Cedar Breaks National Monument

2004 Invasive Non-Native Plant Inventory

Northern Colorado Plateau Inventory and Monitoring Network

Final Report

April 2005

Prepared by

Steven Dewey and Kimberly Andersen

Utah State University

Cover photo:

Bromus inermis invading a small drainage in Cedar Breaks National Monument. Photo by K. A. Andersen.

Cedar Breaks National Monument

2004 Invasive Non-Native Plant Inventory

Northern Colorado Plateau Inventory and Monitoring Network

Final Report

April 2005

Prepared by

Steven Dewey and Kimberly Andersen
Utah State University

Report prepared for: Northern Colorado Plateau Inventory and Monitoring Network, National Park Service, 2282 S. West Resource Blvd., Moab UT 84532 by Utah State University

Suggested citation:

Dewey, S. A. and K. A. Andersen. 2005. An Inventory of Invasive Non-native Plants in Cedar Breaks National Monument (2004) - Final Report. Prepared for the National Park Service, Northern Colorado Plateau Network by Utah State University; Plants, Soils, and Biometeorology Department; Weed Science Research Project Report No. SD0515A, 29 pp. plus appendices.

FINAL REPORT

Inventory of Invasive Non-native Plants Conducted during 2004 in portions of Cedar Breaks National Monument, Northern Colorado Plateau Network of the National Park Service

TABLE of CONTENTS

INTRODUCTION

Utah State University conducted a two-year project to inventory and map invasive non-native plants for the National Park Service, Northern Colorado Plateau Network, in the summers of 2003 and 2004. The project included portions of Arches National Park (ARCH), Black Canyon of the Gunnison National Park (BLCA), Bryce Canyon National Park (BRCA), Canyonlands National Park (CANY), Capitol Reef National Park (CARE), Cedar Breaks National Monument (CEBR), Colorado National Monument (COLM), Dinosaur National Monument (DINO), Hovenweep National Monument (HOVE), Mesa Verde National Park (MEVE), Natural Bridges National Monument (NABR), and Zion National Park (ZION). This document contains the results of the portion of this inventory project that occurred within Cedar Breaks National Monument. Results from other Parks are documented in separate Park-specific project reports.

BACKGROUND AND JUSTIFICATION

Numerous recent studies demonstrate that invasive non-native plant species pose one of the greatest threats to national ecosystems regionally and globally by altering native plant communities, wildlife populations, fire regimes, nutrient cycling, hydrology, and energy budgets of native ecosystems (D'Antonio and Jackson 2003, Duncan and Clark 2005, Mack et al. 2000, Sakai et al. 2001, Westbrooks 1998). A panel of scientists recently commissioned by the Council for Agricultural Science and Technology compiled an extensive list of those invasive plant species considered to be of greatest ecological and economic concern in the United States (Mullin et al. 2000). Most of those species are present in our region, and some have already invaded Parks of the Northern Colorado Plateau Network.

In a 1992 a nationwide survey of Nature Conservancy stewards, 59 percent ranked invasive plants among their top-ten conservation concerns, and 13 percent considered them the greatest challenge they faced (Randall 1995). In a similar survey of National Park superintendents regarding the conditions in their Parks, 61 percent of the 246 respondents indicated that non-native plants were a moderate or major problem (Layden and Manfredo 1994). Currently, invasive non-native plants are estimated to infest in excess of 7 million acres of National Park System lands (USDI-NPS 1996). Scientists estimate that invasive exotic plants are spreading on federal lands at a rate in excess of 4600 new acres per day, and warn that without significantly increased prevention, detection, and control efforts, the situation is certain to worsen dramatically (Asher and Harmon, 1995).

The management and control of invasive non-native species has been identified as a high priority issue within the National Park Service and is specifically, under the Government Performance and Results Act (GPRA 1993), identified as an accountable goal for all National Park units. Executive Order 13112 signed on February 3, 1999 (Clinton 1999), further identifies and strengthens the obligations of federal agencies to address the significant economic and biological threats posed by non-native species.

Additionally, the NPS has emphasized the importance of invasive species issues and their associated impacts by identifying non-native species as one of three major areas of focus under the Natural Resource Challenge initiative (USDI-NPS 1999). The Natural Resource Challenge specifically states, "Identifying, mapping and evaluating nonnative species are critical for

effective management". Similarly, the development of the Exotic Plant Management Team (EPMT) initiative has further confirmed the dedication of the NPS to the management and control of invasive plant species. However, the EPMT program has a primary funding focus on the actual treatment and control of weed infestations and has not been established as a funding source for the actual inventory and mapping of invasive weed populations. Although the Natural Resources Challenge identifies the need for obtaining "accurate data about nonnative species distributions" as critical to meeting the goal of effective and efficient management, a specific funding source to accomplish this goal was not identified.

To meet this need, in 2001, the Intermountain Region Support Office in Denver prepared a successful Natural Resource Preservation Program (NRPP) proposal (USDI-NPS 2001) to conduct invasive plant mapping in high priority areas of Parks throughout the Intermountain Region, including six Parks within the Northern Colorado Plateau Inventory and Monitoring Network (NCPN). NCPN took the lead of coordinating this project and added network funding to increase the project scope to encompass work in 12 Park units. A cooperative agreement was negotiated between NCPN and Utah State University (USU) Extension to conduct inventory work during 2003 and 2004. Cedar Breaks National Monument is a member of the Northern Colorado Plateau Inventory and Monitoring Network. Weed distributions, especially along travel corridors and visitor use areas, were identified as extremely high priority needs by Cedar Breaks National Monument and NCPN.

OBJECTIVES

1) The overall objective of this project was to document distribution and abundance of targeted invasive non-native plant species across the range of habitats represented in areas of management concern in Cedar Breaks National Monument. It was anticipated that these data would provide baseline information useful in the development and implementation of effective vegetation control strategies.

2) Based on the inventory results, efforts were to be made to identify significant sources of weed introductions and vectors involved in weed spread in each area inventoried.

3) Within the scope of this project, USU was to work with regional, Network and Monument staff to test and refine data collection and field inventory techniques that might be used by NCPN in future invasive plant inventories.

METHODS

Utah State University supplied a 6-person crew to inventory designated areas within Cedar Breaks National Monument and certain other NCPN Parks during 2004. Crew qualifications are documented in Appendix A.

SELECTION OF TARGET SPECIES AND INVENTORY AREAS

Fifteen species were identified by NPS staff as high-priority targets in the CEBR inventory (Table 1), and searched for systematically by all inventory crew members. Any additional non-

Table 1. List of invasive plant species targeted in Cedar Breaks National Monument in the 2004 Non-native Plant Inventory.

Invasive species	Common Name
Bromus inermis	Smooth brome
Bromus tectorum	Downy brome
Carduus nutans	Musk thistle
Chenopodium album	Common lambsquarters
Centaurea diffusa	Diffuse knapweed
Centaurea maculosa	Spotted knapweed
Centaurea repens	Russian knapweed
Cirsium arvense	Canada thistle
Dactylis glomerata	Orchardgrass
Elaeagnus angustifolia	Russian olive
Onopordum acanthium	Scotch thistle
Phleum pratense	Timothy
Tamarix ramosissima	Saltcedar
Tragopogon dubius	Western salsify
Ulmus pumila	Siberian elm

native species recognized as relatively new to CEBR and potentially invasive on wildlands in the West were documented if found. Forty-seven species were listed in the GPS data dictionary, representing all species targeted for inventory by the 12 Parks included in this project, plus some additional species of regional or national concern.

General categories of areas to be inventoried had been identified previously in the Intermountain Support Office Project Proposal and Implementation Plan (NPS 2001) based on what was considered to be the most likely invasive plant habitat, with priority given to areas most likely to be impacted by development and visitor-use activities. Areas of likely weed seed introductions as well as sites identified as significant known or potential weed seed sources or "vector areas" were also given priority. The specific areas searched and weed species to inventory in Cedar Breaks National Monument were determined in consultation with Denise Louie, Botanist for Zion National Park, and with other knowledgeable sources. Approximately 1100 acres of land between the canyon rim and the eastern boundary of the Monument were identified as priority units for inventory. The target area included all main roads, parking areas, campgrounds, service roads, housing areas, meadows, and timbered areas above the canyon. The total area targeted within CEBR was relatively small compared to that of most other Parks included in this project, and the terrain was relatively level and open. Native grasses and forbs were abundant in meadows, and forested sections typically had a good diverse understory of native vegetation.

The focus of this inventory project was NPS lands. However, in some cases where infestations of target species extended beyond the Monument boundary onto adjacent property, a small amount of additional land was inventoried. This occurred if crew members found an infestation of a high-priority weed species straddling across the Monument boundary and wanted to determine its full size, or if crew members saw one or more invasive species immediately outside the boundary and considered it a possible "contamination source.

Park natural resource staff at ZION and the NCPN Vegetation Ecologist worked closely with

USU to provide pre-existing weed distribution information and offer advice that might be helpful in planning the 2004 CEBR field inventory and in gathering and analyzing data. NCPN and CEBR staff also helped to ensure that data were assembled and provided to the network in a useable format.

DATA CATEGORIES

The data categories included in this inventory were discussed at length and agreed upon by NCPN and USU project leaders prior to initiation of the project. A complete description of the data categories and value options appears in Table 2. The GPS data dictionary developed to electronically capture data elements while in the field is presented in Appendix B. Data collection categories and definitions comply with the minimum mapping data standards established by North American Weed Management Association (NAWMA 2003) and include most of the core elements contained in the NPS Intermountain Region Weed Mapping Guidelines (Benjamin 2001, USDI-NPS 1995). Appendix C indicates the relationship of NCPN data fields to NAWMA standards and IMR Weed Mapping recommendations. A rationale is presented for any deviations from the IMR-recommended data fields.

Data elements were collected by one of several methods: automatically recorded or manually entered into GPS units in the field (GPS-entered); transcribed from field notes; obtained from previously existing GIS data sets during post-processing (GIS-derived), or added manually in the office during post-processing (office). GIS-entered data included the location and size of each infestation, percent canopy cover, phenology of the weedy species, woody growth stage (if a woody species), presence of site disturbance, hydrology, dominant native species present, date, time, and any additional pertinent notes about the site. Data entered in the office during post-processing included ecological status, Park code, record numbers, detection confidence for inventory area polygons, scientific name, ITIS code, lifeform of species, county, state, and country. Additional data elements (e.g. datum, UTM zone, source of data) that pertain to the spatial data set as a whole are provided as metadata files (e.g., datum, UTM zone).

FIELD PROCEDURES

Some of the terms used in this and subsequent sections of the report have been created by the authors to describe new methods and standards developed by USU for conducting invasive weed inventories on wildlands. Terms unique to this report are defined as follows:

> **Search Target** (ST): Refers to invasive plants that are the object of a field search. ST descriptions must always include species, growth stage, and MDTS.
>
> **Minimum Detection Target Size** (MDTS): The smallest infestation size (single plant or patch) of the least-visible targeted invasive species that searchers are confident of detecting and identifying at a stated level of probability under actual field conditions using their stated protocols. In this project the MDTS was set at 0.01-acre.
>
> **Effective Detection Swath Width** (EDSW): The maximum width of a linear walking search pattern in which an on-the-ground searcher is confident of visually detecting at

Table 2. Description of data fields used in 2004 Inventory of Invasive Non-Native Plants in Cedar Breaks National Monument.

Data Field	Description	Options / Values	Priority	Entry
Species Name	Latin name of species	Pick-list to be provided by Park staff	Required	GPS
Species Code	IT IS		Required	Office
Additional Names	Common name of the species			Office
Date	Date species observed		Required	GPS
Observer	Name of person observing population	First initial of person's last name used in data file name	Required	GPS
Location ID	Unique identifier for species population ("Record #")		Required	GPS
Park Code	Four-letter abbreviation of Park	CEBR	Required	Office
Country	Name of country (e.g. USA)		Required	Office
State	Two-letter state abbreviation		Required	Office
County	County name		Required	Office
UTMN	UTM northing coordinate for population		Required	GPS
UTME	UTM easting coordinate for population		Required	GPS
Elevation	Elevation in meters (and feet)	Meters (or feet)	Required	GPS
Size of Infested Area	Size of population (if a point feature). Based on average diameter of weed infestation.	- 1 to few plants - 0.1 acre - 0.25 acre - 1 acre - 2.5 acres - 5 acres	Required only for points.	GPS
Gross Area		Gross estimate of land area occupied by a weed species	Required in specific situations.	GPS
Cover of infested area	Estimated percent of area infested with weed	trace (<1%) low (1 to 5%) moderate (6 to 25%) high (26 to 50%) majority (51-100%)	Required.	GPS
Distribution	Characterization of density	To be determined by PI		GPS
Phenology	Life stage of majority of population. Use most progressive life stage if population appears evenly split.	- vegetative - bud - flower - immature fruit - mature fruit - seed dispersing - dormant	Required	GPS

Table 2 continued.

Data Field	Description	Options / Values	Priority	Entry
Woody Growth	Predominant growth stage of species. Use for woody weed species only (elm, tamarisk, Russian olive, etc.) If stages are mixed, use most advanced stage. (valuable for planning control efforts)	- seedling - sapling - mature - old-growth	Optional	GPS
Lifeform	Lifeform of species.	-tree -shrub -graminoid -forb	Required	office
Ecological Status	Qualitative description of the level of infestation that identifies ability of site to recover to natural state once the weeds have been removed.	1. No weeds -The management emphasis is preventing weed encroachment. 2. New and/or small infestations - These infestations have good potential for eradication because they are small and there is a good understory of desirable plants. 3. Large scale infestation with 30% or greater understory of residual grasses and good potential productivity – Management of these sites in a way that selects for the recovery of the residual native grasses and shrubs has good potential for control but not eradication of the weeds. May be more that one noxious weed species, but the underlying biologic integrity of the unit is good. 4. Large-scale infestations with few or no (less than 30% cover) desirable grasses in the understory. Infestation often dense and/or multiple weed species. Control will require intense treatment and probably revegetation. Control may be possible but not eradication. In some areas, the infestation may have changed the character of the land so much that attempts for rehabilitation are cost prohibitive.	Required	Field and Office
Dominant Species	Species Latin name for dominant species at site (up to four species can be recorded)	Two to three dominant species need to be provided at each point (list of dominant species provided by Park). If single or few plants, use dominant species in 1/10 acre area.	Required	GPS
Buffer	Buffer needed to encompass population if GPS'ed as a line or polygon feature	Enter number in feet	Required for lines, optional for polygons	GPS

Table 2 continued.

Data Field	Description	Options / Values	Priority	Entry
Hydrology	General hydrologic setting of site. If further specificity is needed in Park, add items as subcategories to existing terms (e.g., wetland - seep).	- upland (above and away from floodplains) - riparian (along rivers or stream channels) - perennial: stream flows continuously in time. - intermittent: stream flows only at certain times of the year (typically on seasonal basis) when it receives water from springs or from melting snow. - ephemeral: stream flows only in direct response to precipitation. Ephemeral streams generally lack obligate riparian vegetation. - wetland (saturated soil for majority of growing season) - playa lakebed (poorly drained depressions)	Required	GPS
Disturbance	Evaluate disturbance at population site	1 - no disturbance apparent 2 - light to moderate disturbance 3 - site heavily disturbed	Required	GPS
Notes	Additional comments	Can include compass bearing for photos, description of non-weed features, etc.	Optional	GPS and field notes
Area ID	Unique identifier for inventory area		Required	GPS
Disturbance Comments	Comments on type and extent of disturbance noted in inventory area. If area is undisturbed, note as such.	-Agriculture/Livestock Grazing -Construction/Development -Fire -Fire Suppression -Flooding -Wind -Geothermal -Animal Disturbance (e.g. gopher mound, buffalo wallow -Irrigation/Ditches -Mining and Quarries -Oil and Gas Exploration/Production -Habitat Improvement Project -Recreation/Visitor Use -Right-of-Way -Construction/Maintenance -Utility -Construction/Maintenance -Trail/Outfitter/ORV use	Required	Field notes

least 90 percent of all invasive plant infestations of the stated minimum target size. EDSW must be adjusted according to factors influencing target visibility, such as species, stage of growth, topography, and associated vegetative cover, in order to maintain the 90 percent minimum detection standard. Effective Detection Swaths in this project generally ranged between 25 and 50 meters wide.

Patch Separation Resolution (PSR): The minimum distance between single weeds or patches of weeds that are considered to be separate infestations. Plants separated by the PSR distance or more are mapped as separate infestations. Plants separated by less than the stated PSR are usually mapped as a single infestation. The PSR for this project was 25 yards.

Detection Confidence (DC): The percentage of the total number of infestations that crew members estimate they were able to find in a searched area, based on the probability of seeing patches of the established minimum detection target size of the least visible target species in that terrain. Detection confidence is essentially meaningless without also stating the search target associated with that DC. The minimum required DC set for this project was 90 percent based on a MDTS of 0.01 acre for plants of the least visible target species in a mature or flowering stage of growth.

Between-Feature Positions (BFP): A series of location points recorded automatically by Trimble GPS units indicating the daily search routes traveled by each crew member. The distance interval for collecting BFP's in this project was set to correspond to the average effective detection swath width for each area inventoried.

The inventory at Cedar Breaks National Monument was conducted on August 4-6, 2004. Terrain, vegetation cover, expected visibility of target weed species, and minimum target size were all considered in the selection of mapping techniques and standards. The inventory of off-road areas in CEBR was accomplished by dividing the land into large blocks (typically 1/4 to 1/2 square kilometer) with a single crew member assigned to each. Searches of these meadows and forested blocks were usually conducted by walking back and forth along parallel transects spaced 50 meters or less apart. UTM northing lines served as the transects, and GPS units ensured that crew members were able to stay on transects, thus maintaining the desired coverage without significant gaps or overlaps. A single crew member was assigned to inventory weeds along all the paved roads within the Monument, focusing specifically on a vegetation band approximately 50 feet wide on either side of the pavement. The order in which areas were inventoried and the assignment of specific crew members to each search area were determined by the USU crew leader. Daily inventory routes of each crew member were recorded and mapped using the BFP tracking function of the GeoExplorer GPS units. BFP tracking distance setting was adjusted as needed to correspond as closely as possible to the EDSW distance (usually 50 meters or less).

Field searches were conducted at as fine of a scale as required to be confident that 90 to 100 percent of all invasive plant infestations 0.01 acre or larger within the inventory area were detected. Because most of the target species in CEBR were grasses which are often more difficult to see than broadleaf and woody invasive species, crew members restricted their searches to narrow detection swath widths of 50 meters or less. Search swath widths were

adjusted as needed based on variations in terrain, walking speed, associated vegetation, and target species. In heavy cover and/or for difficult-to-see species this required slowly walking swath widths as narrow as 25 meters. In very open terrain and/or for highly visible species such as saltcedar, effective detection swaths were generally 50 meters wide.

The overall inventoried area within Cedar Breaks National Monument was assigned a detection confidence value based on the crew's estimated ability to see infestations of 0.01 acre in size of the least visible target species, taking into account terrain, vegetation cover, and the size and growth stage of the targeted plant species. Detection confidence options were: Low (1 to 50 %), Medium (51 to 89 %), and High (90 to 100%).

As inventory units were traversed, locations of all target species were documented by the USU crew using Trimble GeoExplorer 3 global positioning system (GPS) units and GeoExplorer XM GPS units with 2- to 5-meter accuracy. Crews also recorded the location and documented the identity of any other non-target species they encountered if that species has a known history of invasiveness in other regions in the West.

GPS configuration settings used in this project are listed in Appendix D. Additional equipment used by crew members included laser rangefinders, compasses, binoculars, topographic maps, calculators, and radios. Appendix E contains a photograph and complete list of equipment used in this study. Field locations were recorded by GPS as UTM coordinates, and were later differentially corrected in the production of final digital products. The crews recorded invasive plant occurrence data on hard-copy (USGS 7.5-minute topographical maps) in any situation where GPS satellite reception was not possible (such as in heavy timber) or in cases of GPS equipment malfunction. All data from field maps were converted to digital format.

Invasive plant infestations were recorded as point features. The size of each infestation was estimated visually (using a laser rangefinder) and placed in the size category most closely matched to its actual area: 1) 1 to few plants (0.001 acre), 2) 0.01 acre, 3) 0.1 acre, 4) 0.25 acre, 5) 0.5 acre, 6) 1.0 acre, 7) 2.5 acres, or 8) 5 acres. Canopy cover of each infestation was estimated visually and placed in a category of either: 1) trace = less than 1 percent, 2) low = 1 to 5 percent, 3) moderate = 6 to 25 percent, 4) high = 26 to 50 percent or 6) majority = 51 to 100 percent. As a general rule, clustered plants with individuals separated by less than 25 yards were considered a single infestation and were mapped as a single feature. Plants or groups of plants separated by more than 25 yards were mapped as separate infestations. (Refer to definition of PSR.)

In deciding on the dominant vegetation cover, crews identified the two most prevalent or most dominant native species in the region in which the weedy infestation was found growing. The full list was not a part of the data dictionary due to its size, but a paper copy (Appendix F) was carried and referred to by each crew member while working in the field. The vegetation list was compiled by Tamara Naumann, botanist at Dinosaur National Monument, for an inventory conducted by USU in 2002-2003, and it was decided to use the same list for this project. Native species were coded with a 2-digit number and these codes were entered into the data dictionary. The list was not a complete list and crews had the option to add additional native species if they encountered them in the field.

POINTS OF INTEREST

The locations of some non-weed points of interest were recorded by field crews. Points of interest could include springs, seeps, Park boundaries, or other features. Points of interest were collected at the discretion of individual crew members. The information collected was delivered to NCPN, but not included within this report.

GENERAL PHOTOGRAPHS

Representative photos are included in this report showing some of the species and habitats inventoried, as well as a sampling of photographs of field crews doing inventory work. Photographs were taken of each new weed species found in the Monument. Close-up photographs were intended to serve as a type of voucher specimen for weed species encountered, and landscape photos of weeds are expected to assist in relocating small isolated infestations for future control. The location of each weed infestation documentation photo was recorded as a GPS "photo point". In the case of landscape photographs of a weed and/or its surrounding habitat, the UTM coordinates represent the location of the photographer, and the direction that the camera was facing is noted as a compass bearing (magnetic north reference). The locations of photos taken to show general types of terrain and habitat, or crew activities usually were not documented with GPS points. Photographs were taken with 35-mm slide film and later digitized. Pertinent photographs are included with this report (see Appendix G). Digital copies of all photographs were submitted to NCPN as part of the final deliverables.

VOUCHER SPECIMENS

Specimens were to be collected to document new or otherwise unique occurrences of invasive species encountered within Cedar Breaks National Monument. However, no plant voucher specimens were collected in 2004.

FIELD DATA PROCESSING

At the end of each day, field crews marked and dated all inventoried areas on USGS 7.5' topographic maps to assist in determining project progress and thoroughness of coverage. The GPS between-feature positions recorded automatically each day were used for reference when marking the topographic maps. Each crew member kept a daily log of where they searched, what species they encountered, disturbances noted, thoroughness of coverage, and any additional information that they felt might be of importance to the project. Data were downloaded from GPS units onto a laptop computer each day using Pathfinder Office GIS software. Edits (such as eliminating any duplicate features) were made to the data, and any additional information (such as infestations drawn by hand on field maps or other data not recorded with a GPS unit) were added at this time. Four sub-folders were created within the main project folder on the computer hard drive. These were for: 1) unedited raw GPS rover files, 2) edited GPS rover files, 3) differentially corrected edited GPS rover files, and 4) GIS shapefiles created from the

differentially corrected rover files (for export and use in ArcView). Separate disks were used for raw and edited rover files.

Raw data consisted of rover files transferred directly from GPS units to the computer, and stored without any editing or modification. They were named using a 6-digit code (month-day-hour) preceded by a single letter (corresponding to the first letter in the crew member's last name), and ending in ".ssf." For example, "A051913.ssf" would be the file name for raw GPS data collected by Kim Andersen beginning in the thirteenth hour (24-hr local time) on May 19.

Edited data files were created from raw files that were viewed in Pathfinder Office and checked for accuracy. Features were added or deleted in the process of editing to eliminate any duplicate reporting (two crew members finding the same infestation), and to add locations drawn on field maps (as when satellite signals could not be obtained). Any locations added in the editing process were noted as "hand mapped" in the notes section and are denoted as "Non-GPS" under the differential correction section. Notes were sometimes expanded during the editing process to include more detailed information about the surrounding habitat. File names were changed after editing to avoid confusion with the raw files. Edited files were named as a 3-letter month and 2-digit day abbreviation, followed by a dash and the first letter of the crew member's last name. If a crew member collected more than one file for that day, a number would follow the crew identification letter. For example, the edited version of the second file of GPS data collected by Kim Andersen on May 19 would be May19-A2.ssf.

The data from edited GPS rover files were then differentially corrected. Features that were added or deleted in the editing process were not differentially corrected; nor were points for which corresponding base station data were not available. Generally, the closest base station to the inventory area was used. However, if use of a slightly more distant base station resulted in a higher percentage of successfully corrected points, it was used in preference to a closer station. Corrected files retained the same name as their edited counterparts, but used the file extension "cor" rather than "ssf". Example: May19-A2.cor.

Shapefiles were created from exported data by exporting the differentially corrected files from Pathfinder Office into ArcView. The shapefiles were created from the various categories in the data dictionary such as point-weed shapefile, line-weed shapefile, area-weed shapefile, photo-point shapefile, and between-feature point shapefile. Three kinds of files were created from each ".cor" file. These are ".shp", ".shx", and ".dbf." Example: pt-weed.shp, pt-weed.shx, pt-weed.dbf

POST-SEASON DATA PROCESSING

At the end of the field season, the project crew leader again reviewed the data in Pathfinder Office software to ensure all were present and complete. Data files were compared to entries in the field notebooks and maps served to ensure that all species were included in the data set and inventory areas were complete. Data were then exported from Pathfinder Office as shapefiles. Exported files were compiled into specific shapefiles for each type of data collected. The shapefiles created for this project were named according to the year of the data, the type of file, and the feature type of the data collected. For example, points of weeds data collected in 2004

are compiled into one shapefile labeled as 04pt-weed.shp. Between-feature points from 2004 are labeled 04psnpnt.shp. Shapefiles were then imported into ArcView GIS 3.3 for map-making and data analysis. When shapefiles were imported into ArcView, additional data fields were added to comply with the task agreement. These fields include scientific name, ITIS code, life form of the species, county, state, country, and Park code. Individual record numbers, including the four-letter Park code, were assigned to each weed infestation location entry. It was decided to enter this information after the field season to minimize the amount of time spent collecting non-data in the field and maximize the acres inventoried. The data were checked again for any duplication of entries. Any gaps in the sequence of record numbers are due primarily to elimination of duplicated entries.

A polygon of the area inventoried within the various drainages of the Monument was created in ArcView 3.3 using the between-feature positions that tracked each crew member's daily route. Individual areas represent the units used in planning and executing inventories. The inventory unit is identified by a unique area number, and is described using names of associated canyons or other geographical features. Information provided for the inventory area includes area size (acres), dates of the inventory, the persons involved, Park code, county, state, and country. In addition, the area was assigned a detection confidence level indicating the crew's estimated ability to detect 0.01-acre patches of targeted weed species based on the vegetation types and the terrain. The area also was given an ecological status rating which is a qualitative estimate of the ability of a site to recover to a natural state once the weeds have been removed. The levels of ecological status are defined in Table 2. The crew leader assigned this number based on crew field notes and/or personal on-site inspections of the areas.

The shapefiles were used to create maps using ArcView software. Maps show the total area inventoried during the 2004 project as well as weed distribution findings. The weed distribution maps also illustrate weed-free portions within the overall inventoried area, and may help managers plan weed prevention efforts. Queries and summations of the weed acreages were conducted in ArcView and are included in the Results and Discussion portion of this report.

Individual maps were exported and saved as .jpeg files. Any data tables were exported and saved as Microsoft Excel spreadsheets. Metadata was compiled for the final 2004 dataset by Utah State University using ArcGIS ArcCatalog software. The metadata was provided to the Northern Colorado Plateau Network in an electronic format as part of the final project deliverables. All shapefiles, spreadsheets, raw, edited, and differentially corrected data files as well as digital photographs were also provided to NCPN as part of the final deliverables.

QUALITY ASSURANCE

Numerous measures were taken to ensure the quality of data collected by weed mapping crews. Quality assurance began by hiring only highly qualified individuals. In addition to in-person interviews, a written exam was administered to each applicant to evaluate their skills in weed recognition, taxonomic terminology, map reading and orienteering, GPS/GIS terms and applications, math, wilderness survival, and first aid. Crew members completed an intensive 1- to 2-week pre-season training course consisting of classroom presentations and field exercises to

familiarize them with all inventory procedures and policies, and to improve all skills related to the job. Each crew member was provided with a copy of the training manual.

During the first few weeks of the field season, and periodically thereafter, the Crew Supervisor (CS) and/or the Principal Investigator (PI) worked individually with each crew member to ensure that all skills had been mastered and that procedures were consistent among all crew members. The CS reviewed the crew's downloaded data and project log entries at the end of each day. Any gaps in search patterns that were significantly wider than the effective detection swath width were identified, revisited, and inventoried.

Periodically during the field season, the CS and/or PI conducted inservice training in the form of weed I.D. quizzes or demonstrations, reviewing targeted and other invasive weed species at various stages of growth. Time was spent by the project PI on the first day at CEBR helping the crew learn the local vegetation and review the target grasses for the park's inventory. The PI also provided fresh weed specimens for review with the crew. This was done in a paved parking lot at Brian Head to eliminate the risk of introducing any of these weeds into the park. Weed specimens were encased in clear plastic bags and handled without opening. Each time any new weed species was found, the identity was verified by the CS and/or PI. As was done in other Parks, the project PI conducted verification checks by going back to one or more infestation point(s) of *Bromus inermis* or other species mapped earlier by each crew member. In addition, plastic replicas of individual *Centaurea maculosa*, *Centaurea solstitialis*, and *Euphorbia esula* plants were placed at random locations throughout the CEBR inventory area by the project PI to evaluate the single-plant detection efficiency of the crew. Crew members were not told the number of plastic plants nor the placement locations. Data collected by the PL and CS were compared with data collected by individual crew members to evaluate detection thoroughness and data accuracy (species, location, size, canopy cover, stage of growth, associated vegetation, etc.). At the end of the season both the CS and PI reviewed the data again.

New field methods and standards such as effective detection swath widths, minimum detection target size, patch size resolution, MDTS-based between-feature position settings, and detection confidence guidelines (all described previously) that were developed for this project each contributed significantly to the overall quality and repeatability of the data, particularly with regard to collection of weed distribution and abundance data.

RESULTS and DISCUSSION

Field crews inventoried 1,313 acres in Cedar Breaks National Monument during 2004 (Table 3 and Figure 1), an amount representing approximately 21 % of the entire 6,155-acre Monument. An average of 56.1 acres was inventoried per person per 10-hr day.

Table 3: Invasive plant inventory locations, inventory dates, crew members, and acres inventoried in 2004 in Cedar Breaks National Monument.

Location Descriptions	Inventory Dates	Crew Members *	Acres Inventoried
Road shoulders, meadows, timber, developments - rim to east boundary	Aug 04-06	BA, KA, MB, SD, HH, RR	1313

* Crew abbreviations: BA = Bridget Atkin, KA = Kim Andersen, MB = Melanie Ballard, SD = Steve Dewey, HH = Hillary Hudson, RR = Ruth Richards.

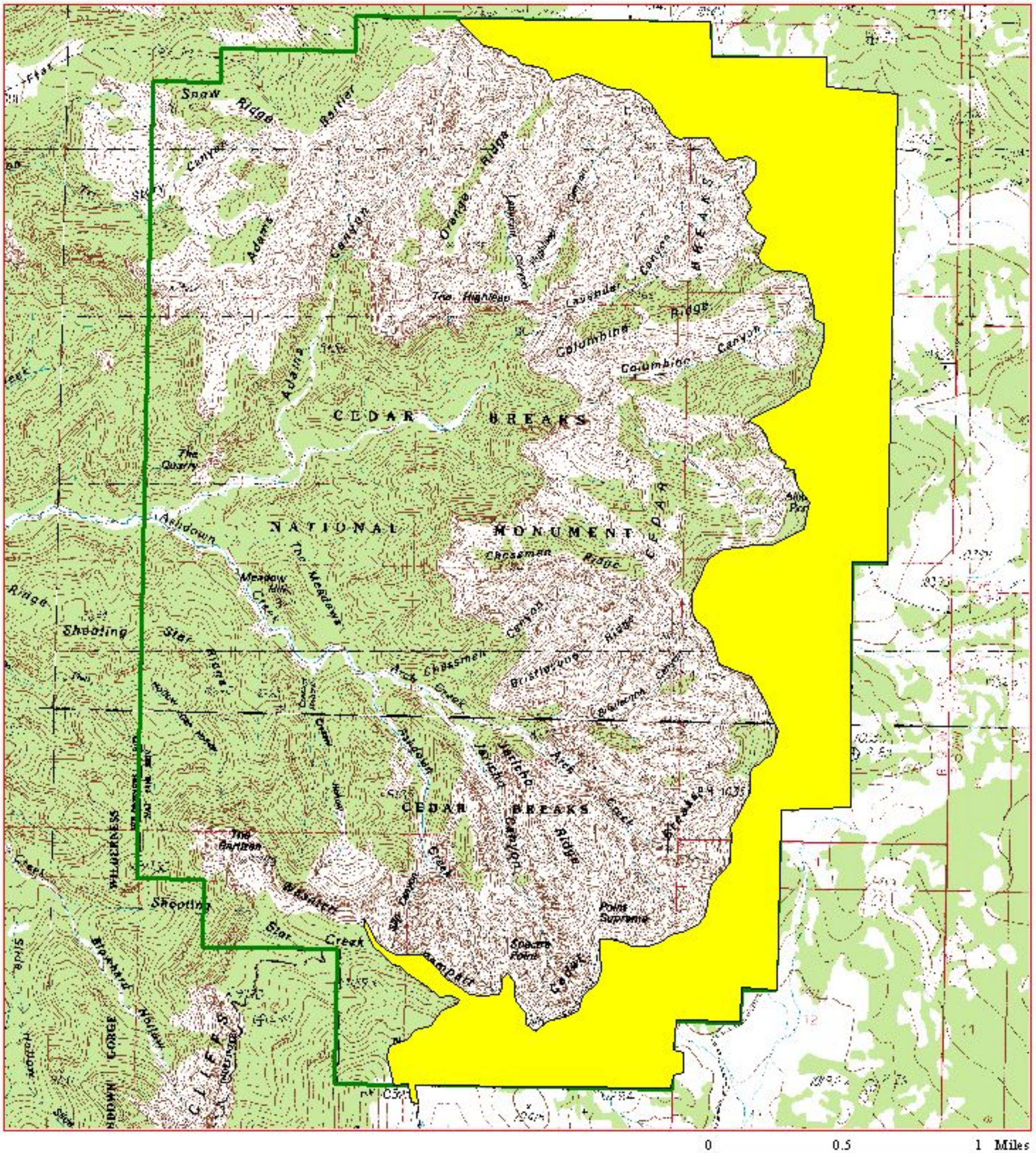
The sum of all infestations of invasive plants found was slightly over 42 acres (Table 4), constituting 3.2 % of the total area inventoried. Of the 15 initial targeted species, only *Bromus inermis, Bromus tectorum, Chenopodium album, Dactylis glomerata, Phleum pratense,* and *Tragopogon dubius* were detected in the Monument. Figure 2 shows the relative abundance and distribution of all mapped species combined within the inventoried area. Figure 3 shows the occurrence of *Bromus inermis,* and Figure 4 indicates the distribution of all other targeted species found within the inventoried portion of Cedar Breaks National Monument in 2004.

Table 4: Acres infested by invasive plant species within the inventory area of Cedar Breaks National Monument in 2004.

Species	Acres (Inside Park)	Acres (Outside Park)	Total Acres
Bromus inermis	39.449	0.200	39.649
Bromus tectorum	1.821	---	1.821
Chenopodium album	0.224	---	0.224
Dactylis glomerata	0.111	---	0.111
Phleum pratense	0.262	---	0.262
Tragopogon dubius	0.010	---	0.010
Totals	41.877	0.200	42.077

A total of 94.3 % of the 42 infested acres in CEBR consisted of *Bromus inermis*, which was especially abundant along road shoulders and in developed areas of the Monument. Some roadside infestations were observed extending well out into adjacent meadows, especially those associated with drainage of runoff water from roads and road shoulders. Occasionally it was

Figure 1. Total area inventoried for non-native plant species in Cedar Breaks National Monument during 2004.



Utah State University
Cedar Breaks National Monument
2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Figure 2. Overall Weed Distribution in Inventoried Area in Cedar Breaks National Monument in 2004.

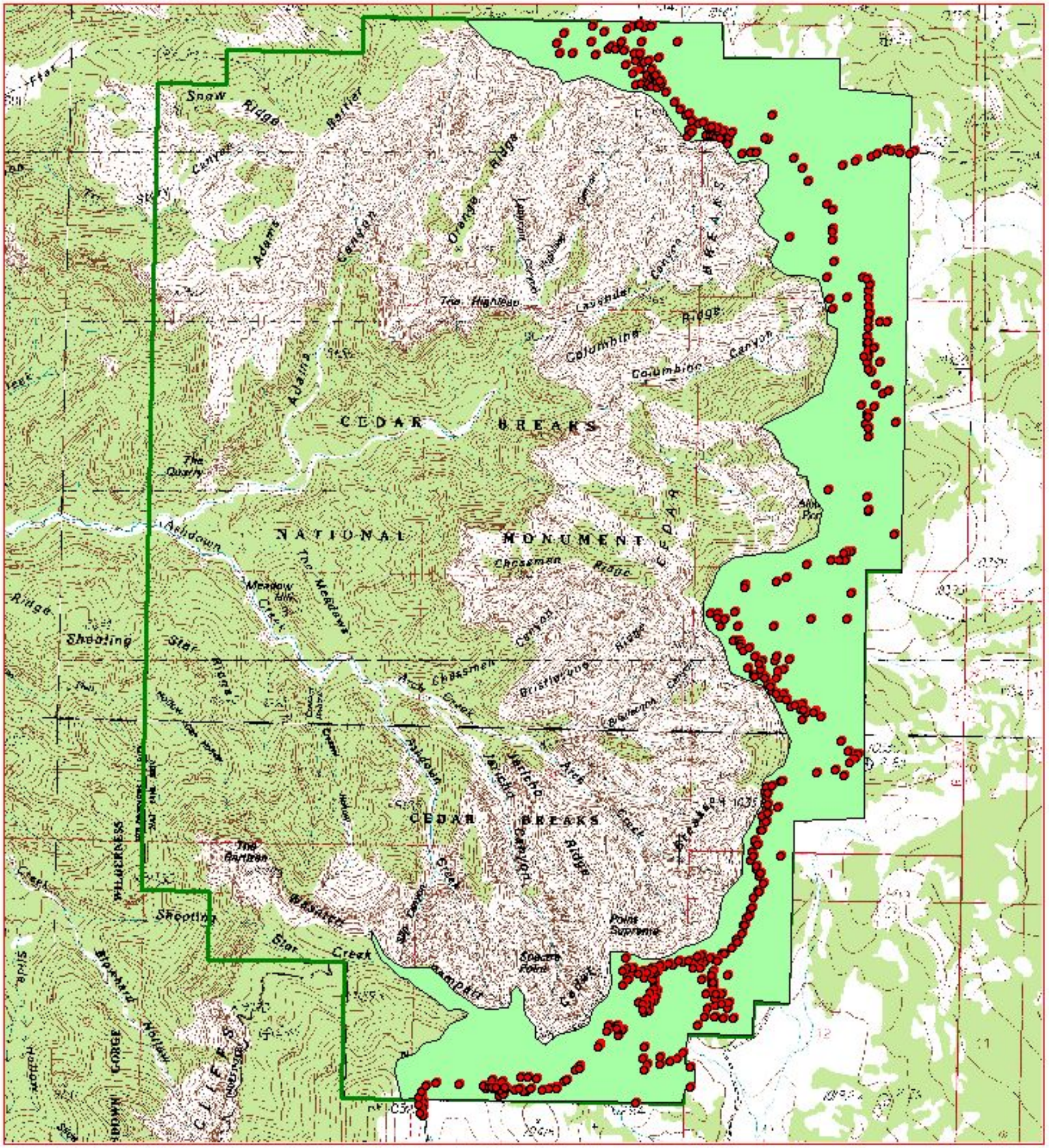
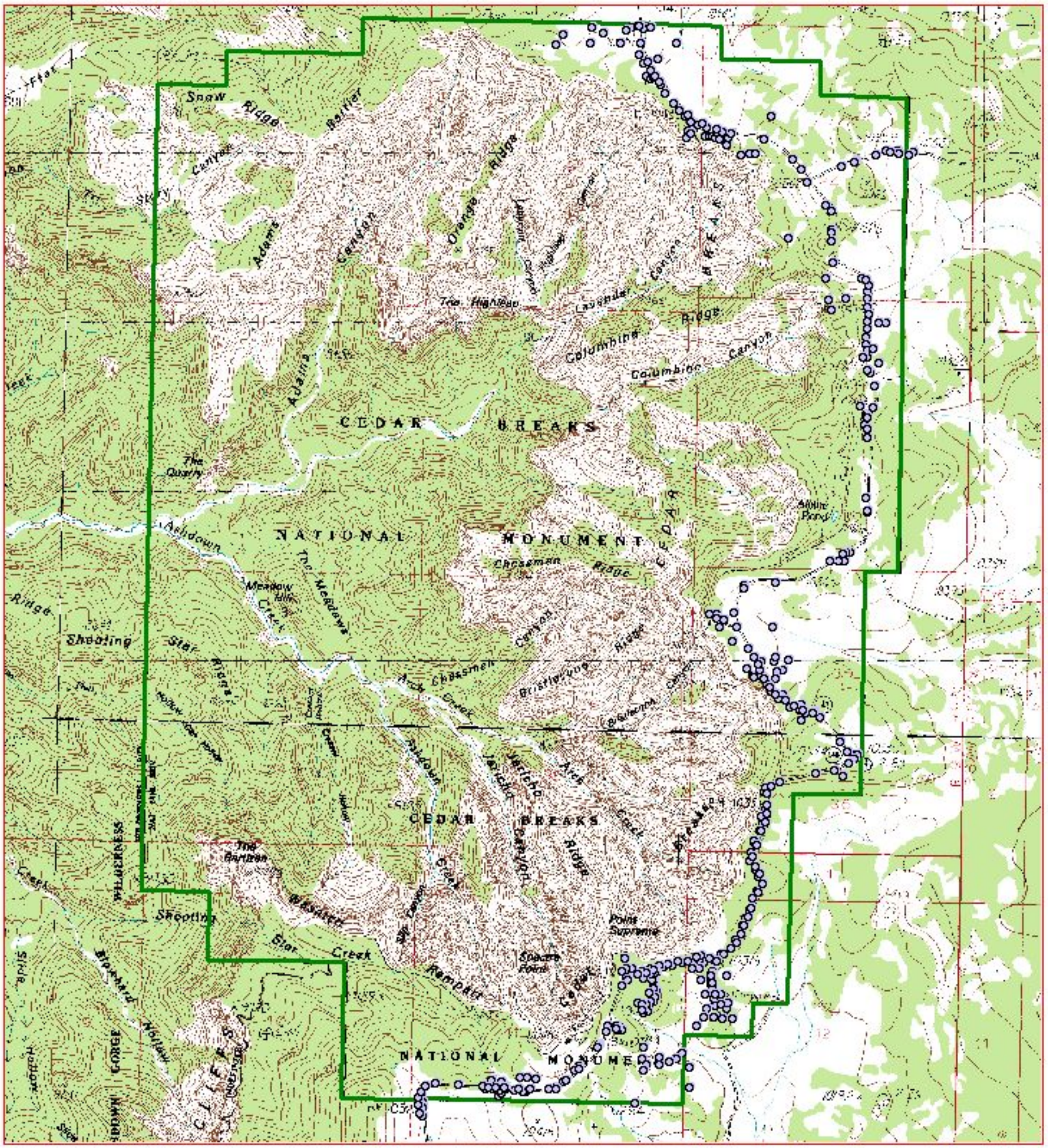
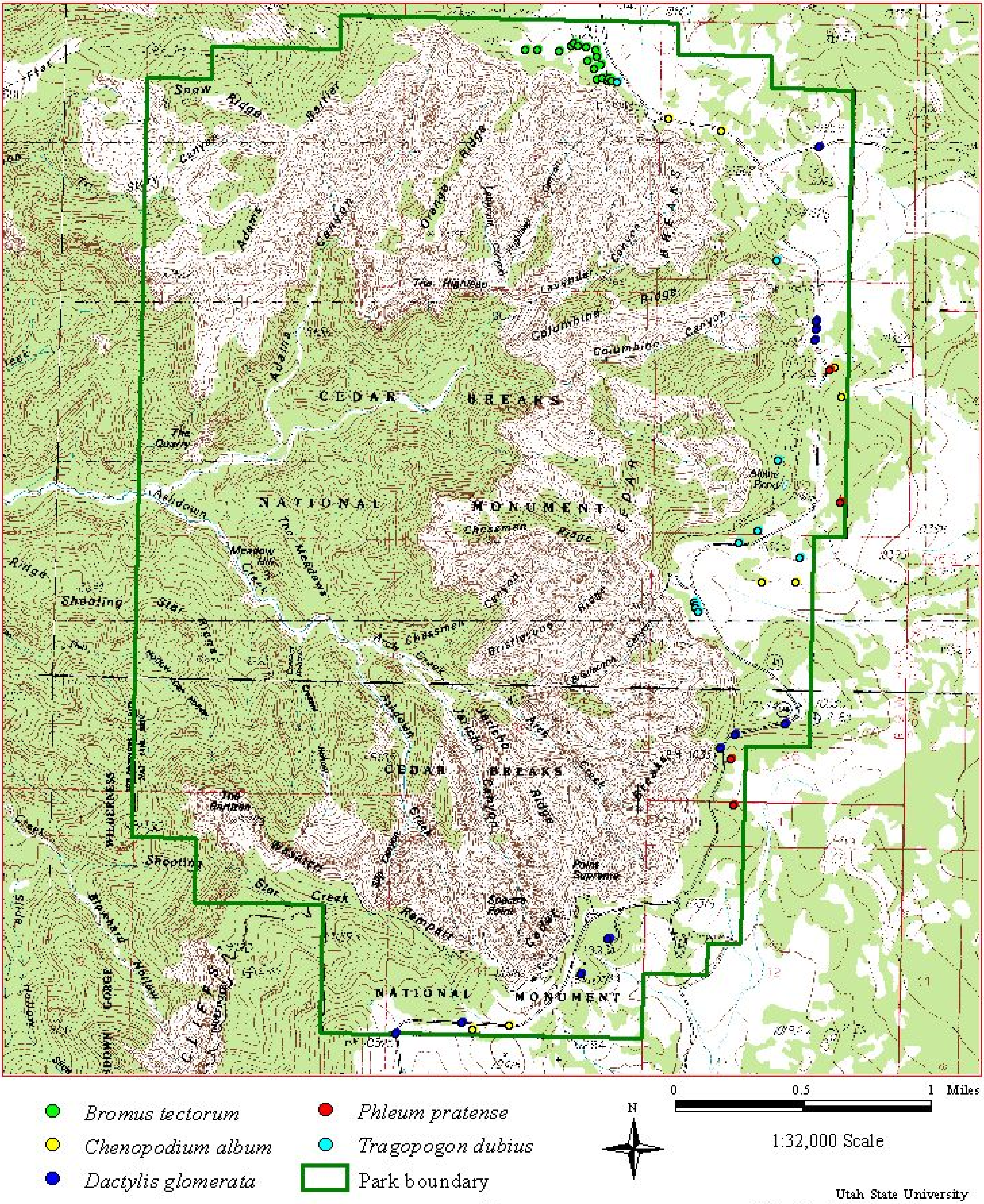


Figure 3. *Bromus inermis* inventoried in Cedar Breaks National Monument during 2004.



Utah State University
Cedar Breaks National Monument
2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Figure 4. Weed species (not including *Bromus inermis*) inventoried in Cedar Breaks National Monument during 2004.



found away from roads as isolated patches in open meadows or edges of timber where little disturbance was apparent.

A survey of non-native plants conducted in Cedar Breaks National Monument in 1997 by a team from Zion National Park (Mason and LaBarre 1997) found *Bromus inermis* to be relatively abundant, having been planted as a revegetation species along the highway. They noted that in most cases the grass did not seem to be spreading out from the originally planted areas; and where it was spreading, it appeared to be moving slowly. They estimated that the average roadside infestation extended about 3 meters out from the edge of the pavement, and in many cases was spotty. It was observed to be spreading into drainages and shallow channels where water was concentrated and funneled from roadsides down into the meadows. Of particular noted concern were: 1) along the road into the campground where it was reported to have spread 50 meters into the meadow, and 2) along the side of the highway (exact location not specified), where it had followed a channel 100 meters from the roadside.

Although it is not possible to quantify from available data, it is our impression that *Bromus inermis* has spread since the 1997 survey. We found it in all of the situations described by Mason and Labarre, but probably in greater abundance. For example, the campground infestation now extends well beyond 50 meters into the meadow, and we estimate the average roadside infestation to extend more than 5 meters from the pavement edge. However, without the establishment of permanent monitoring sites, the question of *Bromus inermis* spread can't be answered conclusively.

Bromus tectorum was the second most common species inventoried in 2004, making up 4.3 % of the infested acreage. It was found exclusively along the northern boundary above Orange Ridge and Highleap Canyon. *Bromus tectorum* was not surveyed in 1997 by the ZION team, apparently due to site inaccessibility.

Other species mapped in 2004 were *Chenopodium album*, *Dactylis glomerata*, *Phleum pretense*, and *Tragopogon dubius*, which together comprised 1.4 % of the total. In almost all cases, these species were confined to within 50 feet of the road shoulder.

Mason and LaBarre also found *Dactylis glomerata* and *Tragopogon dubius* in 1997, apparently in low abundance. They acknowledged previous reports of *Chenopodium album* and *Phleum pratense* but did not encounter any personally. They mentioned that a single plant of *Chenopodium album* had been found and pulled in 1996 along the roadside below the visitor center near the old maintenance road, and that they had checked the location in 1997 without finding any new plants. We did not find *Chenopodium album* at that site either in 2004, suggesting that it may have been successfully eradicated. However, we did find 8 other *Chenopodium album* infestations, including a narrow but relatively dense infestation that extended for more than 100 feet along the north shoulder of the highway near the one of the scenic overlooks.

None of the remaining 47 species in the data dictionary, or other non-native species considered by the USU crew to be potentially invasive was found in the Monument with the exception of *Taraxacum officinale* and *Poa pratensis.* These two species were abundant throughout the

Monument, but were not mapped (Appendix H). Both of these species were reported by Mason and LeBarre to be abundant in CEBR in 1997.

Inventoried areas were generally level and visibility was good on the eastern boundary, thus it is unlikely that any 0.01-acre or larger patches of targeted weeds were missed. Crews were confident of finding 99-100 percent of all 0.01-acre or larger patches of invasive plants between the road and the eastern boundary. The western portion of the target area, between the road and the canyon rim, tended to have thicker vegetation and the terrain was much steeper. Biodiversity was very high in these areas and no obvious disturbance was noticed. Although these areas were harder to search, it is still unlikely that the crews missed any 0.01-acre or larger patches of any weedy species.

There were a number of non-target grass species headed out in CEBR at the time of the inventory. Several native grass species with inflorescences similar in color or shape to *Bromus inermis* were noted. Kentucky bluegrass, *Poa pratensis*, was also common in the inventory area but not mapped. The crew was provided on-site training to eliminate possible confusion when encountering these species.

The ecological status of the inventory area was assigned by the project crew leader based on her impression of the site's ability to recover once the weeds have been removed. Status levels are defined in Appendix B. The target inventory area was assigned a level 2 because the weedy species present (with the possible exception of *Bromus inermis* on roadsides) represent a small acreage and could easily be controlled. The Monument has a high amount of biodiversity and it is likely the infested areas would readily return to their natural state if the proper control measures were taken and proper monitoring took place.

CONCLUSIONS / RECOMMENDATIONS

The overall objective of this project was to document the distribution and relative abundance of targeted invasive non-native plant species across the range of habitats of management concern in Cedar Breaks National Monument, in anticipation that these data would prove useful in the development and implementation of more effective vegetation control strategies.

Species prioritization is an important part of strategic weed management planning, especially when limited budgets don't allow all weed problems to be addressed equally. As a general rule when weed abundance exceeds weed control resources, the least abundant species should be given highest priority, with the ultimate objective being eradication whenever possible. Species that are somewhat more abundant but still highly manageable should be controlled as aggressively as possible, with containment being the initial goal, and followed by a significant reduction in acreage. Infestations of species presently beyond the hope of containment or reduction in acreage should not be ignored, but should not be the object of significant expense until all higher-priority situations have been adequately addressed. Relatively inexpensive methods such as policy and procedural changes aimed at preventing or minimizing further spread (protecting non-infested areas), release of biological control agents, or use of cultural methods are generally recommended for weed species in this category.

Applying that strategy to CEBR would mean that *Bromus tectorum, Tragopogon dubius*, *Chenopodium album*, *Phleum pratense*, and *Dactylis glomerata* should be given the highest control priority of the species mapped, and should be targeted for prompt eradication. *Bromus tectorum*, which is notorious for its ability to create monocultures within ecosystems as well as to dramatically alter fire regimes, would also fit into the highest priority category. The relatively small size of the current infestation within CEBR should encourage managers to contain and eventually eradicate *Bromus tectorum* before it spreads any further.

Bromus inermis, which was the most abundant and most well-established of the targeted invasive species found in Cedar Breaks National Monument would likely fit into the second priority category of "contain and reduce ". Although it infests most roadsides and developed areas, it is still absent and native vegetation is still abundant throughout most portions of the Monument. Containment of existing infestations, complemented by effective prevention (including removal from all re-vegetation seed mixes), early detection, and rapid response strategies on the non-infested portions of the Monument, is the recommended approach to *Bromus inermis*. On the other hand, if the spread of current *Bromus inermis* infestations is not stopped, it appears likely that populations of native plants in meadows may eventually be reduced significantly or even lost. Plants that we would place in the third management category (lowest priority) include *Poa pratensis* and *Taraxacum officinale*, both of which were widespread throughout the Monument and were too abundant for meaningful mapping.

It is not our intent to be critical of previous reports or recommendations. However, we have some concerns about the report by Mason and LaBarre (1997) which included the following assessments and recommendations based on a management prioritization system published by Hiebert and Stubbendieck (1993):

> "The non-native plants found at Cedar Breaks do not pose much of a threat to the native vegetation of the area. Most of the species seem to be fairly contained due to the low level of past disturbance and environmental conditions. *Taraxacum officinale* could be considered an exception to this although it would be futile to attempt to eradicate this well-established species."
>
> "If eradication and/or control is desired, these (*Bromus inermis, Tragopogon dubius*, and *Poa pratensis*) are the recommended species to target (priority I). If all priory I species are treated, next priority lies with the low-threat / easy-to-control species: *Chenopodium album* and *Dactylis glomerata*. *Taraxacum officinale* would take significant effort to control and would not be cost effective."

It seems to us that this approach to the weed situation in CEBR is flawed, particularly with regard to placing the control of *Dactylis glomerata* and *Chenopodium album* as a lower priority than *Bromus inermis* and *Poa pratensis*. It is as if the recommendation is to control first those species that have proven to be invasive before worrying about new non-natives that have not demonstrated a propensity to spread. Perhaps we have misread or misinterpreted the report, but we feel it important to point out this apparent discrepancy between our recommendations and those (at least as we interpret them) from the 1997 report. Waiting to initiate control efforts until after the ecological threat of a new non-native species is certain can be a very costly mistake.

The second objective of this project was to identify potential sources of weed introduction and significant vectors involved in weed spread in the Monument. Humans are the most likely vectors for new introductions of invasive plant species into Cedar Breaks National Monument and all other Parks of the Northern Colorado Plateau Network, and areas of highest human visitation are also the areas where new invaders might be expected to appear first. Millions of visitors come from all over the world to enjoy the unique beauty of this region, and each person potentially brings with them errant seeds of an exotic invasive plant lodged in the tread of a tire or hidden in the dried mud of a hiking boot. The ever-increasing number of visitors, combined with the distant and diverse geographical areas from which they come, all combine to make National Parks highly and uniquely vulnerable to exotic plant invasions. Frequent inspection of high-visitation sites within each Park and Monument is essential to the "early detection and rapid response" strategy of invasive plant management. Roadways, parking areas, visitor centers, picnic sites, campgrounds, view points, trails, and all other high-visitation sites should be searched regularly (at least yearly) at a time when new plants would be visible. Visitors should be informed of the potential damage caused by invasive plants, and ways they can help minimize the chances of it occurring. This might be done in the form of written information distributed at the Park's or Monument's main entrance gate, through displays or a video program at the Visitor Center, and evening fireside presentations to visitors made by NPS personnel.

Routine Monument operations represent a second significant source of potential weed invasions. Road maintenance, fire fighting, and even weed control operations can result in the unintentional introduction or spread of invasive weeds. Specific procedures should be developed and implemented to minimize the spread of weed seeds by NPS employees and/or the creation of unprotected disturbed sites that can be ideal for weed establishment. An excellent example of effective weed prevention methods can be seen in protocols developed for the recent multi-crew EPMT deployment exercise conducted at Arches National Park (USDI-NPS 2004) (Appendix I). Additional weed prevention protocols have been developed by the Forest Service (USDA-Forest Service 2001).

Natural vectors such as wind, water, and wildlife do play a role in weed seed dissemination within the National Parks, and cannot be overlooked. However, they probably play a much less significant role overall, compared to human-related vectors. Control of isolated new weed infestations at the heads of otherwise non-infested drainages could prevent rapid spread associated with flowing streams or flash flood events. Traditional annual migration routes of deer, elk, or other large animals should be considered a high-probability area for weed seed transport and introduction.

All NCPN Parks that were inventoried in 2003 and 2004 are in the enviable situation of still having the majority of their lands free of invasive weeds. Only 3.2 percent of the acres inventoried in Cedar Breaks National Monument were infested with weeds. An important new trend in weed management is the concept of identifying areas that are currently free of one or more species of invasive plants, and officially designating them as "Weed Prevention Areas" (WPA). Land units designated as WPA's are to be given a higher priority for prevention efforts, early detection, and rapid control of any new invaders.

In our opinion, all areas within Cedar Breaks National Monument that are currently "clean" should be identified as WPAs, and Park management should take all appropriate measures to keep invasives from spreading into them. Protecting and preserving lands in this weed-free condition is much more cost-effective than restoring extensive areas already badly infested by invasives, and therefore should be the highest weed management priority for the Northern Colorado Plateau Network. Programs based on prevention, early detection, and rapid response to control all new invaders on presently weed-free lands will be needed to accomplish this objective.

The WPA concept also is an excellent way to emphasize the fact that the majority of NPS lands are still clean and healthy with respect to the threat of invasive plants. The total number of acres in WPA's within a Park or Monument could help to justify increased budgets for prevention practices. Increasing the number of weed-free acres should be recognized as a highly significant accomplishment, and Park managers should be encouraged to make the necessary efforts to convert lightly infested lands to WPA's as quickly as possible (by aggressively controlling and eradicating those few plants keeping these areas from being declared "weed free"). WPA's also present an opportunity for Parks to help the general public feel more involved as visitors see more clearly the focus of the preventive measures they are being asked to adopt.

Cedar Breaks National Monument should consider establishing permanent monitoring sites to evaluate the impact and spread of weeds, as well as evaluate the effectiveness of its weed management approaches. This also was a recommendation in the Mason and LaBarre report (1997). Long-term studies provide valuable insight into the effectiveness of current management techniques and quantify whether management goals have been accomplished. Monitoring standards and protocols exist in the federal agencies and provide guidelines as to selecting appropriate sites and proper techniques for gathering information. Several excellent publications on monitoring methods and standards are currently available for reference (Coulloudon et al. 1999, Elzinga et al. 1998, Kuchler et al.1988, Silsbee et al. 1991, USDI-USGS 1994, Winward 2000).

Cedar Breaks National Monument is also encouraged to become an active member of a local Cooperative Weed Management Area. Weed management goals can be achieved more effectively when managed in cooperation with partner organizations also trying to achieve the same goals. The following excerpt taken from the National Park Service's own 2002 publication "Inventory and Monitoring for Invasive Plants Guidelines" further emphasizes the importance of this concept, particularly as it relates to invasive weed inventories:

> “Although the Park’s primary responsibility is to itself and to upholding the mission for which is was established, Parks have a role and responsibility in promoting and supporting collaborative information exchange among local weed and natural resource management professionals. It is in the self-interest of the Park (in fulfilling its mission) and the agency (as a cooperating federal land management agency) to do more than simply share data passively or opportunistically. To the extent a Park can place the distribution and abundance of its invasive plants in the context of a larger landscape, the Park’s efforts to identify management objectives and allocate resources efficiently will be improved as the scale of that landscape grows in size.”

Dinosaur National Monument is currently a member of a Cooperative Weed Management Area, as are some other NCPN Parks. If interested in more information and advice, we suggest contacting Tamara Naumann, Park botanist at DINO.

Denise Louie was already aware of many of the weed infestations found in this inventory. It is acknowledged that Cedar Breaks National Monument is already implementing many effective weed control strategies and practices, for which they are to be commended. It is anticipated that these new data will add significantly to baseline of current information and will be useful in the development and implementation of even more effective vegetation control strategies in Cedar Breaks National Monument.

If it does not already exist, the Monument is urged to develop a comprehensive written management plan for invasive plant species in CEBR, similar to the plan currently being finalized by Utah State University for Dinosaur National Monument. If there currently is a written plan in place, the Monument is encouraged to review and improve it on a regular basis. An excellent reference that will aid the Monument in crafting specific control methods is the "Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas" developed by The Nature Conservancy (Tu et al. 2001).

Regularly scheduled weed inventories of all Monument lands should be an ongoing part of a weed management plan aimed at early detection. Inspections of all high-visitation areas should be performed at least annually, whereas inventories of the most remote sites or habitats least suitable for weed establishment or spread might need to be performed only once every 5 to 10 years. A rotating schedule should be developed by Cedar Breaks National Monument to inventory a portion of their land each year, so that within a reasonable number of years all of the Monument could be inspected. The key is to schedule inventories often enough to detect all new weed infestations before they exceed a size considered feasible for eradication. Early detection of invasive weeds through regular searches and mapping is just as essential to successful weed management as the early detection of wildfires is to effective fire management.

The final objectives of this project was to test and refine data collection and field inventory techniques that might be used by NCPN in future invasive plant inventories. As part of efforts to meet that objective, USU provided training in weed mapping techniques at several state weed conferences as well as at the regional Western Society of Weed Science Weed Management Short Course held in Montana annually. An overview of the USU weed mapping program was also presented to over 60 EPMT personnel from around the country during a week-long field training exercise held in Arches National Park in 2004. In addition, several documents were published containing detailed information about USU inventory procedures and techniques (Andersen et al. 2003, Andersen and Dewey 2005, Ballard et al. 2003, Dewey and Andersen 2004a, Dewey and Andersen 2004b, Dewey and Andersen 2005a; Dewey and Andersen 2005b, Dewey and Andersen 2005c).

ACKNOWLEDGEMENTS:

We express appreciation to Pam Benjamin at the NPS Intermountain Support Office in Denver, CO, and Angie Evenden and Margaret Beer at the Northern Colorado Plateau Network in Moab, UT, for their vision and efforts in initiating this inventory project. Thanks to Angie and Margaret for their thorough reviews of our data and reports, and to Aneth Wight for always being able to solve our GIS problems. We are grateful to Ian Torrence and Liz Ballenger for their help in logistical planning and coordination with individual Parks. Thanks to the contacts in each Park (Tamara Naumann, Denise Louie, Sean Haile, Kristen Legg, Steve Robinson, Tom Clark, Dave Worthington, and Danguole Bockus) who went out of their way to accommodate the requests of our crews. Above all, we thank the dedicated and hard-working USU and NPS crew members who frequently endured conditions of potential danger and extreme hardship while hiking hundreds of miles in the intense summer heat of southern Utah to collect this information.

References Cited

Andersen, K., S. Dewey, and M. Ballard. 2003. Field Techniques for Improving Accuracy and Efficiency of GPS Wildland Weed Surveys. Proc., Western Society of Weed Science, 56:87.

Andersen, K. and S. Dewey. 2005. Do's and Don'ts of Wildland Weed Mapping - The USU Experience. Proc., Idaho Weed Control Association Conf., Nampa, ID.

Asher, J. E. and D. W. Harmon. 1995. Invasive exotic plants are destroying the naturalness of U.S. wilderness areas. International Journal of Wilderness, Vol 1, No.4, p. 35-37.

Ballard, M., S. Dewey, and K. Andersen. 2003. Using GPS Point Features to Describe Spot, Line, and Area Infestations in Wildland Weed Surveys. Proc., Western Society of Weed Science, 56:86.

Benjamin, Pamela K. 2001. Weed Mapping and Database Development Guidelines for the National Park Service Intermountain Region (IMR). Intermountain Support Office, Denver, CO. 22pp. plus appendices.

Clinton, William. 1999. "Invasive Species." Executive Order 13112 of February 3, 1999 (as amended by E.O. 13286 on February 28, 2003). (64 F.R. 6183, February 8, 1999).

Coulloudon, B, K. Eshelman, J. Gianola, N. Habich, L. Hughes, C. Johnson, M. Pellant, P. Podborny, A. Rasmussen, B. Robles, P. Shaver, J. Spehar, and J. Willoughby. 1999. Sampling Vegetation Attributes. Interagency Tech. Ref. 1734-4. p. 31-130.

D'Antionio, C. and N. Jackson. 2003. Invasive plants in natural and managed systems: linking science and policy. Abstr., 7th International Conference on the Ecology and Management of Alien Plant Invasions, Ft. Lauderdale, FL., 104 pp.

Dewey, S., K. Andersen, M. Ballard, J. Simonsen, R. Richards, and E. Lamalfa. 2003. Invasive non-native plant inventory conducted in portions of Arches, Canyonlands, Hovenweep, Natural Bridges, Black Canyon, and Zion National Parks. Ann Prog Report (8 volumes), submitted to the Intermountain Regional Office of the National Park Service, Denver, CO, and the Northern Colorado Plateau Network, Moab, UT.

Dewey, S.A. and K.A. Andersen. 2004a. Strategies for Early Detection - Using the Wildfire Model. Weed Technol. 18:1396-1399.

Dewey, S.A. and K.A. Andersen. 2004b. Distinct Roles of Surveys, Inventories, and Monitoring in Adaptive Weed Management. Weed Technol. 18:1449-1452.

Dewey, S.A. and K.A. Andersen. 2005a. Determining Effective Search Swath Widths for Wildland Weed Surveys. Proc., Western Society of Weed Science Conf., Vancouver, BC.

Dewey, S.A. and K.A. Andersen. 2005b. Quality Assurance Measures for Invasive Weed Surveys on Wildlands. Abstr., Weed Science Society of America Conf., No. 121, p. 37.

Dewey, S.A. and K.A. Andersen. 2005c. Strategies for Early Detection – Using the Wildfire Model. Weed Technology 18: 1396-1399.

Duncan, C. L., and J. K. Clark (eds.). 2005. Invasive Plants of Range and Wildlands and Their Environmental, Economic, and Societal Impacts. Weed Science Society of America, 222 pp.

Elzinga, C. L, D. W. Salzer, and J. W. Willoughby. 1998. Measuring and Monitoring Plant Populations. USDI-BLM Tech. Ref. 1730-1 BLM/RS/ST-98/005+1730. p. 1-10.

[GPRA] Government Performance and Results Act of 1993. P.L. 103-62 (2003).

Hiebert, R. D. and J. Stubbendieck. 1993. Handbook for Ranking Exotic Plants for Management and Control. Natural Resources Report NPS/NRMWRO/NRR-93/08.

Kuchler, A. W. and I. S. Zonneveld (eds.). 1988. Vegetation Mapping. Handbook of Vegetation Science, Vol. 10. Kluwer Academic Publishers, Boston, MA. p. 193-202.

Layden, P. C. and M. J. Manfredo. 1994. National Park conditions: a survey of Park superintendents. National Parks and Conservation Association, Washington, D.C.

Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout, and F. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. Issues in Ecology, 5:1-20.

Mason, K. and B. LaBarre. 1997. Cedar Breaks National Monument Non-Native Plants Survey Report. Resource Management and Research Division, Zion National Park, 3 p.

Mullin, B. H., L. W. J. Anderson, J. M. DiTomoso, R. E. Eplee, and K. D. Getsinger. 2000. Invasive plant species. Council for Agric. Science and Technology, Issue Paper No. 13, 17 pp.

[NAWMA] North America Weed Management Association. 2003. North American Invasive Plant Mapping Standards. (Web page: http://www.nawma.org).

Randall, J. M. 1995. Assessment of the invasive weed problem on preserves across the Unites States. Endangered Species Update 12 (4&5): 4-6

Sakai, A. K., F. W. Allendorf, J. S. Holt, D. M. Lodge, J Molofsky, K. A. With, S. Baughman, R. J. Cabin, J. E. Cohen, N. C. Ellstrand, D. E. McCauley, P. O'Neil, I. M. Parker, J. N. Thompson, and S. G. Weller. 2001. The Population Biology of Invasive Species. Ann. Rev. Ecol. Syst., 32:305332.

Silsbee, D.G. and D.L. Peterson. 1991. Designing and implementing comprehensive long-term inventory and monitoring programs in the national parks. NPS Natural Resources Rept. NPS/NRUW/NRR-95/16.

Tu, M., Hurd, C., & J.M. Randall, 2001. Weed Control Methods Handbook, The Nature Conservancy. Web page: http://tncweeds.ucdavis.edu/handbook.html, Version: April 2001.

[USDA-FS] United States Department of Agriculture, Forest Service. 2001. Guide to Noxious Weed Preventive Practices. Version 1, July 5, 2001. 25 pp. (Web page: http://www.fs.fed.us/rangeland/ecology/invasives)

[USDI-NPS] United States Department of Interior, National Park Service. 1995. Natural resource inventory and monitoring guidelines. NPS-75.

[USDI-NPS] United States Department of Interior, National Park Service. 1996. Preserving Our National Heritage - a Strategic Plan for Managing Invasive Nonnative Plants on National Park System Lands. Natural Resources Stewardship and Science, National Park Service, Washington, D.C. 16 pp.

[USDI-NPS] United States Department of Interior, National Park Service. 1999. Natural Resource Challenge: The National Park Service's Action Plan for Preserving Natural Resources. U.S.D.I. National Park Service, Washington, D.C. 21 pp. (Web page: http://nature.nps.gov/challengedoc)

[USDI-NPS] United States Department of Interior, National Park Service. 2001. Initiate an Intermountain Region Noxious Weed Inventory and Mapping Program. Implementation Plan prepared by Intermountain Support Office PMIS #72973. January 2001. 77 pp. plus appendices.

[USDI-NPS] United States Department of Interior, National Park Service. 2002. Inventory and Monitoring for Invasive Plant Guidelines. Workshop report held in Fort Collins, CO, June 4-6, 2002. 60 pp.

[USDI-NPS] United States Department of Interior, National Park Service. 2004. Weed Seed/Propagule Decontaimination Procedures. Arches National Park EPMT Strike Team Incident Action Plan, Courthouse Wash Project, March 9-14, 2004.

[USDI-USGS] United States Department of Interior, U. S. Geological Survey. 1994. USGS-NPS Vegetation Mapping Program Documents and Standards. Web page: http://biology.usgs.gov/npsveg/standards.html.

Westbrooks, R. 1998. Invasive plants, changing the landscape of America: Fact book. Federal Interagency Committee for the Management of Noxious and Exotic Weeds, Washington, D. C. 109 pp.

Winward, A. 2000. Monitoring the Vegetation Resources in Riparian Areas. USDA Forest Service General Technical Report RMRS-GTR-47. p. 10-32.

Appendix Tables and Figures

Appendix A. Crew Qualifications and Project Quality Assurance for 2003-2004 Invasive Non-native Plant Inventory in Cedar Breaks National Monument.

The Utah State University wildland weed mapping team has considerable experience conducting the type of survey required in this NPS project. Previous weed surveys conducted by USU include:

1997 Mt. Naomi Wilderness Area, Cache County, UT
1998 Wellsville Mountains Wilderness Area, Cache and Box Elder Counties, UT
1999 Franklin Basin Recreation Area, USFS Logan Ranger District, Cache County UT
2000 Rich County Public Lands (BLM, USFS), UT
2001 Hardware Ranch WMA, UDWR, Cache County, UT
2001 Bud Phelps WMA, UDWR, Cache County, UT
2002 Hawkins Fire, USFS, Bannock County, ID
2002 Canyon Fire, USFS, Franklin County, ID
2002 Cherry Creek Fire, USFS, Bannock County, ID
2002 West Fork Fire, BLM, Bannock County, ID
2002 Dinosaur National Monument, Green River District, UT

Kim Andersen (crew leader) and Melanie Ballard (assistant crew leader) have considerable experience working on the USU crew in past years. Kim has a Bachelor of Science degree in Fisheries and Wildlife from the College of Natural Resources and is currently working towards a Master's Degree in Weed Science. Melanie has a Bachelor of Science degree in Plant Science. Kim began work on the USU crew in 1999, and has been crew leader since 2000. Melanie started on the crew in 2002. Both Kim and Melanie have additional experience with invasive weed GPS mapping projects in National Parks (Grand Teton and Yellowstone). Ruth Richards has a Bachelor of Science degree in Crop Science and is currently working towards a Master's Degree in Weed Science. She has worked on the crew in 2003 and 2004. Janna Simonsen has worked as a biological technician for the Wasatch-Cache National Forest since 1999 conducting vegetation analyses and range monitoring studies using GPS/GIS technologies. Janna has a BS degree from USU in Environmental Studies. Hillary Hudson has a Bachelor's degree and has worked on an Exotic Plant Management Team in California from 2003 to 2004. She has also worked as a national park ranger in the Maze District of Canyonlands National Park. Eric Lamalfa is a student at USU in the Plant Science department. Liz Ballenger has a Bachelor's degree in Biology from the College of Wooster and a Master's Degree in Ecology from the University of Michigan. Heather Rickleff has a Bachelor's degree in Outdoor Recreation and Resource Management from Indiana University.

All USU weed survey crew members were required to pass a written exam in weed identification and mapping skills before being hired. Each also had passed an upper-division university course in weed identification, biology, and management, and/or has extensive practical experience in wildland plant identification. Once hired, USU and NPS crew members also attended a 3-week classroom and outdoor training course in late April and early May in wildland weed mapping

techniques taught by Dr. Dewey at Logan and Zion National Park during 2003. A similar training course was offered to the USU crew in 2004. Crew members were provided with weed identification field guide book, taxonomic keys, and pressed reference specimens of all targeted weeds. During the course of the summers USU crew members were quizzed periodically with fresh plant specimens provided by the crew leader and/or Dr. Dewey. Dr. Dewey also spent several days in the parks working with individual crew members under field conditions. To further authenticate findings, Dr. Dewey and/or the crew leader re-visited representative areas in each park that had been previously mapped by the USU crew, using the most recent crew-generated weed infestation maps to compare them against their own field observations.

Appendix B. Standard GPS Data Dictionary used in the 2003-2004 Invasive Non-native Plant Inventory in Cedar Breaks National Monument.

NPS-2004
Inventory of invasive weeds in NCPN

pt-weed Point Feature, Label 1 = Species Code 1 = IT IS code Code 2 = Plant Code

Species	Menu, Required, Normal	
Asparagus sp.	[42782]	[ASPAR]
Bells of Ireland	[32569]	[MOLA]
Bindweed, field	[30705]	[COAR4]
Blackberry, Himalayan	[24852]	[RUDI2]
Brome, downy	[40524]	[BRTE]
Brome, smooth	[40502]	[BRIN2]
Burdock	[36546]	[ARMI2]
Camelthorn	[508549]	[ALMA12]
Chamomile	[36330]	[ANTHE]
Cress, hoary	[23072]	[CADR]
Dock, curly	[20937]	[RUCR]
Elm, Siberian	[19057]	[ULPU]
Halogeton	[20692]	[HAGL]
Hemlock, poison	[29473]	[COMA2]
Henbane, black	[21454]	[HYNI]
Houndstongue	[31890]	[CYOF]
Horehound	[32561]	[MAVU]
Johnsongrass	[42111]	[SOHA]
Knapweed, diffuse	[36958]	[CEDI3]
Knapweed, Russian	[510530]	[CERE6]
Knapweed, spotted	[36964]	[CEMA]
Knapweed, Squarrose	[533280]	[CETR8]
Lambsquarter	[20592]	[CHAL7]
Loosestrife, purple	[27079]	[LYSA2]
Marshelder	[36041]	[IVA]
Mullein, common	[33394]	[VETH]
Mustard, Sahara	[23064]	[BRTO]
Olive, Russian	[27770]	[ELAN]
Orchardgrass	[193446]	[DAGL]
Pepperweed, perennial	[503379]	[LELA2]
Puncturevine	[29057]	[TRTE]
Reed, giant	[41450]	[ARDO4]
Saltcedar	[22310]	[TARA]
Salsify, western	[38564]	[TRDU]
Spurge, leafy	[28064]	[EUES]
Starthistle, yellow	[36972]	[CESO3]
Thistle, bull	[36428]	[CIVU]
Thistle, Canada	[36335]	[CIAR4]
Thistle, musk	[35787]	[CANU4]
Thistle, Russian	[20655]	[SAKA]
Thistle, Scotch	[38140]	[ONAC]
Timothy grass	[41062]	[PHPR3]
Toadflax, Dalmatian	[33219]	[LIDA]
Toadflax, yellow	[33216]	[LIVU2]
Tree of Heaven	[28827]	[AIAL]
Wheatgrass, crested	[40371]	[AGCR]
Woad, dyer's	[23151]	[ISTI]

OTHER	[XXXX] [XXXX]
% Cover Trace: < 1 % Low: 1 to 5 % Mod: 6 to 25 % High: 26 to 50 % Majority: 51 to 100 %	Menu, Required, Normal, weed canopy within infested area
Size 0.01 acres 0.1 acres 0.25 acres 0.5 acres 1.0 acres 2.5 acres 5.0 acres	Menu, Required, Normal, based on average perimeter diameter
Phenology Vegetative Bud Flower Fruit-immature Fruit-mature Seed dispersing Dormant/senesced	Menu, Required, Normal, weed growth stage
Woody Growth Seedling Sapling Mature Dormant/senesced	Menu, Normal, Normal, growth stage of woody species
Dominant Native Spp.	Text, Maximum Length = 30, 2-digit codes, 2 species, order of prevalence Normal, Normal
Disturbance None Low-Mod (default) High	Menu, Normal, Normal
Hydrology Upland (default) Rip-perennial Rip-intermittent Rip-ephemeral Wetland Playa-lakebed	Menu, Normal, Normal, site hydrology
Notes	Text, Maximum Length = 30 Normal, Normal
Date	Date, Auto generate Create, Month-Day-Year Format Normal, Normal

Time	Time, Auto generate Create, 24 Hour Format Normal, Normal
Ln-weed	Line Feature, Label 1 = Time
Species	Menu, Required, Normal

******See species list under pt-weed.

Line Width (ft)	Numeric, Decimal Places = 0, average width of linear area Minimum = 5, Maximum = 500, Default Value = 20 Required, Normal
Notes	Text, Maximum Length = 50 Normal, Normal
Time	Time, Auto generate Create, 24 Hour Format Normal, Normal
Date	Date, Auto generate Create, Month-Day-Year Format Normal, Normal
Ar-weed	Area Feature, Label 1 = Time GPS-generated polygon
Species	Menu, Required, Normal

******See species list under pt-weed.

Notes	Text, Maximum Length = 50 Normal, Normal
Time	Time, Auto generate Create, 24 Hour Format Normal, Normal
Date	Date, Auto generate Create, Month-Day-Year Format Normal, Normal
Gross-weed	Point Feature, Label 1 = Time, Office-generated polygon
Species	Menu, Required, Normal

******See species list under pt-weed.

Infested (% of Area Infested)	Numeric, Decimal Places = 0, (% of gross area actually infested) Minimum = 1, Maximum = 100, Default Value = 1 Required, Normal
% Cover (IA only) Trace: < 1 % Low: 1 to 5 % Mod: 6 to 25 % High: 26 to 50 % Majority: 51 to 100 %	Menu, Required, Normal, % weed cover in typical infestations

Area ID (# on map)	Numeric, Decimal Places = 0, From infestation ID # noted on field map
	Minimum = 1, Maximum = 100, Default Value = 1

	Required, Normal
Notes	Text, Maximum Length = 50 Normal, Normal
Date	Date, Auto generate Create, Month-Day-Year Format Normal, Normal
Time	Time, Auto generate Create, 24 Hour Format Normal, Normal
Point	Point Feature, Label 1 = Notes
Notes	Text, Maximum Length = 50 Normal, Normal
Line	Line Feature, Label 1 = Notes
Notes	Text, Maximum Length = 50 Normal, Normal
Area	Area Feature, Label 1 = Notes Text, Maximum Length = 50 Normal, Normal
Photo	Point Feature, Label 1 = Notes, Label 2 = Bearing (MN)
Species	Menu, Required, Normal

******See species list under pt-weed.

Bearing (MN)	Numeric, Decimal Places = 0 Minimum = 0, Maximum = 360, Default Value = 0 Normal, Normal
Notes	Text, Maximum Length = 50 Normal, Normal
Date	Date, Auto generate Create, Month-Day-Year Format Normal, Normal
Time	Time, Auto generate Create, 24 Hour Format Normal, Normal
Voucher	Point Feature, Label 1 = Notes
Species	Menu, Required, Normal

******See species list under pt-weed.

Notes	Text, Maximum Length = 50 Normal, Normal

Appendix C. Relationship of NCPN Project Data Elements to IMR and NAWMA Weed Mapping Standards used in 2003-2004 Invasive Non-native Plant Inventory in Cedar Breaks National Monument.

Relationship of NCPN Weed Mapping Project Database Elements to proposed IMR Weed Mapping Data Elements and NAWMA Standards. Column labeled 'NCPN Data Element Status' indicates whether or not data element were included in NCPN Weed Mapping Database. If data element was included (=YES) an indication is made whether or not the data was field collected or compiled in an office setting.

CATEGORY	*DATA ELEMENTS*	NPS Intermountain Region	NAWMA	NCPN Data Element Status	NCPN Data Source	Comments
AGENCY METADATA	1. Collection Date (yyyymmdd)	Required	Required	YES	Field	
	2. Source of Data (contact of individual who manages data)	Required	Required	YES	Office	Included in metadata only
	3. Scale of Data Source	Required (recommend 1:24000)	Required (recommend 1:24000)	YES	Office	Included in metadata only
	4. Datum of Original Data (N_{27}/N_{83})	Required	N/A	YES	Office	Included in metadata only
	5. Surveyor Name	Optional	Optional	YES	Field	
	6. Site ID (Name or Number)	Optional	Optional	YES	Field	
	7. Quality Control Assessment (Yes/No)	Optional	N/A	(yes)	Office	This will be done but not entered as a data field.
	8. Methodology Used For Inventory (casual observation/formal survey/remote)	Optional	Optional	YES	Office	Included in metadata only
INVASIVE SPECIES INFORMATION	1. Plant Scientific Name (Genus/species) a. Intraspecific Name b. Authority for Name	Required a. Optional b. Optional (Recommend Kartez)	Required a. Optional b. Required (Kartez)	YES	Field	Scientific Name only
	2. ITIS Code (allows for link to NPSpecies)	Required	N/A	YES	Office	ITIS code will allow linkage to authority, common name, state status etc.
	3. Common Name	Optional	Optional	YES	Office	
	4. Plant Code (Based on USDA "PLANTS" web Database)	Optional	Optional	NO		ITIS is cross-walked with PLANTS database.
	5. Species Status a. State listed noxious weed b. Species of concern to park	Optional	Optional	NO		
	6. Species On Priority List For Park (Yes/No)	Optional	Optional	NO		

LOCATION DATA (For Survey Unit and Each Weed Population	1. Country (USA/Canada/Mexico)	*Required*	Required	YES	Office	
	2. State (2-Letter Code)	Required	Required	YES	Office	
	3. County	Required	Required	YES	Office	
	4. Site Location (Lat/Long/ UTM/legal)	Required (UTM preferred)	Required	YES	Field	
	5. USGS 7.5 Quad Name	Optional	Optional	NO		This is readily available in GIS
	6. USGS 7.5 Quad Number	Optional	Optional	NO		This is readily available in GIS
	7. Hydrologic Unit Code (HUC#) for watershed	Required for aquatic invasives only	Required for aquatic invasives only	NO		This is readily available in GIS
	8. NPS LOCATION DATA a. Park Unit (4-letter code) b. Park Subunit c. Network Name d. Region e. Weed Management Area f. Other	a. Required b. Optional c. Required d. Required e. Optional f. Optional	N/A	a. YES b. NO c. YES d. NO e. NO f. NO	Office Office	
CHANGES IN SPECIES POPULATION OVER TIME	1. Infested Area a. Unit of Measure (Acre or Hectare)	Required a. Required	Required a. Required	YES	Field	
	2. Gross Area a. Unit of Measure (Acre or Hectare)	Optional a. Optional	Optional a. Optional	YES	Field	
	3. Canopy Cover (% Aerial) A. Type of Measurement (actual/estimated/mid-pt of cover class)	Required a. Required	Required a. not used	YES	Field	
	4. Distribution (light/moderate/heavy) (density)	Optional	N/A	YES	Field	Note: USU will experiment with defining a useful density characterization here – possibly by species
	5. Phenology (Vegetative/ flower/seed/senesced)	Optional	N/A	YES	Field	
	6. Distance to Water (horizontal & vertical	Optional	N/A	NO		
	7. Management Actions Taken (Manual/Chemical/BioControl/Domestic Livestock) a. Date of Action b. % of Population treated (1-25)(/26-50)(51-75)(76-100)	Optional a. Optional b. Optional	N/A	NO		
	8. Site Undergoing Active or Inactive Management	Optional	N/A	NO		

SITE ENVIRONMENTAL INFORMATION	ABIOTIC DATA	1. Elevation (Avg, max/min) - Unit of Measure (feet/meters)	Optional (highly recommended)	N/A	YES	Field	Also available in GIS
		2. Aspect	Optional (highly recommended)	N/A	NO		Can be derived in GIS
		3. Percent Slope - Actual or estimated	Optional (highly recommended)	N/A	NO		Can be derived in GIS
		4. Slope Position (top 1/3, mid 1/3, low, 1/3, toe)	Optional (highly recommended)	N/A	NO		Not a helpful data field – too variable, also can be derived in GIS
		5. Soil Type	Optional (highly recommended)	N/A	NO		Field crews not knowledgeable about soils. Can be derived from soil maps.
		6. Landform	Optional (highly recommended)	N/A	NO		We tried this last year, too much variation & difficult to interpret. Data quality not sufficient.
		7. Geologic Substrate	Optional (highly recommended)	N/A	NO		Can be derived in GIS from geologic maps.
		8. Climate (Develop Link to Separate Table with Avg. Temp & Precip.)	Optional (highly recommended)	N/A	NO		Tabular and spatial climate data are available for GIS analysis.
	BIOTIC DATA	1. Life Form (Grass/Forb/Shrub/Tree)	Required	N/A	YES	Office	
		2. Ecological Status	Required	N/A	YES	Field and Office	
		3. Values At Risk	Required	N/A	NO		Relationship of weed occurrences to resource values can be derived through GIS analysis as needed.
		4. Vegetation Classification	Optional (highly recommended)	N/A	NO		Vegetation classifications not available yet for NCPN parks
		5. Dominant Associated Species	Optional (highly recommended)	N/A	YES	Field	
		6. Cover Type	Optional (highly recommended)	N/A	NO		Standard cover type classifications not yet being applied in NCPN parks.
		7. Habitat Type	Optional (highly recommended)	N/A	NO		Not applicable to NCPN parks.
		8. Seral Stage	Optional (highly recommended)	N/A	NO		These relationships not described for NCPN parks.
		9. Disturbances *(See Below)	Optional (highly recommended)	N/A	(yes)	Field and office	Describe for broader survey areas, but only generally at polygon or point level

Appendix D. GPS Settings using in 2003-2004 Invasive Non-native Plant Inventory in Cedar Breaks National Monument.

System / Setup

Configurations

Data

Log between features:	Distance, 500 ft, (Set at surveyor's discretion)
Log PPRT data:	No
Log velocities:	No
Antenna height	4 ft
Allow GPS update	Yes
Warning distance:	Never
Filename prefix:	R

GPS

(Advanced mode window)

PDOP mask:	6.0 (Can be higher in areas where satellite reception is difficult, GPS will take best PDOP if set at a higher number)
SNR mask:	4.0
Elevation mask	15 deg
Minimum satellites	4
2D altitude	N/A

Real Time

Mode	Best available
Velocity filter	Off
RTCM age limit	50 s
Station ID	Any

Coordinates

System	UTM
Zone	12 North
Datum	NAD 1927 (Western U.S.)
Altitude reference	MSL
Geoid:	DMA 10x10 (Global)
Coordinate units	Meters
Altitude units	Feet

Units

Distance	Feet
Area	Acres
Velocity	Miles/Hour
Angle	Degrees
North reference	True
Declination	Auto

Formats

Language	English
Offset	Horz/Vert
Degrees	DD-MM-SS-ss
Date	YYYY/MM/DD
Time	12 Hour

Appendix D . GPS Settings using in 2003-2004 Invasive Non-native Plant Inventory in Cedar Breaks National Monument. (cont)

Time Zone	-06.00 (daylight savings, Mtn Zone)
Coordinate order	North/East
COMMS	
Data transfer	Support module (must change to "Serial clip" when using clip)
RTCM input	Off
NMEA output	Off
Port settings	
Input baud rate	N/A
Output baud rate	N/A
Data bits	N/A
Stop bits	N/A
Parity	N/A
Other	
Beep volume	On
NMEA output interval	5s
NMEA messages	
GGA	Yes
VTG	Yes

Data Dictionaries

(Select NCPN-04)

Feature Settings

(Do not adjust. Interval and minimum positions are set in office upon creation of dictionary)

About

(Nothing to set here)

Reset (Do not adjust. It will reset everything to factory defaults)

Appendix E. Photograph and list of equipment used in 2003-2004 Invasive Non-native Plant Inventory in Cedar Breaks National Monument.

Equipment

- Trimble Geo3 Explorer GPS units
- Laser Range Finder
- Binoculars
- Clinometer
- Compass
- Calculator
- 2-way Radios
- Cellular Phone
- Field notebook
- Field Sheets
- Uinta Basin Flora and other plant taxonomic keys
- Plant dissection kits
- Hand lens
- Collection bags
- Topographic maps
- Geology maps
- 35-mm camera and slide film
- Surveyor marking ribbon

Appendix F. Dominant Vegetation Types Key used in 2003-2004 Invasive Non-native Plant Inventory, Cedar Breaks National Monument.

Key Code	Common Name	Scientific Name	Class Type
10	Rocky Mountain maple	Acer glabrum	T
11	boxelder	Acer negundo	T
12	Utah juniper, white cedar, bone-seed juniper	Juniperus osteosperma	T
13	Rocky Mountain juniper, R. Mtn. red cedar	Juniperus scopulorum	T
14	piñon, piñon pine, pinyon pine	Pinus edulis	T
15	ponderosa pine, Western yellow pine	Pinus ponderosa	T
16	Douglas fir	Pseudotsuga menziesii	T
17	narrow-leaf cottonwood, alamo sauco	Populus angustifolia	T
18	Fremont cottonwood, alamo	Populus fremontii	T
19	hackberry, net-leaf hackberry	Celtis reticulata	T
20	Gambel Oak	Quercus gembelii	T
21	Singleaf ash	Fraxinus anomala	T
22	*Add up to #29*		T
30	Basin big sagebrush, chamiso hediondo	Artemisia tridentata	S
31	spreading rabbitbrush	Chrysothamnus linifolius	S
32	rubber or gray rabbitbrush, chamiso blanco	Chrysothamnus nauseosus	S
33	gray horsebrush	Tetradymia canescens	S
34	mountain alder, thin-leaf alder	Alnus incana	S
35	red birch, river birch, water birch	Betula occidentalis	S
36	mountain snowberry	Symphoricarpos oreophilus	S
37	four-wing saltbush, chamiso	Atriplex canescens	S
38	hopsage, spiny hopsage, applebush	Grayia spinosa	S
39	greasewood, black greasewood	Sarcobatus vermiculatus	S
40	red osier dogwood	Cornus stolonifera	S
41	Torrey ephedra, Mormon tea, popotillo	Ephedra torreyana	S
42	green ephedra, Mormon tea, cañutillo	Ephedra viridis	S
43	serviceberry, Saskatoon serviceberry	Amelanchier alnifolia	S
44	Utah serviceberry	Amelanchier utahensis	S
45	dwarf or little-leaf mountain mahogany	Cercocarpus intricatus	S
46	curl-leaf mountain mahogany	Cercocarpus ledifolius	S
47	true or birch-leaf mountain mahogany	Cercocarpus montanus	S
48	chokecherry, capulin	Prunus virginiana	S
49	bitterbrush, antelope bitterbrush	Purshia tridentata	S
50	wild rose, Woods rose	Rosa woodsii	S
51	Salix sp.?	Willow	S
52	tamarisk, tamarix, salt cedar	Tamarix ramosissima	S
53	Mazanita sp.	Arctostaphylos sp	S
54	Three-leaf sumac	Rhus trilobata	S
55	Seep-willows	Baccharis sp	S
56	Apache plume	Fallugia paradoxa	S
57	Cliffrose	Cowania stansburiana	S
58	Shrub oaks	Quercus sp.	S
59	*Add up to #59*		S
60	Bigelow sagebrush	Artemisia bigelovii	DS
61	black sagebrush	Artemisia nova	DS
62	rough brickellbush	Brickellia microphylla	DS
63	mountain low rabbitbrush, green rabbitbrush	Chrysothamnus viscidiflorus	DS
64	broom snakeweed, matchbrush	Gutierrezia sarothrae	DS
65	hairy goldenaster	Heterotheca villosa	DS
66	mountain peppergrass	Lepidium montanum	DS
67	shadscale	Atriplex confertifolia	DS
68	mat saltbush, mat atriplex	Atriplex corrugata	DS
69	winterfat, white sage, winter sage	Ceratoides lanata	DS
70	*Add up to #79*		DS
80	prairie sage, Louisiana sage, estafiate	Artemisia ludoviciana	H

Appendix F. Dominant Vegetation Types Key used in 2003-2004 Invasive Non-native Plant Inventory, Cedar Breaks National Monument.

Key Code	Common Name	Scientific Name	Class Type
81	arrow-leaf balsamroot	Balsamorhiza sagittata	H
82	Russian thistle, tumbleweed, tumbling thistle	Salsola iberica	H
83	bluebunch wheatgrass	Agropyron spicatum	H
84	slender wheatgrass	Agropyron trachycaulum	H
85	cheatgrass, downy chess, cheat	Bromus tectorum	H
86	Idaho fescue	Festuca idahoensis	H
87	Indian ricegrass, ricegrass	Oryzopsis hymenoides	H
88	needle-and-thread grass	Stipa comata	H
89	Wyoming big sagebrush	Artemisia tridentata var. wyomingensis	S
90	Mountain big sagebrush	Artemisia tridentata var. vaseyana	S
91	Common reed	Phragmites australis	H
92	Horsetail	Equisetum laevigatum	H
93	Cattail	Typha latifolia	H
99	Other		
99	Needlegrass (accidentally used in COLM for short time)	Stipa comata	H

Appendix G. Project Photographs of Weed Species Detected, Inventoried Landscapes, and Crew working in Cedar Breaks National Monument during the 2004 Invasive Non-native Plant Inventory.

Weeds Detected

Figure 1. *Bromus inermis* flower heads. CEBR PR-12.

Figure 2. *Bromus inermis* patches found along road shoulder. CEBR PR-5.

Figure 3. *Bromus inermis* on road shoulder. CEBR PR-14.

Figure 4. Ruth Richards mapping *Bromus inermis* patches in field.

Weeds Detected

Figure 5. Melanie Ballard mapping *Bromus inermis* patch in field.

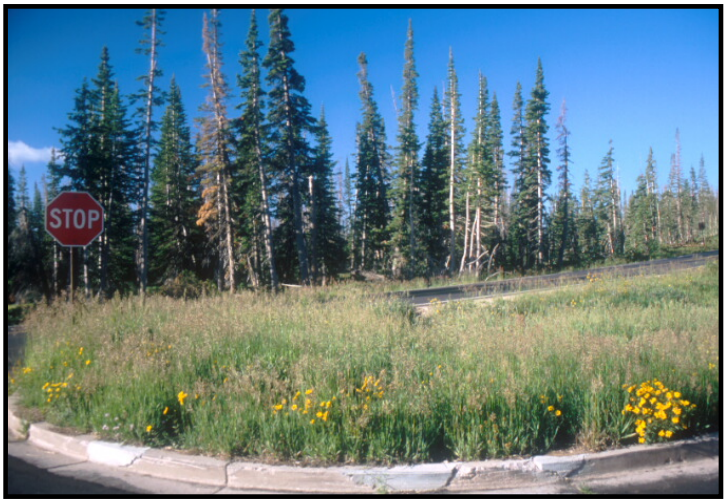


Figure 6. *Bromus inermis* in parking lot of the Visitor Center. CEBR PR-25.

Figure 7. *Bromus inermis* found in the Visitor Center parking lot. CEBR PR-25.

Figure 8. *Bromus inermis* in Visitor Center parking lot. Near CEBR PR-25.

Weeds Detected

Figure 9. *Bromus inermis* infesting drainage near southern park boundary. CEBR PR-24.

Figure 10. *Bromus inermis* spreading along drainage near southern park boundary. Near CEBR PR-24.

Figure 11. *Bromus inermis* along road shoulder. CEBR PR-1.

Figure 12. *Bromus inermis* plants on road shoulder. CEBR PR-4.

Weeds Detected

Figure 13. *Dactylis glomerata* flower heads. CEBR PR-11.

Figure 14. *Dactylis glomerata* along road shoulder. CEBR PR-9.

Figure 15. *Dactylis glomerata* along road shoulder. CEBR PR-10.

Figure 16. *Dactylis glomerata* along road shoulder. CEBR PR-11.

Weeds Detected

Figure 17. *Dactylis glomerata* in maintenance yard. CEBR PR-22.

Figure 18. *Phleum pratense*.*

Figure 19. *Chenopodium album* found along road shoulder. CEBR PR-13.

Figure 20. *Chenopodium album* found on road shoulder. CEBR PR-13.

* Photo not taken within the Monument but included for reference.

Cedar Breaks Landscapes

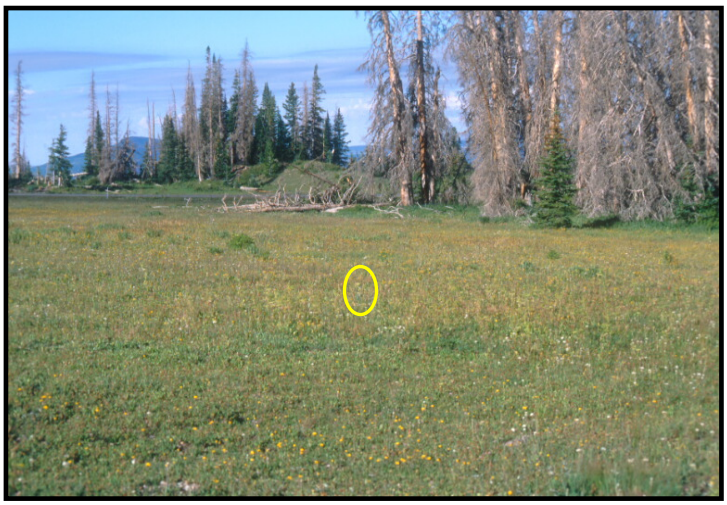


Figure 21. Plastic *Euphorbia esula* at 25 yards in the inventoried area in inventoried meadow. CEBR PR16.

Figure 22. Inventoried area along canyon rim.

Figure 23. Inventoried meadows. *Centaurea solstitialis* quality assurance site. CEBR PR-18.

Figure 24. Inventoried area underneath pines. CEBR PR-19.

Cedar Breaks Landscapes

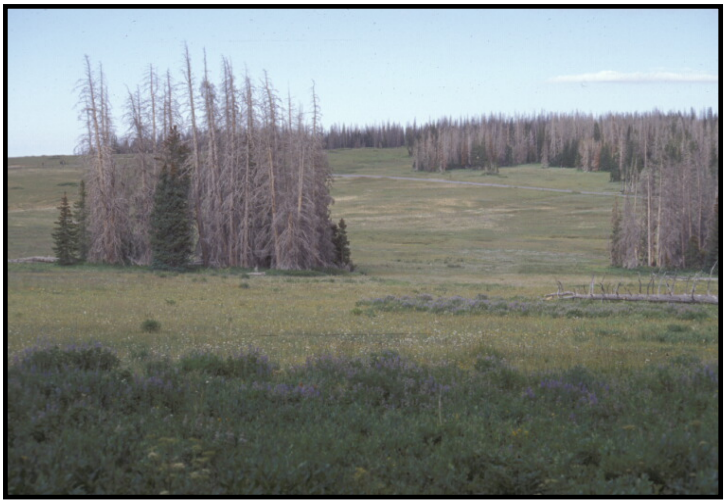


Figure 25. Inventoried meadows in northern region of the Monument. CEBR PR-13.

Figure 26. Bridget Atkin inventorying meadows.

Figure 27. Crew inspecting a *Bromus inermis* patch found in the inventoried meadows in the northern section of the Monument.

Figure 28. Meadows inventoried at northern end of the park.

Cedar Breaks Landscapes

Figure 29. Inventoried forest area between the canyon rim and the road.

Figure 30. Inventoried meadows near Alpine Pond. CEBR PR-15.

Figure 31. Inventoried meadow near Alpine Pond. Near CEBR PR-15.

Figure 32. Inventoried meadows southwest of the campground. CEBR PR-23.

Cedar Breaks Landscapes

Figure 33. Inventoried meadows along southern Monument boundary.

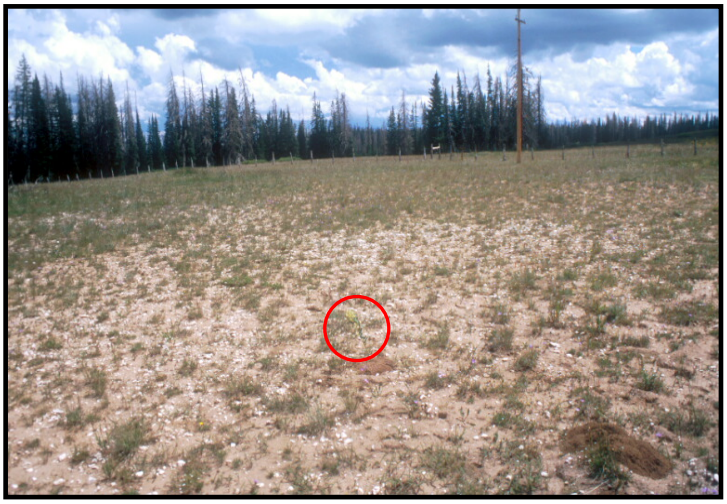


Figure 34. Plastic *Euphorbia esula* quality assurance site. *Euphorbia esula* is barely visible in the foreground.

Figure 35. Plastic *Centaurea maculosa* quality assurance site. *Centaurea maculosa* is visible in the foreground.

Figure 36. Melanie Ballard walking a transect east of the water tanks.

Cedar Breaks Landscapes

Figure 37. Inventoried meadows east of the water tanks.

Figure 38. Melanie Ballard inventorying meadows south of the Visitor Center and east of the water tanks.

Figure 39. Inventoried meadows at southern boundary of the Monument.

Figure 40. Melanie Ballard walking a transect near the southern boundary of the Monument.

Crew

Figure 41. Ruth Richards, Bridget Atkin, Melanie Ballard, Hillary Hudson, Kim Andersen, Steve Dewey (left to right) at overlook next to the Visitor Center.

Figure 42. Bridget Atkin measuring bearing along her transect.

Figure 43. Bridget Atkin mapping *Bromus inermis* in meadow.

Figure 44. Kim Andersen and Ruth Richards checking GPS configurations.

Crew

Figure 45. Kim Andersen inventorying along her transect near the northern Monument boundary.

Figure 46. Crew reviewing taxonomy of brome spp. during weed in-service training.

Figure 47. Dr. Steven Dewey conducting weed identification training at Brian Head ski resort. Here he is showing medusahead, kept inside a plastic bag to prevent accidental introductions to the area.

Figure 48. Crew reviewing grass species during a weed identification training session in the parking lot at Brian Head ski resort.

Crew

Figure 49. Crew in-service weed training at Brian Head ski resort.

Figure 50. Ruth Richards surveying along her transect in the southern region of the Monument.

Other Pictures

Figure 51. Plastic *Centaurea solstitialis* used for quality assurance to estimate the number of single plants found by crew. CEBR PR-18.

Figure 52. Plastic *Centaurea maculosa* used for quality assurance to estimate the number of single plants found by crew. CEBR PR-19.

Figure 53. Native grass resembling *Phleum pratense*, found in the Monument. CEBR PR-21.

Figure 54. Native brome found along road shoulder. CEBR PR-7.

Appendix H. Summary of occurrence and inventory status of the 47 non-native species listed in the GPS data dictionary, plus any additional species noted in the 2004 inventory of invasive plants in Cedar Breaks National Monument.

GPS Species	A	B	C	D	E	GPS Species	A	B	C	D	E
Agropyron cristatum					X	*Lepidium latifolium*				X	
Ailanthus altissima				X		*Linaria dalmatica*				X	
Alhagi pseudalhagi				X		*Linaria vulgaris*				X	
Anthemis L.					X	*Lythrum salicaria*				X	
Arctium minus				X		*Marrubium vulgare*				X	
Arundo donax				X		*Moluccella laevis*					X
Asparagus sp.					X	*Onopordum acanthium*				X	
Brassica tournefortii					X	*Phleum pratense*	X				
Bromus inermis	X					*Rubus discolor*				X	
Bromus tectorum	X					*Rumex crispus*					X
Cardaria draba				X		*Salsola kali*					X
Carduus nutans				X		*Sorghum halepense*				X	
Centaurea diffusa				X		*Tamarix ramosissima*				X	
Centaurea maculosa				X		*Tragopogon dubius*		X			
Centaurea repens				X		*Tribulus terrestris*				X	
Centaurea solstitialis				X		*Verbascum thapsus*				X	
Centaurea virgata				X		*Ulmus pumila*				X	
Chenopodium album	X										
Cirsium arvense				X		**Other:**					
Cirsium vulgare				X		*Poa pratensis*			X		
Conium maculatum				X		*Taraxacum officinale*			X		
Convolvulus arvensis					X						
Cynoglossum officinale					X						
Dactylis glomerata	X										
Elaeagnus angustifolia				X							
Euphorbia esula				X							
Halogeton glomeratus					X						
Hyoscyamus niger				X							
Isatis tinctoria				X							
Iva xanthifolia					X						

A = Present - Full inventory
B = Present – Partial inventory
C = Present – Not Mapped
D = Searched For - Absent
E = No Information

Appendix I. Weed Seed/Propagule Decontamination Procedures, 2004 EPMT Field Training Exercise, Arches National Park

EPMT COURTHOUSE WASH PROJECT

Arches National Park
March 9 – 14, 2004

EPMT Deployment to Arches NP:
The risk of this type of mobilization is that we will bring all types of nasty weeds from all over the country to Courthouse Wash. A recent exotic plant inventory has been conducted within the project area and the only high priority weeds detected were tamarisk and Russian olive. So we will know who to blame if nasty stuff like leafy spurge, miconia, malelueca, kudzu, and spotted knapweed show up (each team has its own signature).

Weed Seed/Propagule Decontamination Procedures:

If you are flying or driving:
Make sure that everything you bring has been cleaned/washed/decontaminated.
Especially be vigilant with gear and clothing you wear in the field at your home units:

- Backpacks
- Boots and shoes
- Socks
- Pants
- PPE

If you are driving be sure to clean/wash/decontaminate:

- Make sure your entire vehicle is power washed before you leave your home unit or go to a local car wash.
- Be extra vigilant while cleaning the undercarriage of the vehicle
- All your equipment
- Chainsaws
- Backpack sprayers
- Saw chaps
- Hard hats
- Gloves
- PPE

Demobilization Decontamination Process:
Same thing in reverse, because I know you don't want tamarisk, Russian olive or cheatgrass in your area!

- Visit a car wash in town
- Lake Mead EPMT will be bringing our steam cleaner power washer to share
- Clean boots in the hotel bath
- Wash clothes in the hotel laundry facilities