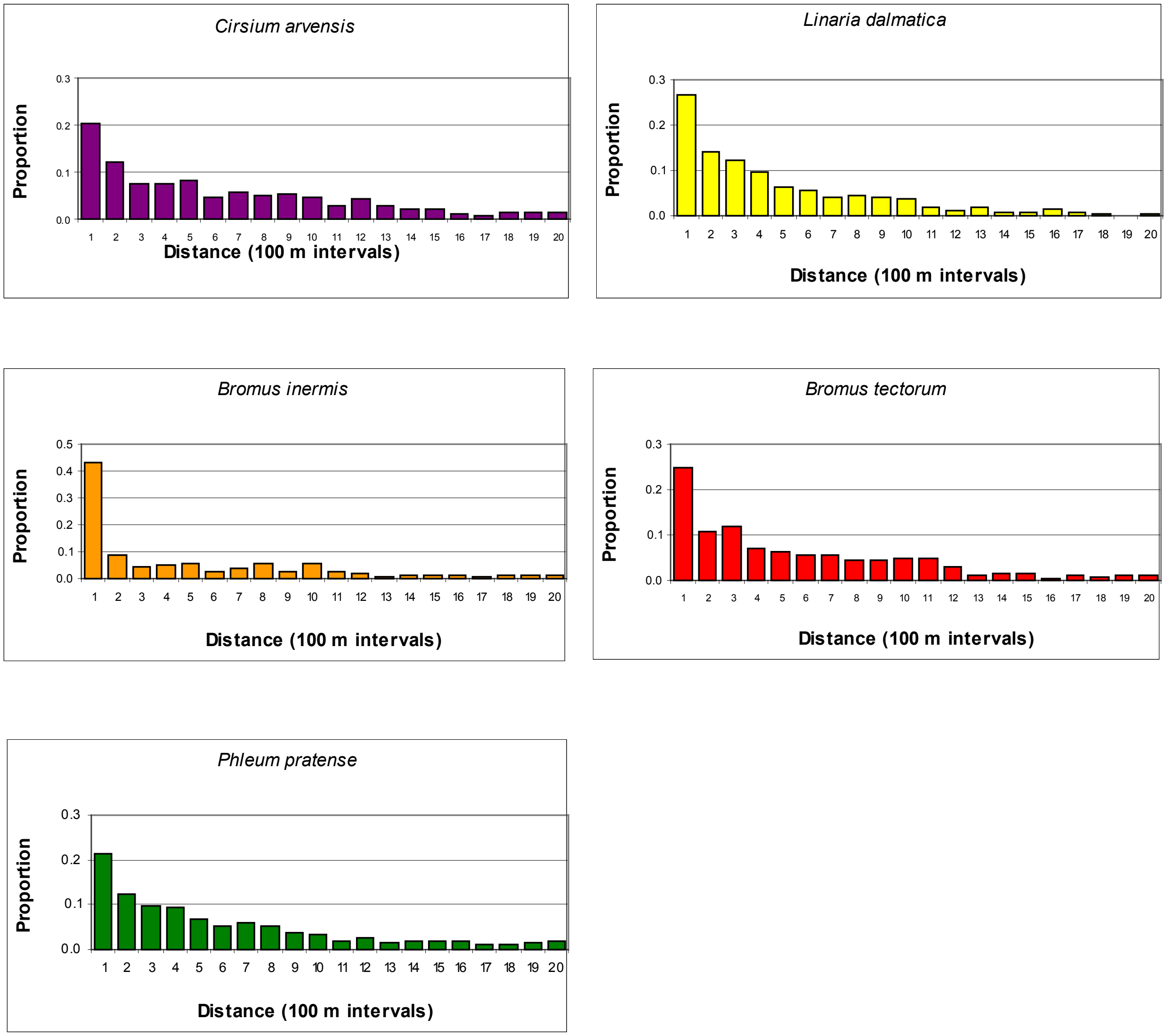

Fig. 8. Proportion of selected species observed within 100 m intervals of roads/trails in the northern range of Yellowstone National Park. Data from 2001 and 2002 combined.

Plotting the proportion of observations made in different habitats suggests that some species occur more in certain habitats than they would by chance (Fig. 9).

However, the agreement between our data which has a 10 m resolution and the GIS layer is poor (35%) which means that the accuracy of projecting our field habitat data predictions onto the GIS layer will be limited. We are trying grouping both data sets into a smaller number of categories, e.g. sagebrush, grass etc. habitats to see if that improves the agreement. Should such simplification of the habitat groupings work it would make the work easier to extend to other areas with less habitat information than is available for the park.

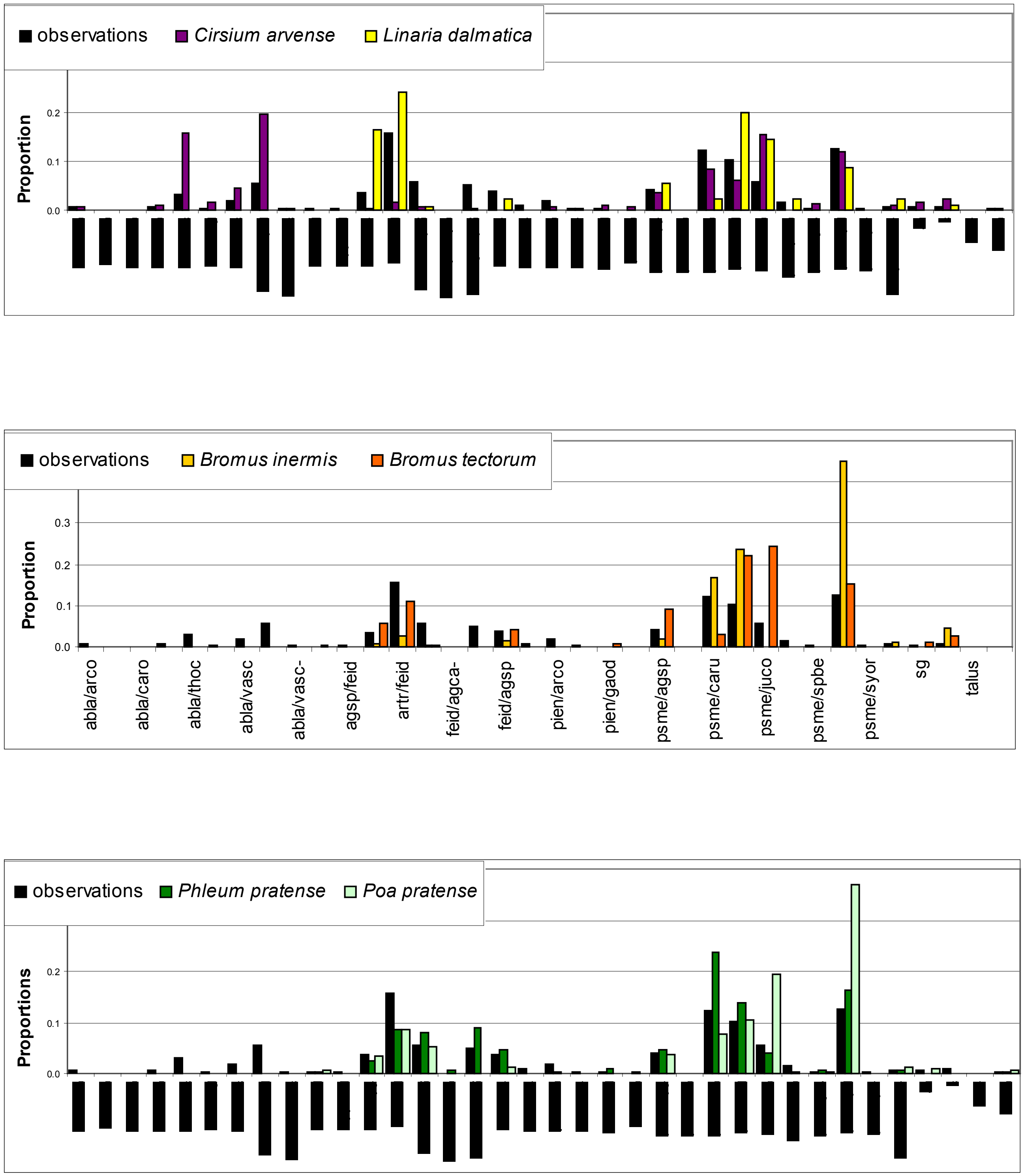

Fig. 9. Proportion of different habitat types sampled and target species in different habitats, 2002 data only. See Table 3 for habitat definitions.

Table 3. List of common, scientific and abbreviated code names for the habitats recorded in the northern range study area.

Common names	***Scientific names***	Abbreviated name
Big Sagebrush/Bluebunch Wheatgrass	*Artemisia tridentata/Agropyron spicatum*	artr/agsp
Big Sagebrush/Idaho Fescue	*Artemisia tridentata/Festuca idahoensis*	artr/feid
Big Sagebrush/Idaho Fescue-Sticky Geranium Phase	*Artemisia tridentata/Festuca idahoensis-Geranium viscosissimum*	artr/feid/gevi
Bluebunch Wheatgrass/Idaho Fescue	*Agropyron spicatum/Festuca idahoensis*	agsp/feid
Douglas Fir/Bluebunch Wheatgrass	*Pseudotsuga menziesii/Agropyron spicatum*	psme/agsp
Douglas Fir/Common Juniper	*Pseudotsuga menziesii/Juniperus communis*	psme/juco
Douglas Fir/Heartleaf Arnica	*Pseudotsuga menziesii/Arnica cordifolis*	psme/arco
Douglas Fir/Idaho Fescue	*Pseudotsuga menziesii/Festuca idahoensis*	psme/feid
Douglas Fir/Mallow Ninebark	*Pseudotsuga menziesii/Physocarpus malvaceus*	psme/phor
Douglas Fir/Mountain Snowberry	*Pseudotsuga menziesii/Symphoricarpos oreophillus*	psme/syor
Douglas Fir/Pine Grass	*Pseudotsuga menziesii/Calamagrostis rubescens*	psme/caru
Douglas Fir/Shiny-leaf Spirea	*Pseudotsuga menziesii/Spiraea betulifolia*	psme/spbe
Douglas Fir/Snowberry	*Pseudotsuga menziesii/Symphoricarpos albus*	psme/syal
Douglas Fir/Snowberry, Big Sagebrush/Idaho Fescue, Sticky Geranium Phase	*Pseudotsuga menziesii/Symphoricarpos albus, Artemisia* □ *ridentate/Festuca idahoensis-G. viscosissimum*	psme/syal/artr/feid/gevi
Engleman Spruce/Common Horsetail	*Picea engelmanni/Equisetum arvense*	pien/eqar
Engleman Spruce/Heartleaf Arnica	*Picea engelmanni/Arnica cordifolia*	pien/arcq
Engleman Spruce/Sweetscented Bedstraw	*Picea engelmanni/Galium odoratum*	pien/gaod
Engleman Spruce/Twinflower	*Picea engelmanni/Linnaea borealis*	pien/libo

Table 3 (cont.). List of common, scientific and abbreviated code names for the habitats recorded in the northern range study area.

Common names	***Scientific names***	Abbreviated name
Idaho Fescue/Agropyron sp.	*Festuca idahoensis/Agropyron sp.*	feid/agsp
Idaho Fescue/Agropyron sp.-Sticky Geranium Phase	*Festuca idahoensis/Agropyron sp.-Geranium viscosissimum*	feid/agsp/gevi
Idaho Fescue/Richardson's Needlegrass	*Festuca idahoensis/Stipa richardsonii*	feid/stri
Idaho Fescue/Tufted hairgrass	*Festuca idahoensis/Deschampsia cespitosa*	feid/dece
Lodgepole Pine	*Pinus contorta*	pico
Lodgepole Pine/Elk sedge	*Pinus contorta/Carex rossii*	pico/caro
Sedge bogs	*Carex sp. bogs*	Carex sp.
Silver Sage/Idaho Fescue	*Artemisia cana/Festuca idahoensis*	arca/feid
Spruce/Common Horsetail	*Picea sp./Equisetum arvense*	Picea sp./eqar
Subalpine Fir/Globe Huckleberry	*Abies lasiocarpa/Vaccinium globulare*	abla/vagl
Subalpine Fir/Grouse Whortleberry	*Abies lasiocarpa/Vaccinium scoparium*	abla/vasc
Subalpine Fir/Grouse whortleberry-Whitebark Pine	*Abies lasiocarpa/Vaccinium scoparium-Pinus albicaulis*	abla/vasc-pial
Subalpine Fir/Grouse Whortleberry-Grouse Whortleberry	*Abies lasiocarpa/Vaccinium scoparium-V. scoparium*	abla/vasc-vasc
Subalpine Fir/Heartleaf Arnica	*Abies lasiocarpa/Arnica cordifolia*	abla/arco
Subalpine Fir/Mountain Arnica	*Abies lasiocarpa/Arnica latifolia*	abla/arco
Subalpine Fir/Pinegrass	*Abies lasiocarpa/Calamagrostis rubescens*	abla/caru
Subalpine Fir/Ross's Sedge	*Abies lasiocarpa/Carex rossii*	abla/caro
Subalpine Fir/Western Meadowrue	*Abies lasiocarpa/Thalictrum occidentale*	abla/thoc
Willow/Sedge	*Salix sp./Carex sp.*	Salix sp./carex

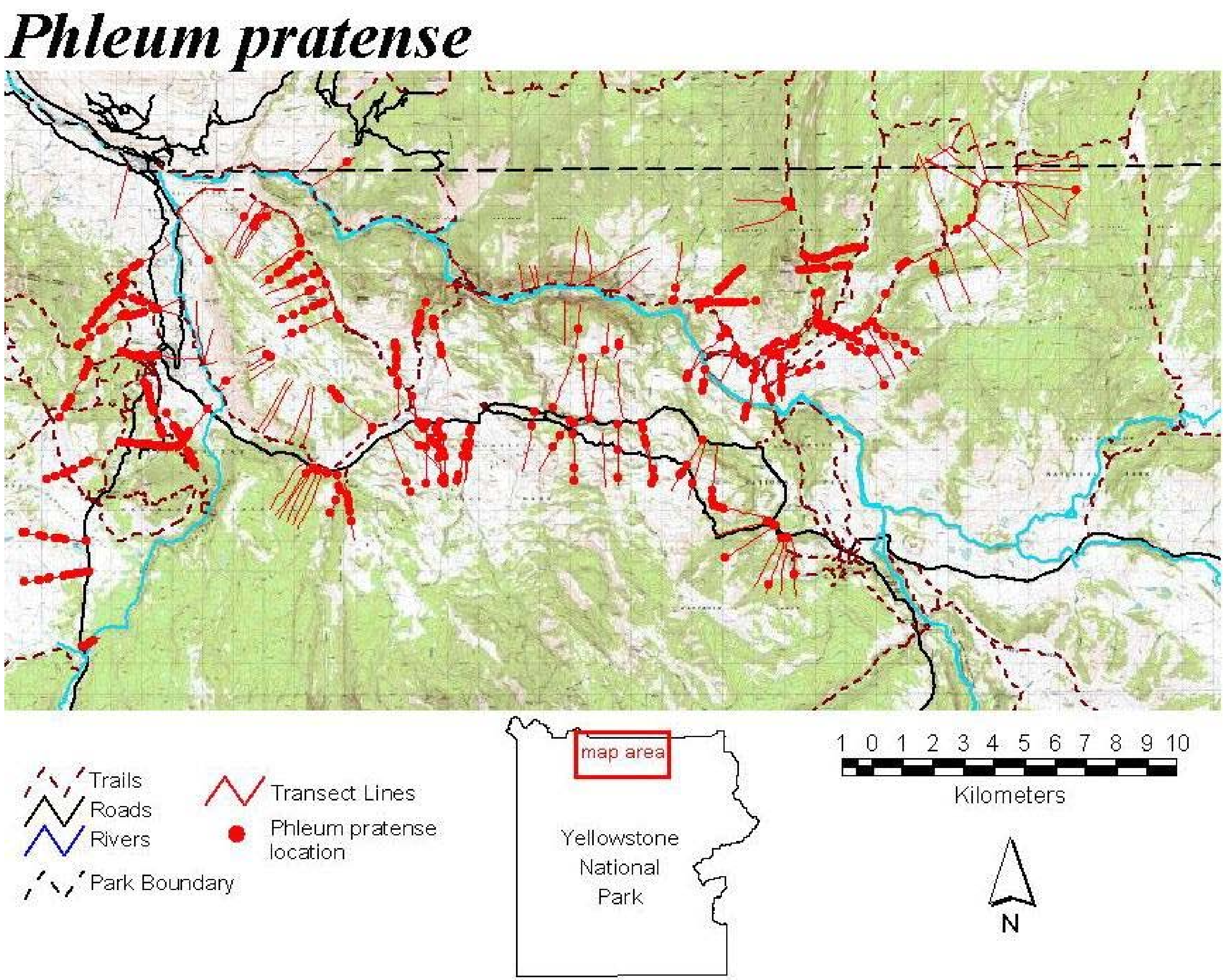

Fig. 3. Observed presence of *Phleum pratense* in the northern range of YELL in 2001 and 2002.

Bromus tectorum

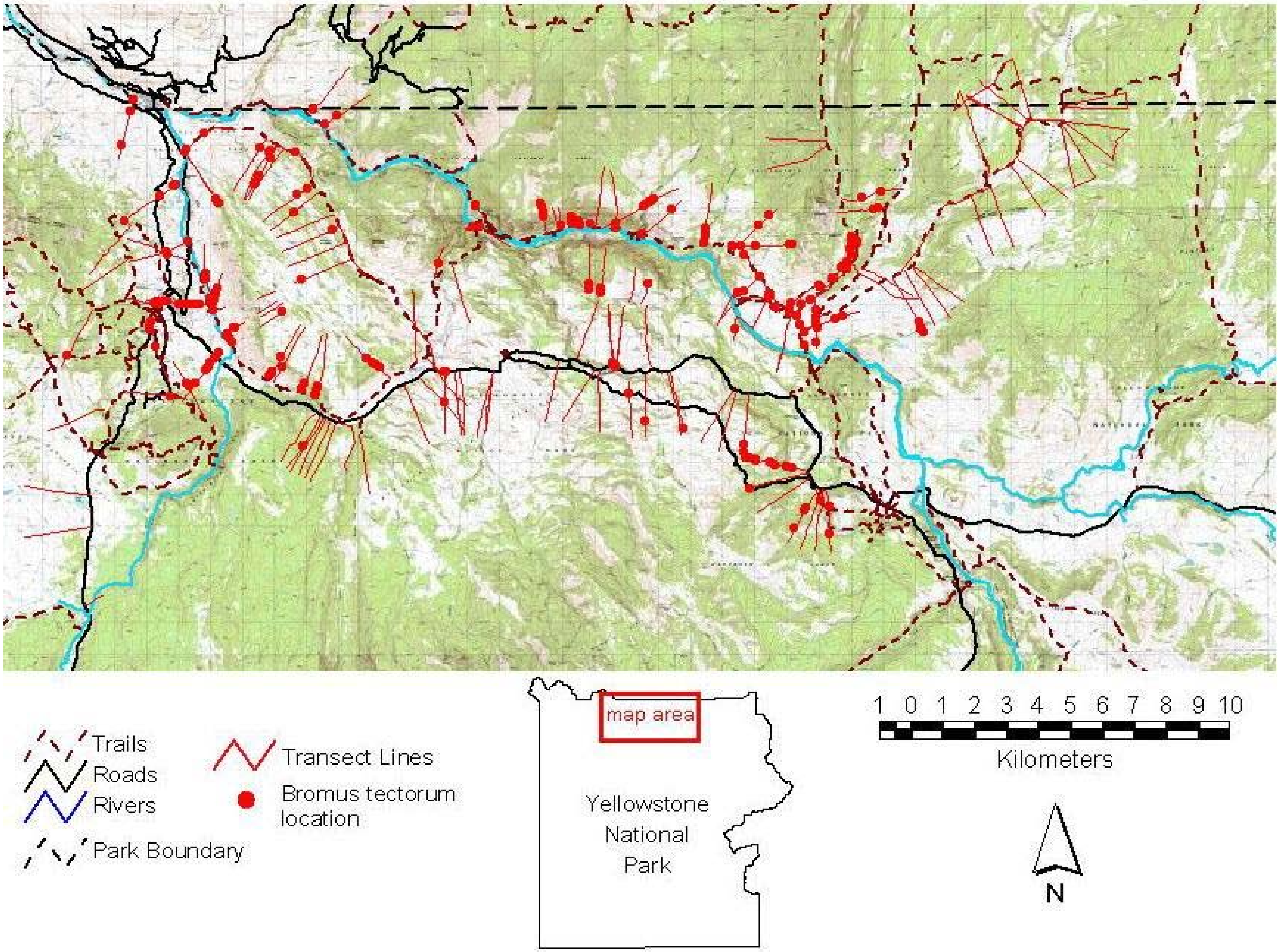

Fig. 4. Observed presence of *Bromus tectorum* in the northern range of YELL in 2001 and 2002.

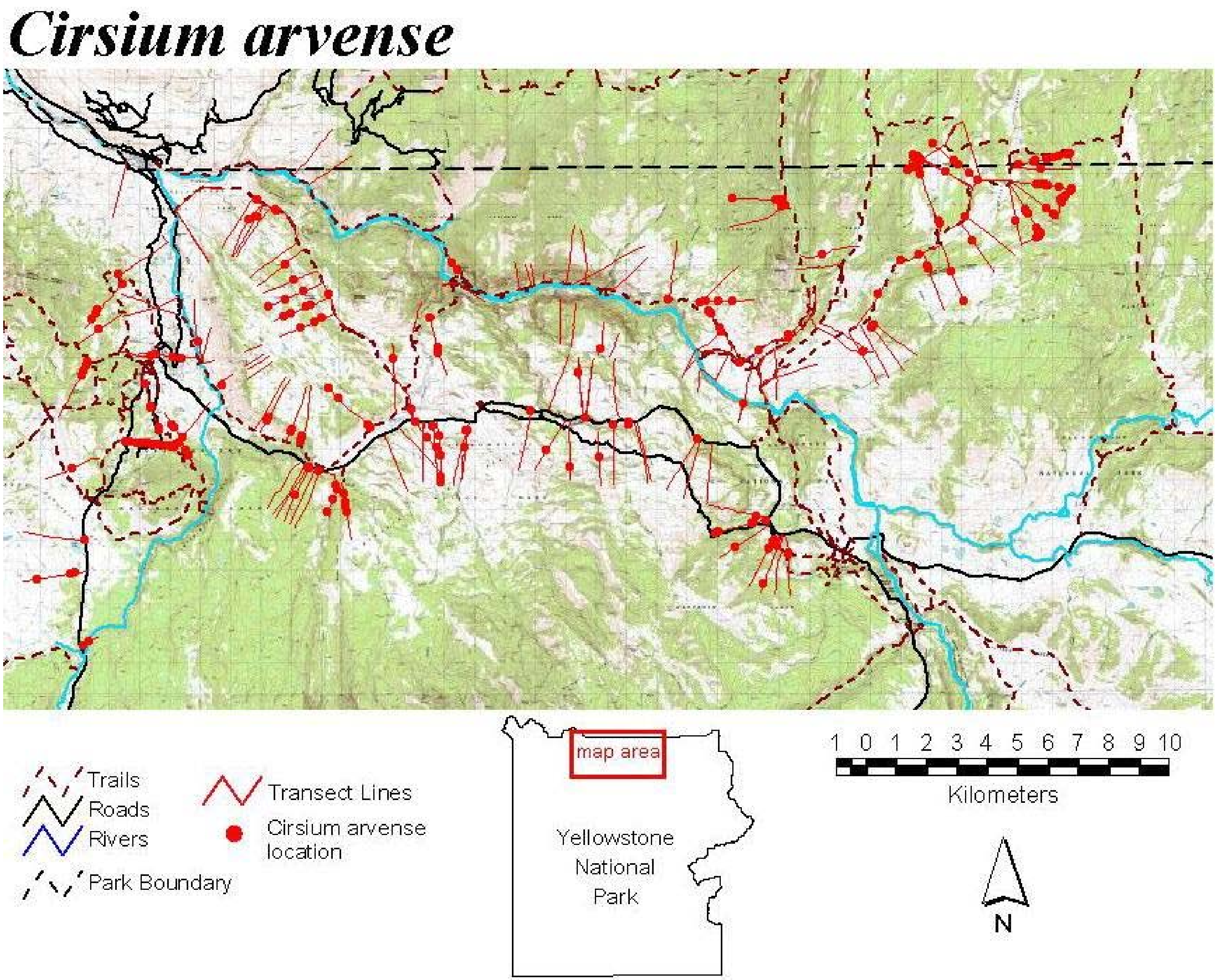

Fig. 5. Observed presence of *Cirsium arvense* in the northern range of YELL in 2001 and 2002.

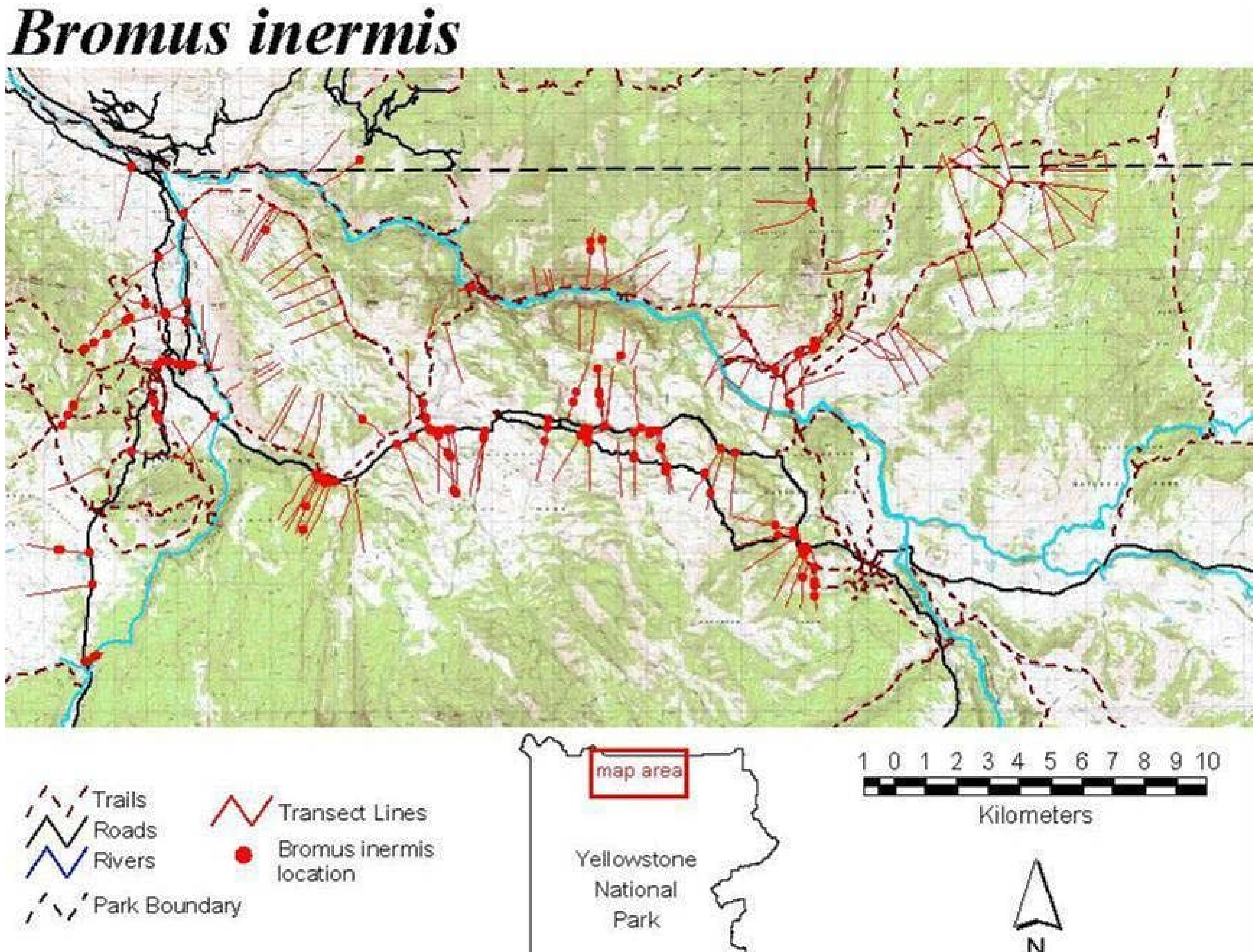

Fig. 6. Observed presence of *Bromus inermis* in the northern range of YELL in 2001 and 2002.

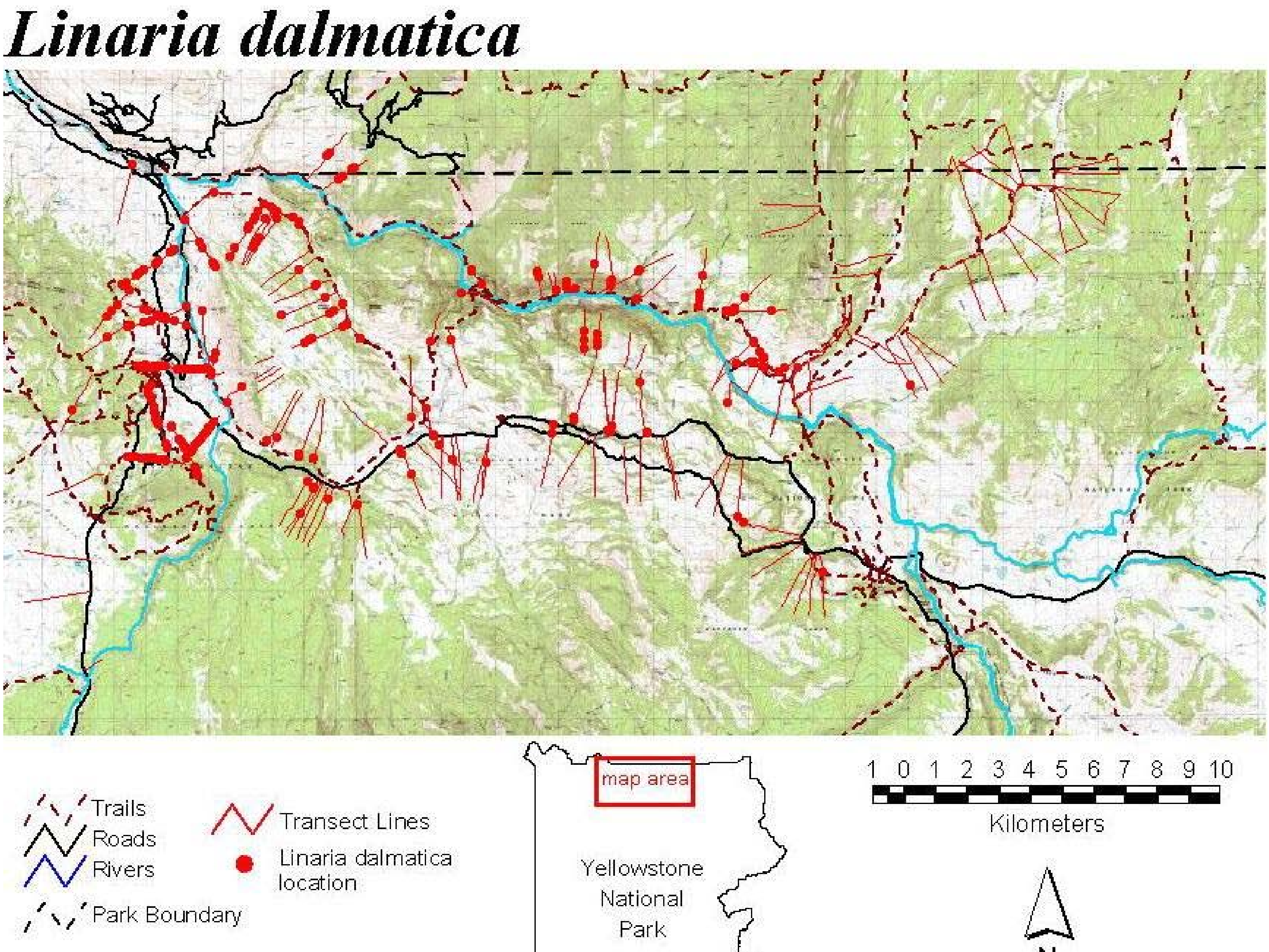

Fig. 7. Observed presence of *Linaria dalmatica* in the northern range of YELL in 2001 and 2002.

Statistical analysis

A procedure was developed in Arcview to generate presence/absence data for each of the NIS allowing for patch length, using a 10 m resolution. Thus, for each 10 m interval there were field collected data for NIS occurrence, habitat, four locally dominant species, disturbance (fire, etc), distance to nearest road and trail was calculated, information on aspect, elevation and slope was obtained from a 10 m DEM, and the classification using the current habitat grid was collected.

These data were analyzed using a logistic regression model to predict the occurrence of selected NIS species. The model took the form:

$$P(y = 1 \mid x_j) = \frac{\exp(\beta_0 + \beta_1 x_1 + \ldots \beta_i x_j)}{1 + \exp(\beta_0 + \beta_1 x_1 + \ldots \beta_i x_j)}$$

where, y = NIS of interest, x_j = slope, elevation, distance from road, distance from trail, and vegetation habitat type. The best model was determined using Akaike Information Criterion (AIC) and the results used to generate a predictive NIS map for the northern range. The predicted occurrence of *Cirsium arvense* (Fig. 10), *Linaria dalmatica* (Fig. 11) and *Phleum pratense* (Fig. 12) are provided. These are preliminary maps and further adjustments need to be made. The main problem is the lack of agreement between the finer resolution field classification of the habitats and the coarser scale GIS layer. We are investigating this.

The data were also analyzed with an inductive modeling procedure based on Bayes' theorem, within ArcView (Aspinall, 1992). Inputs to the theorem, in the form of conditional probabilities, are derived from an inductive learning process in which attributes of the data set to be modeled (presence/absence) are compared with attributes of a variety of predictor data sets (see Aspinall, 1992, for more detail). These predicted models were similar to the logistic regression models and we are evaluating these different approaches.

2003 field season

We plan to use the same sampling protocol as 2002 and spend 70% of our sampling time in the Lamar Valley area of the park where we have spent little time. 30% of the time will be spent collecting data to test the probability models. The models will be evaluated and then the test data and the transect data used to improve the models. Further data collection and model testing will be performed in 2004.

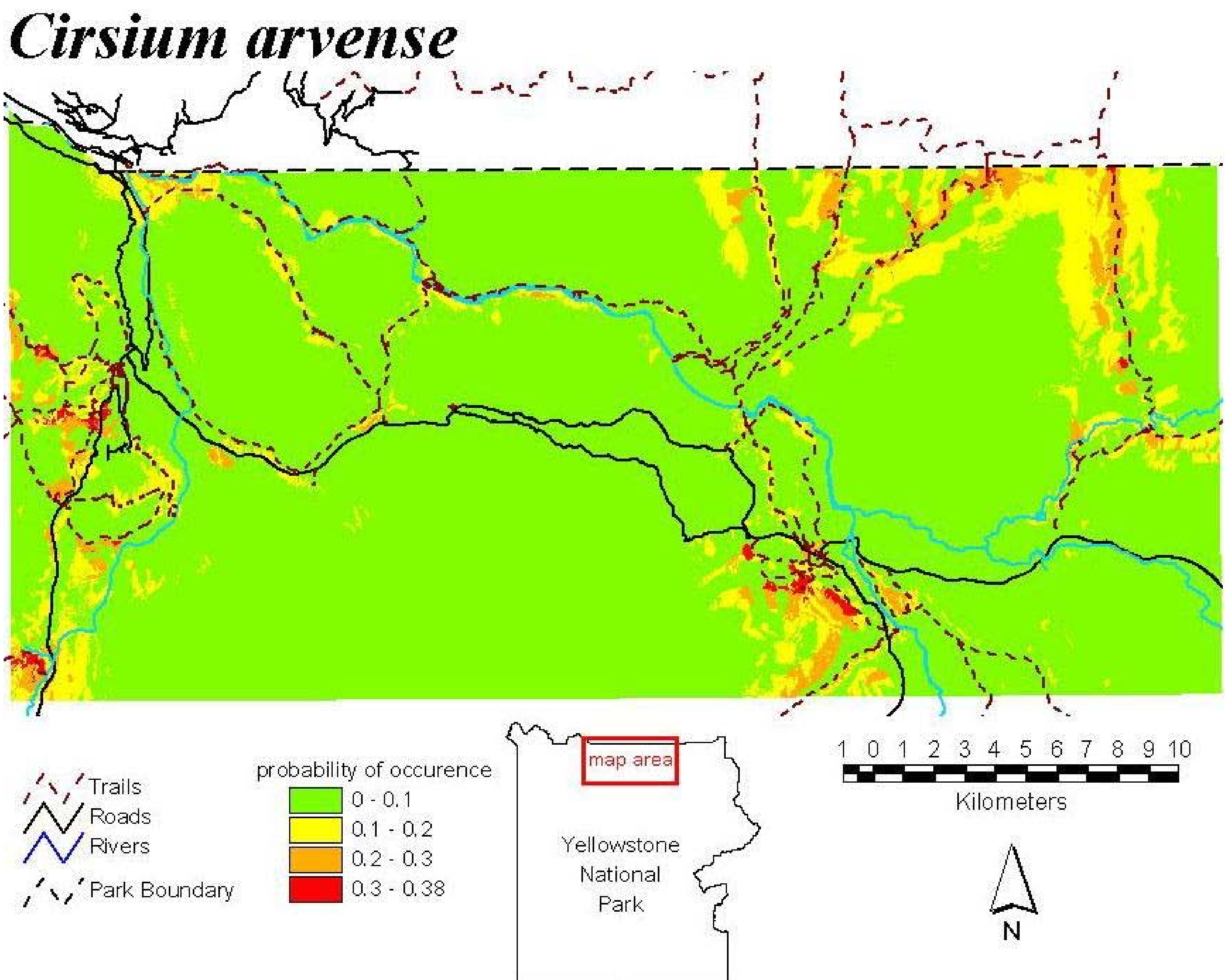

Fig. 10. Predicted probability of *Cirsium arvense* occurrence in the northern range of YELL.

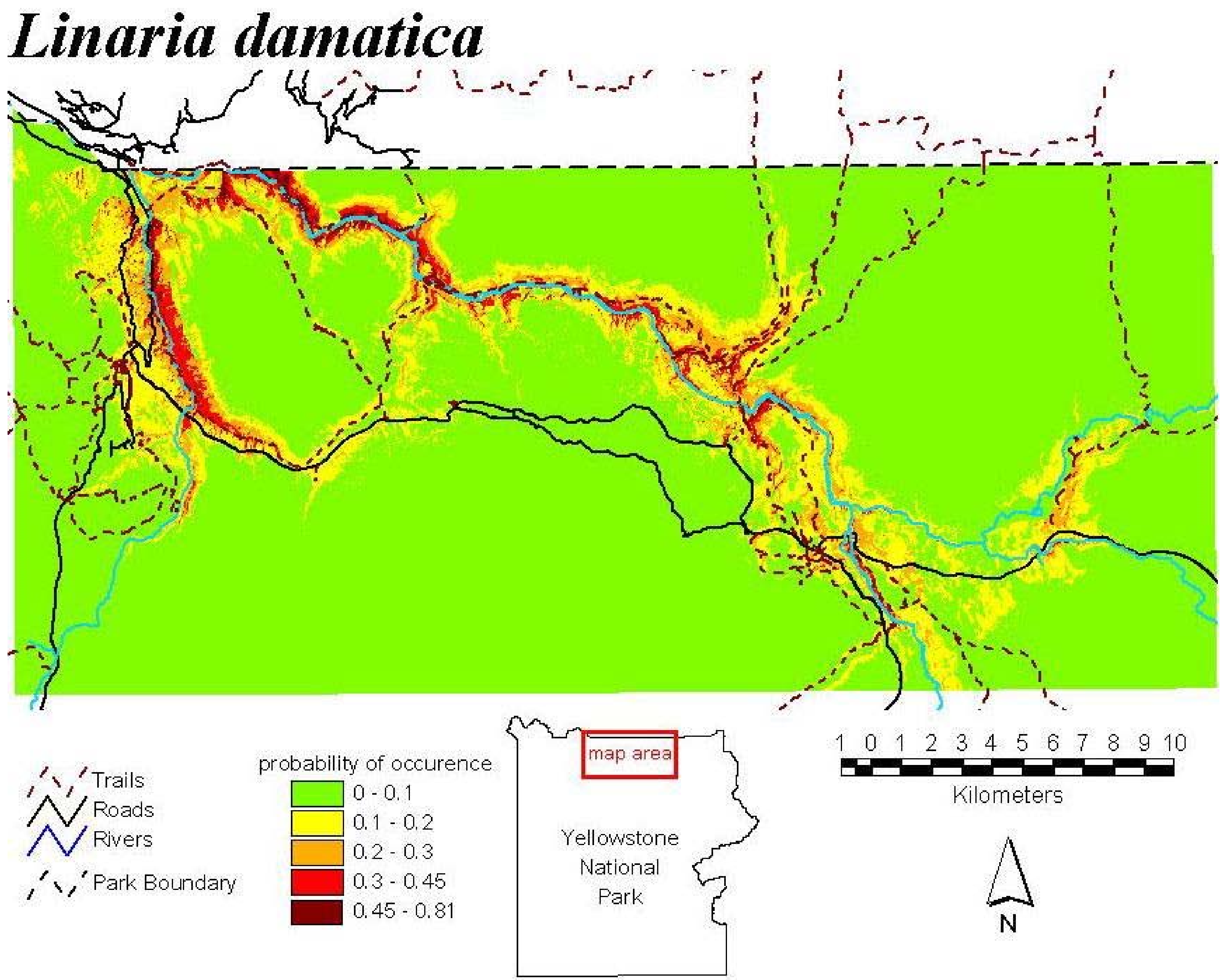

Fig. 11. Predicted probability of *Linaria dalmatica* occurrence in the northern range of YELL.

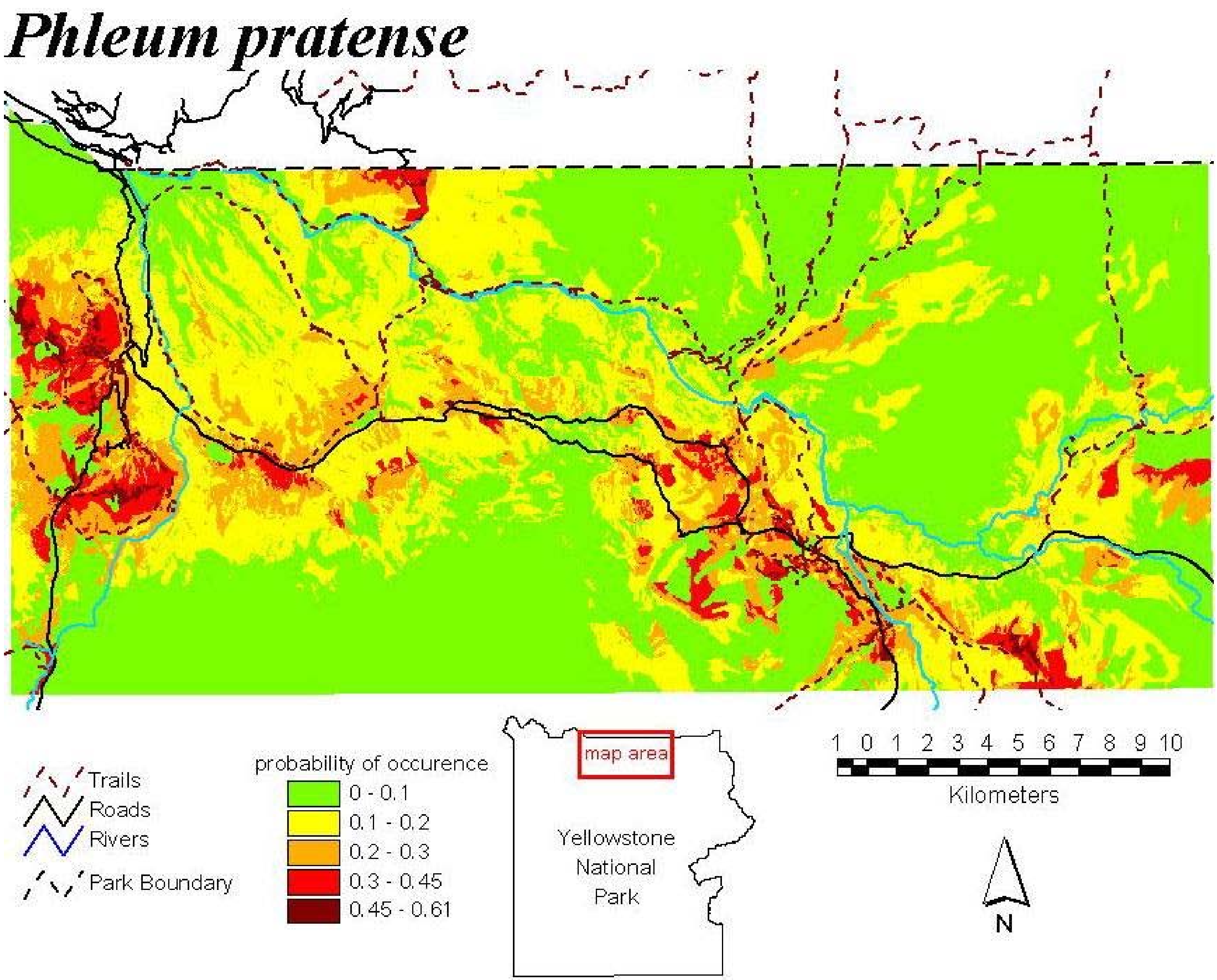

Fig. 12. Predicted probability of *Phleum pratense* occurrence in the northern range of YELL.

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Budget

2003											
Labour	Number	Annual pay	Hourly rate	Month	No. hours	Cost	% of time	Actual cost	Benefits (%)	$ Benefit	Total cost
Ass. Research Prof. (L J Rew)	1	61538	29.47	2	320	9431.11	100	9431.11	34	3206.58	12637.69
Technical Assistant (F Dougher)	1	30000	14.37	2	320	4597.70	100	4597.70	34	1563.22	6160.92
Field assistants	3	21000	10.06	2	320	3218.39	100	3218.39	11	354.02	10717.24
Total											**29515.85**
Travel		$ / month	No. days		sub-total						
Per diem - accommodation	1	300	0.00	3	900						900.00
Per diem - sustenance	4	23	4.00	3	276						4416.00
Vehicles maintainance	1										1000.00
Extra vehicle supplied by MSU											
Total											**6316.00**
Supplies											
Equipment (Maps, first aid, bearspray,backpacks, radios etc)					2000						400.00
Geoexplorer 3 (3 supplied by YELL)											
Mileage (2000miles/month @ .32 c)	2	432		3	1296						2592.00
Notebook - supplied by MSU											
Radios - rental											500.00
Total											**3492.00**
Indirect costs @ 15%											**5898.58**
2003 Grand Total											**45222.43**

Project timetable	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec
Project implementation	**2002**											
Advertise positions												
Reserve accommodation												
Purchase GPS, rent vehicles etc.												
Apply for Research Permit												
Program GPS												
Phase I - Non-indigenous survey												
Field Assistants commence												
GPS and botanical initiation (1 week)												
Data collection												
Data collation and analysis												
Data collated												
Data analysis & report												
Project implementation	**2003**											
Advertise positions												
Reserve accommodation												
Apply for Research Permit												
Program GPS												
Phase I - Non-indigenous survey												
Field Assistants commence												
GPS and botanical initiation (1 week)												
Data collection												
Data collation and analysis												
Data collated												
Data analysis & report												
Project implementation	**2004**											
Advertise positions												
Reserve accommodation												
Apply for Research Permit												
Program GPS												
Phase I - Non-indigenous survey												
Field Assistants commence												
GPS and botanical initiation (1 week)												
Data collection												
Data collation and analysis												
Data collated												
Data analysis & report												

Appendix 1 Non-indigenous NIS of interest for Yellowstone National Park

Watch List: Exotic species not documented/established in the park. The goal is to prevent establishment through staff education, early detection, and eradication. Those species noted with an asterisk (*) have been found in the park, but were removed prior to seed dispersal.

1. *Arctium lappa**	(great burdock)
2. *Arctium minus**[1]	(common burdock)
3. *Centaurea pratensis**	(meadow knapNIS)
4. *Centaurea solstitialis*	(yellow starthistle)
5. *Chondrilla juncea*	(rush skeletonNIS)
6. *Crupina vulgaris*	(common crupina)
7. *Isatis tinctoria**	(dyer's woad)
8. *Lepidium latifolium*	(perennial peppergrass)
9. *Lythrum salicaria*	(purple loosestrife)
10. *Onopardum acanthium**	(scotch thistle)
11. *Senecio jacobaea**	(tansy ragwort)

Priority 1: Species that have produced seed in the park, but populations are small and limited in number. These species have a high probability for eradication with continued annual monitoring and treatment. They are also the most cost effective species to control (<1 acre infestation).

1. *Astragalus cicer*	(chick-pea milkvetch)
2. *Carduus acanthoides*	(plumeless thistle)
3. *Centaurea diffusa*	(diffuse knapNIS)
4. *Centaurea repens*	(Russian knapNIS)
5. *Chorispora tenella*	(blue mustard)
6. *Conium maculatum*	(poison hemlock)
7. *Dianthus armeria*	(grass pink)
8. *Euphorbia esula*	(leafy spurge)
9. *Hyoscyamus niger*	(black henbane)
10. *Potentilla recta*	(sulfur cinquefoil)
11. *Ranunculus acris*	(tall buttercup)
12. *Tamarix chinensis*	(tamarisk)
13. *Tanacetum vulgare*	(tansy aster)
14. *Trifolium aureum*	(yellow clover)

Priority II: Aggressive invaders, some of which are well established in some localities making eradication impractical (identified by •), but most are confined to relatively small areas at specific locations. Containment will be the primary goal for these species in established infestations, and as funding permits as a secondary goal, annual control to reduce seed production with possible future eradication. Individual plants or small infestations away from core infestation areas will be a high priority for aggressive control. Control efforts have a high probability of successfully limiting the spread, and will be undertaken. Monitoring of and for these species should by frequent and regular.

[1] Only basal rosettes have been found, so identification to species is uncertain

1. *Berteroa incana*• (berteroa)
2. *Cardaria* spp.[2] (whitetop)
3. *Carduus nutans* (musk thistle)
4. *Centaurea maculosa*• (spotted knapNIS)
5. *Chrysanthemum leucanthemum*• (oxeye daisy)
6. *Cirsium vulgare* (bull thistle)
7. *Convolvulus arvensis* (field bindNIS)
8. *Cynoglossum officinale*• (houndstongue)
9. *Hieracium auranticum* (orange hawkNIS)
10. *Hieracium caespitosum* (yellow king devil)
11. *Hieracium floribundum* (glaucous king devil)
12. *Hieracium flagellare* (whiplash hawkNIS)
13. *Hypericum perforatum* (St. Johnswort)
14. *Linaria dalmatica*• (Dalmatian toadflax)
15. *Linaria vulgaris*• (yellow toadflax, butter and eggs)
16. *Melilotus albus* (white sweet clover)
17. *Melilotus officinalis*• (yellow sweet clover)
18. *Silene vulgaris* (bladder campion)
19. *Sonchus arvensis* (perennial sow-thistle)
20. *Verbascum thapsus* (wooly mullein)
21 *Veronica biloba* (bilobed speedwell)

Priority III: Aggressive exotics, which are dispersed over large areas of Yellowstone and have deleterious effects on the park ecosystem. Control efforts are likely to be ineffective and costly. However, work may be done to confine the spread of these plants in sensitive areas. Monitoring would be beneficial, but will come after Priorities I & II.

1. *Alyssum desertorum* (desert elyssum)
2. *Bromus inermis* (smooth brome)
3. *Bromus tectorum* (cheatgrass, downy chess)
4. *Cirsium arvense* (Canada thistle)
5. *Elymus repens* (quackgrass)
6. *Medicago lupulina* (black medic)
7. *Phleum pratense* (common timothy)
8. *Poa* spp.[3] (bluegrass)
9. *Trifolium hybridum* (alsike clover)
10. *Trifolium repens* (white clover)

Priority IV: Exotics, for which little or no control efforts are foreseen. Even though many of these plants displace native vegetation, control of high priority species takes precedence. Limited

[2] *Cardaria chalepensis, Cardaria draba,* and *Cardaria pubescens*
[3] *Poa annua, Poa bulbosa, Poa compressa, Poa palustris,* and *Poa pratensis*

monitoring actions may be undertaken. Approximately 134 species fall into this category. None of the plants in this category are listed noxious by the surrounding states.