Non-native Plants Survey of Greater Yellowstone Inventory and Monitoring Network (GRYE): Study Plan

Objectives of the GRYE Weed I&M Weed Inventory Program

The Greater Yellowstone Network (GRYE) Biological Inventory Program is supporting an exotic plant inventory program to acquire baseline information on distribution and abundance of selected non-native plant species which are of management concern (noxious and others) in targeted areas of network parks. This program is intended to complement base-funded and other soft-funded weed management activities within network parks. The Biological Inventory Program is a four-year program scheduled to run through NPS Fiscal Year 2004, which focuses on vertebrate, and vascular plant inventory related projects. Funds allocated for weed inventory within the GRYE included a one year pilot study and planning effort (completed in FY01) followed by three years (FY02 through FY04) of intensive surveys to identify and map exotic plant species within selected area of network parks. While exotic plant invasions are of general concern to each of the parks in the Greater Yellowstone Network, the specific concerns and planned responses vary among the parks.

All three parks will be surveying for the weed species listed as noxious by the states in which they are located (i.e., Bighorn Canyon: Montana and Wyoming; Grand Teton: Wyoming; and Yellowstone: Montana, Wyoming, and Idaho) (See Appendix 1). Several of the listed species are not known to be in the parks; however, they will be kept on a "watch" list and inventoried if encountered. The parks have also identified other non-native (non-noxious) species of special concern, which they will also be surveying. These species have been chosen because they are perceived to be having major impacts on native plant communities.

PROGRAM OBJECTIVES FOR 2001-2004

- Increase baseline knowledge on the locations of exotic, invasive, noxious weed populations within network parks.
- Survey targeted areas (habitats and areas at risk for invasion by priority non-native plant species and areas that have not been adequately surveyed in previous efforts) to acquire baseline distribution and abundance information on selected non-native plant species.
- Identify environmental characteristics that correlate with exotic plant distribution.
- Identify high priority areas for weed management action.
- Gain an increased knowledge of resource threats related to noxious weed establishments (e.g. degradation to native habitats, loss of wildlife forage, threats to T&E species, loss of cultural landscape, accelerated erosion).
- Produce GIS-based maps/database for each weed species' distribution that can be queried for weed management planning.
- Increase individual parks ability to establish effective weed monitoring programs/ activities.

PROGRAM OBJECTIVES 2002

- Further refine the MSU sampling methodology by applying it to a broader geographic region of the GRYE.

- Complete the first year of a three-year program of exotic plant mapping that will provide information on invasive plants within YELL NR and GRTE VF, and to adequately capture information on environmental factors that contribute to the distribution and abundance of these plants.
- Gather distribution and abundance data on a greater number of exotic species of interest to network parks.
- Provide information to support a network-wide workshop to adaptively plan successive years sampling efforts.

Rationale and need for locating weeds in National Parks

The National Park Service is required by law to keep the 34 million ha (≈ 84 million ac) of Parks under it's stewardship classified as "natural areas…unaltered by human activities" (National Park Service, 1996). "Any animal or plant species that occurs in a given location as a result of direct, indirect, deliberate or accidental actions by humans" is defined as being non-native (National Park Service, 1996). This distinguishes between changes to animal and plant distributions caused by natural processes and human disturbance resulting from European settlement of North America in the past century and most specifically in the last 50 years. The invasion of exotic plants is considered by many biologists to be the most significant threat to the integrity of native plant communities in National Parks (Olliff *et al.*, 2001), therefore maintaining National Parks as "natural areas" requires aggressive management and removal, where possible, of non-native species.

Many countries have designated specific areas as "wilderness" or "natural ecosystems" and seek to preserve these in a pristine state. From an ecologically purist point of view, maintaining such areas should involve the protection of these areas from infestation by exotic species and the total removal of non-native species when they occur. From a practical resource management perspective this may not be possible in most cases. At best we may only be able to control the spread of exotic species into non-infested areas or areas of current low infestation. For many large expanses of presumed natural areas we do not know the range of non-native species present, the frequency of their occurrence, nor the patterns of their distribution. We do not know the dynamics of how their distributions may be changing and finally what impact they are having on endemic ecosystems. It is only when armed with this information that resource managers can effectively target and manage non-native species populations.

The language used to describe the presence and impact of non-native species is often very emotive: "aggressive non-native 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-native species is stated as proof enough of present (or the potential for future) environmental damage, particularly if the species is highly competitive and if the increase in the non-native species is associated with the decline of native species. While this may reflect the realities associated with the introduction of exotic plants into previously pristine ecosystems, Weaver *et al.*, (2001) found that the majority of the 29 most commonly found exotic species in the northern Rocky Mountains were intentionally introduced (e.g. the grasses common timothy and Kentucky bluegrass). Furthermore, none of the most common exotic plants are generally considered to be noxious weeds.

The Park Service has a mandate to address the occurrence of non-native plants, therefore integrated strategies have been adopted to manage exotic vegetation in all three parks of the GRYE Inventory and Monitoring Network (Yellowstone National Park [Olliff *et al*., 2001], Grand Teton National Park [McCloskey, personal communication], Bighorn Canyon National Recreation Area [Morstad, personal communication]). These strategies emphasize prevention, employee and visitor education, early detection and eradication, prioritization of established weed species or vegetative habitats for control or containment, and the revegetation of disturbed or reclaimed areas with appropriate native plant species.

General Approach to Exotic Plant Management within the GRYE

YELLOWSTONE NATIONAL PARK

It has been documented that the number of exotic plant species is increasing throughout the Greater Yellowstone Ecosystem. In YELL the number of exotics has increased from 85 in 1986 to over 185 in 2001 of which 30 are listed as noxious in 1 the of 3 states (Wyoming, Montana and Idaho) in which YELL is located (Whipple, 2001). In response to this increase and to be in compliance with legal and policy mandates for the control of exotic/noxious weed species, the general management approach has been an aggressive effort to control or contain established weed infestations (Olliff *et al*., 2001). The majority of non-native plants are believed to occur around areas of disturbance or regular human use such as roads, trails, campgrounds, visitor centers etc. (Figure 1). The approach in YELL has been to concentrate weed management efforts to within a few hundred meters of disturbed areas. As a result 2812 ha (4500 ac) are surveyed annually, primarily along roadsides and developed areas, with emphasis on eradicating small, new infestations of highly invasive target species (Olliff *et al*., 2001). Exotic plant surveys or control efforts in backcountry areas are only opportunistically accomplished. Time, money, and manpower constraints limit exotic plant control efforts, and backcountry areas are perceived as having less of a weed problem than front-country areas.

This approach, limited as it is by funding (Olliff *et al*., 2001), has left the majority of land within YELL unexamined for the occurrence of established exotic plant individuals or patches. Despain (1990) has divided YELL into roughly five vegetative zones influenced by interactions between climate and vegetation. Of these, the cold-desert environment of YELL's northern range is considered to be the most vulnerable to exotic plant invasions (Olliff *et al*., 2001). Yet little effort at exotic plant discovery and control occurs beyond the roads, trails, and otherwise developed areas of the northern range.

GRAND TETON NATIONAL PARK

Grand Teton National Park is home to approximately 1,200 plant species. Of these at least 117 are non-natives. These species pose a significant threat to native plant species, and to the perpetuation of park ecosystems (Weaver & Woods, 1986). Unless the continued invasion and expansion of noxious weeds can be curtailed, the opportunity "to conserve the scenery and the natural objects and wildlife within" the park (National Park Service Act, 1916), may be lost forever. Recreational and historic economic uses of Grand Teton National Park lands have aided the spread of these species, as seeds are transported with pack feed, on animals, on car tires, and on visitor's shoes and clothing.

Grand Teton National Park has in place a weed management plan, and works effectively as a member of the multi-agency Jackson Hole Weed Management Association to reduce weed populations in the area and increase public awareness of the problems associated with weed infestations. Current efforts focus on the right-of-way and developed zones of the park, roads, developed areas of the park, grazing lands, and river corridors (Figure 2). These areas are highly visible vectors of movement for exotic plants. Infestations in these areas are mapped, and many are continually treated and monitored to keep the area of infestation as small as possible (Figure 2). The degree of weed infestation in many of the less accessible areas of the park is not known. A lower degree of infestation in these areas is expected due to less human disturbance of the ground surface, and less human traffic transporting seed. However, these backcountry areas also contain resources and habitats with the very properties that the park seeks to conserve.

BIGHORN CANYON NATIONAL RECREATION AREA

Bighorn Canyon National Recreation Area is unique among the three network parks in several ways. Bighorn Canyon is considerably smaller in total acreage being only 3% the size of Yellowstone. It is predominately Great Basin Desert of the Wyoming Basin Ecological Region[1] whereas Grand Teton and Yellowstone National Parks are Boreal Forests of the Middle Rockies Ecological Region. BICA is dominated by the Bighorn Lake formed by the construction of the Yellowtail Dam near Ft. Smith, MT, and, because of it's size and geography BICA's approach to weed mapping is much less problematic that either that of GRTE or YELL.

The land of Bighorn Canyon NRA has sustained many disturbances before becoming part of the National Park System. Continued disturbance includes cattle trailing and grazing, visitor use, and fluctuations in the elevation of Bighorn Lake. Issues of concern relative to exotic plant management within Bighorn Canyon NRA focus a great deal on the Yellowtail Wildlife Habitat Management Area (see Figure 3). A 19,424 acre reserve managed by Wyoming Game & Fish Department through cooperative agreements with the National Park Service (Bighorn Canyon NRA), the Bureau of Land Management, and the Bureau of Reclamation. The Yellowtail Wildlife Habitat contains one of Wyoming's richest concentrations of wildlife species, as well as one of the largest remaining examples of an old growth riparian cottonwood forest in Wyoming. It has a history of repeated and continuing human disturbance including farming, livestock grazing, fluctuating water level and heavy hunter use. While the Wyoming Game and Fish Department is the lead agency for managing the habitat, Bighorn Canyon NRA is responsible for managing ≈ 12,000 acres, which includes most of the lake flood pool area, and specifically the 4,250 acres that are above the flood pool level.

The Yellowtail Habitat has become heavily infested with a mixture of noxious and or invasive exotic plants, especially Russian knapweed, tamarisk, whitetop, Russian olive, and Canada thistle. It is estimate that over 34% of the southern end of the habitat has one or more noxious weed

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[1] Common Ecological Regions of the Conterminous United States, USDA, Natural Resources Conservation Service.

species. A conservative estimate leaves ≈ 1,500 acres of noxious weed infestations above the flood pool level within the Yellowtail Wildlife Habitat managed by the NPS not yet mapped.

Current state of Weed Inventories in GRYE Network Parks

MAPPING STANDARDS

Several standards for mapping and recording data on exotic weed distribution and abundance are in use within the GRYE (see below). Most of weed management agencies of the Greater Yellowstone Area use the Montana Noxious Weed Survey and Mapping System protocol[2] or a variant thereof to capture data on weed infestations. The North America Weed Management Association (NAWMA) has also developed mapping standards for interagency reporting of exotic plant distribution and abundance along with providing a recommended data dictionary for specific direction on recording the data[3]. Using both the NAWMA and Montana standards as a starting point the National Park Service Intermountain Region has also developed minimum mapping standards to recommend to region parks for use in gathering information on exotic plant invasions and their response to management efforts. The IMR standards were developed by a committee of subject matter experts that met in Salt Lake City, UT in March of 2001. With slight modification to organize exotic plant mapping data in a Microsoft Access database that conforms to the I&M Natural Resources Database Template, these guidelines are being used as the benchmark mapping protocol for all GRYE sponsored exotic plant surveys.

Appendix 2 contains a spreadsheet display of the IMR mapping and data capture guidelines including notations on the specific data fields that will be collected as part of the mapping proposed herein. It also presents information on the current state of weed mapping data capture within GRYE network parks.

YELLOWSTONE NATIONAL PARK

Yellowstone National Park has organized an Exotic Plant Management Committee for directing alien-plant management efforts throughout the park. This committee consists of the four weed management districts District Resource Operations Coordinators, the Branch Chief of Resource Operations, the park Vegetation Management Specialist, and the park Botanist. YELL is also a partner in a multi-jurisdictional weed management area that was established in accordance with the guidelines contained in the Coordinated Management of Noxious Weeds in the Greater Yellowstone Area (GYCC Guidelines, Free *et al.*, 1990). See Olliff *et al.* (2001) for a detailed description of the weed management activities within YELL.

Over 140 national park staff participate in weed management efforts within YELL each year. These include field and entrance station rangers, maintenance division staff, the park Landscape Architect, and park concessionaires. Interpretation rangers educate the public on the dangers to YELL from alien plant invaders, and more that 100 volunteers assist annually with detection, mechanical control, and native plant seed collection for revegetation efforts.

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[2] http://www.montana.edu/places/mtweeds/transfer.html

[3] http://www.nawma.org/

Most weed management efforts in YELL focus on mechanical control, pulling, grubbing, mowing, or cutting. Chemical control is a small but important aspect of the program as well. Herbicides are used to control aggressive species that do not respond well to mechanical control, or when insufficient staff are available for adequate mechanical control activities.

Ongoing weed inventory efforts within YELL include GPS mapping of specific weed locations and/or the area of infestation by estimating infestation size or by walking the perimeter of an infestation. Along with location, 30 other data items are captured and stored in a computer database that contains information on yearly survey and control efforts by management district.

Additionally, funding from the Henry's Fork Weed Management Area, the Greater Yellow Coordinating Committee, and the Idaho Department of agriculture allowed the West District Resource Operations Coordinator to conduct a one-time survey for leafy spurge (*Euphorbia esula*) at the boundary of the Targhee/Caribou National Forest and Yellowstone National Park. This survey was a preventative reconnaissance effort to establish baseline information on the distribution of leafy spurge a highly invasive noxious weed that may be gaining a foothold in the area. A total of 8820 acres were surveyed by foot and helicopter in September and October of 2001 (Figure 4).

GRAND TETON NATIONAL PARK

GRTE's Draft Weed Management Plan divides the park into five weed management zones (Figure 2):

1. Right of Way (roadways)
2. Developed (maintenance, housing, concession and campground areas)
3. Riparian (river corridors – Snake River, Gros Ventre River, Spread, Pacific, Ditch and Pilgrim Creeks) – valley waterways, come from the East, disturbance prone.
4. Valley (including trails, untrailed, and historic use areas)
5. Backcountry (trailed and undeveloped backcountry areas, as well as cabin sites)

The Park is in the process of surveying these areas systematically. The Riparian areas were surveyed for exotic species distribution and abundance in FY00. Park personnel surveyed the Right-of-Way and Developed zones in FY01. Grand Teton National Park uses the Montana Noxious Weed Survey and Mapping System for recording inventory results. Additionally, the Park has adapted four survey methods that were developed and described by USDA Forest Service Region 6 (Pacific Northwest Region), and are currently in use by Region 6 forests for plant inventory surveys. These are as follows:

1. **Intensive survey** – a survey in which virtually every square meter of the target area is searched for the target species. This technique has been used, and will continue to be used in the developed zone of the Park.
2. **Intuitive controlled survey** – a survey in which the area of interest is surveyed less intensively, often using a zigzag pattern, with locations of particular interest receiving additional attention at the discretion of those conducting the survey (thus the

"intuitive" controlled title). This technique was used in conducting the FY2000 survey of the riparian corridors.

3. **Transect survey** - a survey method wherein medium to large areas with potentially significant levels of infestation are examined in some detail. These may also incorporate an aspect of the intuitive controlled technique in that areas of higher probability may receive closer attention, survey crew may travel short distances off the transect to inspection specific areas of interest.
4. **Spot survey** – medium to large areas with anticipated low levels of infestation may be surveyed using spot surveys wherein the surveyor looks closely at small areas within a larger area. Spot survey locations may be based on accessibility, likelihood of infestation, or may be selected randomly.

Weed inventory crews map all surveyed areas as well as the specific locations where target species were found. This provides a record of areas that were apparently free of target species to correlate with information on areas that are infested.

BIGHORN CANYON NATIONAL RECREATION AREA

For weed management purposes BICA has been divided into the area north of Sykes Mountain and the Yellowtail Wildlife Habitat (see Figure 3). North of Sykes Mountain the dominant vegetation is basin grasslands and plateau woodlands. Extensive surveys on the context of looking for rare plants and abandoned mineral lands have shown weeds to be confined to areas of recent and/or ongoing disturbance. These include historic ranches, areas of previous heavy cattle grazing, cattle trailing routes, fires in the past 15 years, lake high water marks, an old airport, and disturbed areas near park roads. In FY00 a concentrated effort mapped 56 total acres of noxious weeds in the park area north of Sykes Mountain. Approximately 20 acres of weed-infested lands were mapped in FY01.

Exotic plants, for mapping in BICA, are located from previous records of weed sightings during exotic plant management activities, systematic walking and mapping in areas known to be at high risk, and from observations of resource management staff and botanists working in the park on other projects. A comprehensive display of mapped weeds revealed few gaps in coverage and a distinct trend towards infestations associated with known disturbances. Except for the Yellowtail Wildlife Habitat, obvious gaps in the mapping effort are walked by a park vegetation ecologist.

The Intermountain Region has received NPS funding (PMIS# 72973) to implement a noxious weed inventory and mapping program in several small parks within the region. BICA is one of the participant parks and under this program will have the area remaining in the Yellowtail Wildlife Habitat mapped by a group headed by Dr. Roger Sheley of the Montana State University at Bozeman. FY02 will be a planning year for this effort with weed mapping taking place in FY03. Mapping of exotic plants under this initiative will be done in accordance with the IMR standards described above (see Appendix 2).

Development of a Probability Based Sampling Strategy

It has been recognized that a more quantitative assessment of exotic vegetation in the backcountry areas is needed to supplement existing weed management activities (Olliff *et al.*, 2001). While the perception that non-native plants have lower occurrence in backcountry areas of national parks or areas further from known disturbances is probably true, it has not been quantified. By quantifying the frequency of non-native species within the environment and determining if or how their distributions are correlated with abiotic and biotic factors it then becomes possible to develop more efficient and effective strategies for the management and control of these problematic invasive plants. Thus, an inventory of non-native exotic plants and the subsequent assessment of population and metapopulation dynamics must have the objective of creating an unbiased estimate of their distributions over some given area of concern in proportion to their true abundance in order to prioritize the management of those metapopulations that pose the greatest threat to the ecosystem.

The resultant data will enable the development of species distribution maps in relation to the factors described above. It then becomes possible to stratify or prioritize management efforts into areas with the greatest likelihood of invasion by exotic plants. An unbiased sampling process requires locating populations or metapopulation over the extent of the environments where they may exist in relation to their true abundance. Therefore, we are reliant upon an inventory process that maximizes the probability of finding exotic plants and simultaneously builds a data set from which models that predict weed occurrence can be developed. Thus ensuring that we represent, through observation or prediction, all environments where exotic plants may be found.

SIMULATION OF SAMPLING METHODOLOGIES

A computer based simulation was conducted to develop the most effective sampling regime for large areas of backcountry park land. This was performed in ESRI ArcView© GIS using a routine developed by R. Aspinall, which 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-native plants.

Using equation 0.1 it is possible to use a random sample to determine the percentage of the study area occupied by non-native plants.

$$p = \left(\frac{100n}{N} \right) \qquad (0.1)$$

Where:
p = the percentage of the study area occupied by non-native plants,
n = the number of sample points at which the non-native plant is found, and
N = the total number of sample points searched.

The same relationship applies to samples along lines (transects) in which case n is the length of transects occupied by the target non-native plant, and N is the total transect length searched.

Working through an example of this, within ArcView GIS we simulated 100 non-native plant patches, each 3 m long. 100 transects, each 2,000 m in length, were randomly generated. ArcView was then used to identify the length of transects that were occupied by non-native plants (by intersecting the 3 m non-native plant patches with the 100 transects). The length of transect occupied by non-natives was 300 m. Inserting this in equation 0.1 with n = 300, N = 200,000 gives p = 300/200,000 or 0.15%. In general, with any random sampling scheme the target species is sampled at the frequency with which it occurs in the landscape; this applies to any distribution pattern. Note that, for sampling, frequency is measured as the area occupied by the species of interest and not as the level of abundance of the species.

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-native 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 provided the highest number of sample points for the shortest time in the field and, also provided geographic coverage necessary for estimating distribution of the non-native 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 is not used for data collection. Surveying along transects allows data to be collected continuously and a large sample size to 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 species (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-native weeds, 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 2,000 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 four areas were selected from the northern range (NR) of Yellowstone National Park and from the valley floor (VF) of GRTE; one area at each location was considered to be intensively disturbed and the other three areas were considered to be minimally disturbed (Figures 5 & 6). Within each of these areas the position of the starting point of each transect was randomly selected and the direction of the transect oriented perpendicular to the road or trail from the starting point. Transect starting points were selected and orientation determined using ArcView GIS prior to arriving at the site.

The species targeted for the pilot study are given below in Table 1. These particular species were chosen as they present at a range of frequency of occurrence and of growth habits that would define a two dimensional continuum from widespread to local occurrence and from easy to hard to identify. In Grand Teton another 30 non-native species were targeted, of which only five were located (Rew *et al.*, 2001).

Table 1. List of the non-native species used as targets in the field-sampling program.

Distribution /Ease of observation	**Widespread**	**Scattered**	**Local**
Easy	Dalmatian toadflax (*Linaria dalmatica*)	Yellow sweetclover (*Melilotus vulgaris*)	Ox-eye daisy (*Chrysanthemum leucanthemum*)
Moderate	Common Timothy (*Phleum pratense*)	Cheatgrass (*Bromus tectorum*)	Spotted knapweed (*Centaurea maculosa*)
Hard	Canada thistle (*Cirsium arvense*)	Smooth brome (*Bromus inermus*)	Houndstongue (*Cynoglossum officinale*)

Transects were walked and exotic plant locations recorded with a GPS (Global Positioning System), by two person teams. Transects were 10 m wide. Trimble Pro XRS and GeoExplorer® 3 GPS receivers were used for recording location data. Location data were post-processed to improve accuracy. The location of any of the target species was recorded along with key environmental variables including, climax habitat type and dominant vegetation cover, aspect, topography and disturbance. If the habitat/cover class changed or a human disturbance was reached but no target weeds were present the location was again recorded along with the other environmental variables. Habitat classifications in the NR were based on the classifications devised by D. Despain (1990) and have been incorporated into the YELL GIS layers by the YELL Spatial Analysis Center.

RESULTS OF PILOT STUDY

Over the field season 42 transects were walked in YELL NR and 21 in the GRTE VF. Due to difficulties with the terrain, not all transects were exactly 2,000 m long. The overall length sampled in the YELL NR was 86,053 m x 10 m wide 43,959 m x 10 m in the GRTE VF.

The percentage of the study area infested with weeds can be calculated using equation 0.1 above. In the northern range, when all sites were combined the percentage of the study area infested was above 0.2% for all species except ox-eye daisy (*Chrysanthemum leucanthemum*) and spotted knapweed (*Centaurea maculosa)*. Since infestations were perceived to be higher around Mammoth Hot Springs, which could skew the results, percentage infestations were calculated separately for Mammoth Hot Springs from the three remaining sites. The percentage infestation for the 16 transects around Mammoth Hot Springs were relatively high; dalmatian toadflax (*Linaria dalmatica*) and common timothy were present at levels of 1.4 and 1.9 % respectively, the remaining species were present at densities above 0.4%, with the exception of ox-eye daisy and spotted knapweed. When considering only the Blacktail, Tower and Lamar sites the percentage infestation of common timothy was still relatively high (1.5%) but the values for all the other species were less than half those calculated for Mammoth Hot Springs.

In the valley floor area of Grand Teton, the percentage of the study area infested was much lower than the northern range of Yellowstone. Only two species were present at infestations above 0.2%, these were common timothy and musk thistle; 3 species were present at infestations just below 0.2%, smooth brome (0.17%), Canada thistle (0.16%) and houndstongue (0.16%); the remainder were present at very low frequencies (<0.05%). No ox-eye daisy or dalmatian toadflax plants were observed, though they have been recorded in the park.

The distance from road/trail data had to be re-calculated to allow for the fact that while transects initially were perpendicular to the road or trail at the point at which they commenced, this does not mean that they monotonically increased in distance from any road or trail. The distance to trails and roads was re-calculated for each transect and the distance partitioned into 100 m intervals. The proportion of observations made within each of the 100 m intervals was used to weight the proportion of each target species observed within those intervals (see equation 0.2). For all species there is a very marked decline after 100 m - 200 m from road/trails (Figure 5). Very few species were observed after 1,000 m at either site. Only 7% and 4% of all weed observations made between 1,100 m – 2,100 m at NR and VF, respectively.

The equation used to weight the data is provided below:

$$P = \left(\frac{n_x}{\sum n}\right) \cdot \left(\frac{n_i}{\sum i}\right) \qquad (0.2)$$

Where:
P = proportion,
n = number of observations,
x = variable of interest (habitat, distance, etc.), and
i = target species of interest.

Graphical display and analysis of the target species data juxtaposed with environmental data was performed using the data collected in the field, rather than environmental data previously developed and incorporated into GIS. The resolution of the GIS data is 30 m for the DEM and 50 m for the habitat and geology data; these resolutions are considered too coarse to analyze environmental associations of the non-native plants for the pilot study.

Dalmatian toadflax, houndstongue (*Cynoglossum officinale*) and yellow sweetclover were more common on an easterly aspect (67.6 – 112.5°). Cheatgrass was more common on the easterly and southerly aspects (67.6 – 112.5° and 157.6 – 202.5° respectively). Common timothy, Canada thistle and smooth brome (*Bromus inermus*) were equally prevalent on all aspects. Too few data points were collected for ox-eye daisy and spotted knapweed to determine a pattern. All the species, except common timothy, occurred more frequently on sites with no aspect, i.e. level areas, but it should be considered that this information is confounded with moisture and angle of slope factors, as level areas generally also indicated increased moisture availability. Data were weighted to allow differences to be detected when there were different numbers of observations recorded for each aspect.

In the Grand Teton valley only common timothy and musk thistle were present at sufficient infestation levels to tabulate and graph. However, the majority (79%) of observations in GTV were recorded with a flat aspect. Therefore, it was not appropriate to analyze for aspect prevalence. Topography and slope details were recorded but the classes/options will be more clearly defined in future years.

Data from the YELL NR suggest that the big sage/bluebunch wheat grass (*Artemisia tridentata/Agropyron spicatum*), big sage/Idaho fescue (*Artemisia tridentata/Festuca idahoensis*) and to a lesser extent douglas fir/pinegrass *(Pseudotsuga menziesii/Calamagrostis rubescens*) habitats had a higher proportion of the target species, even when the data were weighted to allow for the higher numbers of observations taken in these habitats (Rew *et al.*, 2001).

A different habitat key is used in GRTE. The dominant habitat recorded was big sage/Idaho fescue/bluebunch wheatgrass (*Artemisia tridentate/Festuca idahoensis/Agropyron spicatum*), a combination of two different habitats within YELL. When the data were weighted to allow for the proportion of observations taken in different habitat types more smooth brome, common timothy, houndstongue and Canada thistle species were found in the *Artemisia tridentate/Festuca idahoensis/Agropyron spicatum* habitat type. Musk thistle was also present in higher proportions in the hayfield habitat (Rew *et al.*, 2001). This habitat class was farmed prior to becoming part of the GRTE and contains many introduced species.

Proposed Weed Inventories in Network Parks

NORTHERN RANGE, 2002-2004

Three further years of data collection are planned for the northern range. The number of non-native weed species to be targeted is much expanded and these are listed in Appendix 3.

We propose to maintain the 10 m wide transects and record the same variables as in the pilot study, which include habitat type, dominant cover type, aspect, topography, disturbance and non-native weed occurrence. Information on weed density, area of infestation, spatial pattern of the weeds and percentage cover will be collected for target weeds along with location, time and date. Percent cover estimates will be collected to be in accordance with the North American Weed Mapping Association (NAWMA) minimum mapping standards and National Park Service Intermountain Region (IMR) weed mapping guidelines (P. Benjamin, in preparation). Other fields that will be additionally recorded to meet the guidelines include information about the site: region, I&M network, park unit, state, county, ownership, type of survey, ecological status of survey site, values at risk, and non-native weed plant and ITIS code all of which can be added to the database in the office.

In the pilot study occurrence of weeds declined with distance from road/trail, even when data were weighted for different number of observations made at the different distances. Less than 9% of all weed observations were recorded between 1,100 – 2,100 m from roads and trails this season in YNR. Therefore, we have to take proportionally more observations as the distance from roads and or trails increases. Locations of backcountry cabins and campsites are available for YELL as GIS layers. These data will be defined as human disturbance and lengths of the trail within 0.5 km either side of cabins/campsite will be highlighted and added as buffers to the GIS layer. To investigate the influence of these structures on weed distribution a number of transects will also be randomly selected to commence at these areas and then increase in distance monotonically from the start position to 2000 m from these structures. Proportionally increased sampling with distance from the disturbance e.g. roads, trails, cabins, or camp sites will be performed for the first 6-8 weeks of the 2002 sampling effort.

If this proportionally increased sampling strategy confirms that there is a decline in non-native weed occurrence this type of sampling will stop. We would then sample more intensively within a determined distance from roads/trails and human habitation stratifying on habitat type. This should maximize the probability of finding the weeds and simultaneously build an informative dataset from which models that predict weed occurrence can be developed and/or refined. Such flexibility in the sampling methodology is necessary to ensure the aims of the project are met. Using habitat type as the second stratification variable has some limitations. The GIS habitat layer has a 50 m resolution. Overlaying the habitat information collected in the pilot study on the GIS layer it was observed that small microcosms of habitat type were missed within the GIS layer. For example, within areas classified as *Artemisia tridentata/Festuca idahoensis* and *Artemisia tridentata/Festuca idahoensis – Geranium viscosissimum* in the GIS we recorded *Artemisia tridentata/Agropyron spicatum*, *Pseudotsuga menziesii* and *Pinus contorta* habitats in the field. Field data will be used to define the proportional weightings of the different habitat types and the GIS layer will be used to define the habitat areas with the expectation that habitat microcosms noted in the field will be recorded and used in data analysis. Therefore, the actual number of observations made in the different habitat type will differ from the number defined from the GIS layer.

The National Park Service has historically recorded habitat types rather than dominant vegetation/cover types. For the purpose of evaluating the environment where non-native weeds 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 habitat classification as presently used by park staff.

Using data from last season we can expect to complete approximately 180 transects of 2,000 m in length with 2 crews. However, as we plan to make proportionally more observations at distances further from the roads/trails, at least initially, it is impossible to determine exactly the number of transects to be surveyed. Unpredictable terrain structure, the increased number of non-native species to be targeted, and the extra data records to be recorded to meet Intermountain Region Guidelines will impact, in an unforeseeable manner, the amount of time required to complete each transect. Sampling methodology may be adapted as the project progresses, the data collected are analyzed, and our understanding of non-native species distribution improves.

The start position and direction of transect lines will be defined in ArcView prior to visiting the sites. Start positions will be randomly generated using the stratification process outlined above, and checked to ensure that transects are not clustered into particular elevations or aspects. Random points that commence on unsuitable terrain (e.g. cliff tops, river gorges etc.) will be deleted. Transects projected to run through potentially difficult terrain will be retained and sampled until the terrain becomes impassable. Geographic position of weed observations will be made with Trimble GeoExplorer® 3 GPS receivers. Data will be post-processed to improve accuracy. The GeoExplorers will be programmed with a data dictionary, including all required database records and their classes. Having all the possible classes for each record defined in the GPS receiver will reduce the time spent collating the data and will prevent inappropriate descriptions being entered while in the field. The coordinate system and projection used will be 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.

Four different types data will be recorded for non-native plants encountered: area, density, spatial pattern, and percentage cover. Weed patches will be mapped by estimating the centroid point of the patch and recording it's location with GPS. The length and width of patches will be estimated to the nearest meter. Estimates of weed density will also be made using the classes/categories shown in Table 2. These classes/categories have been generated from classes already in use by the park staff, and are based on a log scale. Initially the field crews will both estimate and count 1 m^2 to record density information. Thereafter, they will estimate density and count only when necessary to define between different categories. The unit of measure for density will be defined for rhizomatous and non-rhizomatous species. Categorical data collection allows more observations to be made within a shorter time frame and is a useful technique where general trends or baseline information are required from the data (Rew *et al.*, 2000).

Table 2. Categories and density to be used to assess non-native weed populations.

Category	**Density/m^2**
A	>0 - <1
B	1 - 11
C	12 – 32
D	33 – 100
E	101 – 316
F	317 - 1000
G	>1000

Data on spatial distribution will be divided into three classes: individuals plants, discrete patches and interconnected patches. Finally, a visual estimate of percentage cover will be collected, in accordance with IMR guidelines.

In the pilot study, aspect was recorded parallel to the gradient at the sample point. As such this practice represents the aspect at that specific point. However, there were instances when only change of habitat was recorded that this practice represented the preceding habitat's aspect rather than the succeeding one. To improve on this when observation points are recorded solely due to habitat changes the aspect will be recorded to represent the aspect of the new habitat.

ADDITIONAL DATA COLLECTION

The vegetation management staff in YELL and GRTE have been recording weed occurrence along primary roads within both parks and will continue to do so. The data are entered into databases and updated yearly for new or previously unrecorded populations and any management actions that may have taken place. Many of the trails in the northern range of YELL have also been examined for key invasive weeds and this activity will continue (P. Miller, personal communication). Surveys of non-native weed distribution and abundance were conducted in the riparian zones and developed areas of the valley floor of GRTE in 2000 and 2001 respectively. GIS layers reflecting these data are currently used in planning weed management activities.

It is probable that large ungulates transport some seeds on their coats and these will be dispersed as they travel around the park. If suitable data becomes available on migration routes or main feeding areas within the parks we would complete some transect sampling along and perpendicular to the routes in the second or third year of the study. Other data, such as waterways and fire polygons will also be assessed in the second or third year if they become available at suitable resolutions.

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Two further years of data collection are planned for the GRTE including the John D. Rockefeller Jr. Memorial Parkway (134,947 ha or 333,320 ac). A list of non-native weed species to be targeted is included in Appendix 3.

A similar methodology is proposed for the GRTE VF (54,466 ha or 134,531 ac) although transect positions will be stratified on road and trails, sites of human habitation including campsites, buildings and historical homesteads, plus areas where fire has occurred. Transects will be followed for the predefined length but deviations will occur to perform "intuitive controlled sampling". This technique is based on prior knowledge and the "intuition" of observers, and permits them to move into areas where non-native weeds are expected to occur and to survey the area more intensively. This technique has been used extensively in rare plant studies by USFS Region 6. Locations of the intuitive sample points will be tagged so that they can be separated from the transect data for analysis purposes. This technique was used in addition to the transect methodology in the pilot survey of the valley floor of GRTE in 2001.

During the 2002 field season trails passing into the moderate and higher elevations of GRTE will be walked and examined for non-native weeds present within 5-10 m of either side of the trail. The same information will be recorded when walking the trails as when walking random transects. In moderate elevations intuitive controlled sampling will be performed in meadow areas, around backcountry campsites, horse trails, dude ranches, and avalanche paths. In the higher country intuitive controlled sampling will be performed around backcountry campsites and avalanche chutes.

As part of the vegetation cover mapping program 500 random samples will be taken over the GRTE area during 2002-2003. Habitat, vegetative cover, occurrence of non-native weeds, and environmental data will be recorded. These data will be available to the inventory study team.

Trimble GeoExplorer® 3 GPS receivers will be used for position data collection, and the data post-processed to improve accuracy. The coordinate system and projection used will be Universal Transverse Mercator (UTM) Zone 12N, NAD 1927, the park standard. The GeoExplorers will be programmed with a data dictionary, which will include all the required data record fields and their classes. Having all the possible classes for each record defined will reduce the time spent collating the data and prevent inappropriate descriptions to be used while in the field.

Quality Assurance

Field Data Collection

Two-person field crews will be selected from experienced botanists or vegetation ecologists familiar with the exotic plants of the Greater Yellowstone Ecosystem. A four-day field-training program in exotic plant identification, GPS operation, and data acquisition will be completed prior to the beginning of actual data gathering. Transect starting points will be located and headings maintained using pre-programmed Trimble GeoExplorer 3 GIS receivers. A predetermined data dictionary containing pre-selected value responses will be loaded onto the GIS receivers eliminating the possibility for spurious data entry errors in the field. All post-entry data processing will done automatically. GPS locations will be refined with post-collection processing by comparison to fixed station locations and corrected for differential error programmed into satellite transmissions.

The project supervisor will make periodic evaluation of crew performance in the field, and will review all data for uncontrollable outliers. Ten percent of completed transects will be walked twice to compare results. Transects for double enumeration will be selected randomly and will be temporally weighted to repeat more transects early in the data gathering process. Weekly debriefing of field crews will be accomplished and problems or difficulties in plant identification or data acquisition discussed and resolved. Detailed records will be kept of all quality assurance related actions, their outcomes, and the process by which they were resolved. These records will be included as an appendix with the annual report.

Data Analysis and Modeling

Principle component analysis will be used to determine the contribution of each of the environmental variables recorded to the overall variance in weed distribution. While, results from this analysis will direct further analyses, we envision using an inductive modeling procedure based on Bayes' theorem (Aspinall, 1992) to evaluate the correlation between non-native weed and environmental data collected in the field. In addition, the non-native weed data will be evaluated against existing environmental data for the YELL NR and GRTE VF that are available as GIS data layers in ArcView. One limitation to the use of these existing GIS themes is that they are much coarser than the equivalent data collected in the field. With the large numbers of observations collected we trust that significant correlations between some environmental variables and weed occurrence will become apparent. This will permit us not only to create maps of weed occurrence within our study areas but also create probability maps of specific non-native weeds occurrence. Such maps could then be used to target further inventory sampling in the remainder of YELL.

The detailed information regarding weed occurrence including, infestation size, density and spatial pattern can be used to select areas or populations where monitoring of changes to the population size, density and dynamics can be initiated; and to stratify areas for management according to susceptibility to invasion or non-native weed intensity etc.

This project will generate abundance and distribution information for selected exotic plants that are considered to be noxious weeds or that may be of other management concern in targeted areas in Grand Teton and Yellowstone National Parks. We will provide an annual reports at the conclusion of this field season, Arcview GIS themes, and an MS Access database of all information collected during the project. The GIS themes will document abundance and distribution of all targeted species. The MS Access database will include data that documents each sampling event, such as date, field person, site location, site description, species name, and species abundance. Voucher specimens and detailed photographs for any invasive plant discovered but not yet know to be in either of the parks will be provided in accordance with accepted procedures for archiving vascular plant materials. This documentation will include information on the time of collection, location, collector, and site notes. The biological inventory coordinator will ensure that project findings are updated in the Service wide biological databases including NPSpecies, ANCS+, Natural Resource Bibliography, and the Dataset Catalog. Metadata will be provided in accordance with Federal Geographic Data Committee standards.

Adaptive Management of the Sampling Process.

Following the completion of analysis and reporting of the FY02 field sampling season the network will convene a meeting of the network technical committee, the cooperator, and other park service staff to review the results of the sampling program and to make recommendations for developing the sampling strategy for the FY03 field season. This meeting will be held in a location convenient to all parties and should take no longer than half a day. Items to be covered include: 1. a summary presentation of the results of the sampling effort, 2) a debrief of all field activities that impacted the sampling process, 3) a review of data products, 3) a formulation of recommendations for preparing the FY03 sampling plan, and 5) assignment of tasks to complete the FY03 sampling plan.

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Proposed FY02 Budget.

The total budget for 2002 for the northern range is $57,450, which includes $35,486 for salaries for Dr Lisa J Rew the primary project investigator, Frank Dougher, GIS specialist, half time for 1 graduate student and 3 field assistants. This funding will allow for approximately 150 - 200 transects to be completed in the Northern Range in the areas between Blacktail Creek and Tower Junction. If a further 2 field assistants were added to the crew ($12,400) an additional 80-100 transects in another area such as Lamar Valley could be completed. The crew could also complete some supplementary data collection around rivers and streams. Alternatively, a further $7,400 for the year could fund a Masters student full time on this study making it his thesis project.

MSU Northern Range Mapping

Personnel	No.	Rate/hr.	No./hrs.	% time	Cost
Ass. Research Prof. (LJ Rew)	1	$ 39.50	800	25%	$ 7,900
Technical Assistant	1	$ 19.25	800	25%	$ 3,850
Student Research Assistant	1	$ 7.97	960	100%	$ 7,651
Field Assistant	3	$ 11.17	480	100%	$ 16,085
Total					**$ 35,486**
Travel		**Unit Cost**	**No. d**	**No. mo**	
Housing	1	$ 450		3	$ 1,350
Meals	4	$ 23	4	52	$ 4,780
Total					**$ 6,130**
Vehicle Purchase	1	$ 2,500			**$ 2,500**
Supplies					
Miscellaneous Equipment		$ 2,000			$ 2,000
Vehicle Mileage	2	$ 640		3	$ 3,840
Total					**$ 5,840**
Indirect Costs @ 15%					**$ 7,493**
2002 Grand Total					**$ 57,450**
Prefunded from FY01					$ 6,351
Proposed MSU FY02 Costs					**$ 51,099**

GRTE Weed Mapping

Personnel	**$ 36,000**
Total Projected Costs	**$ 87,099**
Total Program Allocation	**$ 77,000**
FY02 Unfunded	**$ 10,099**