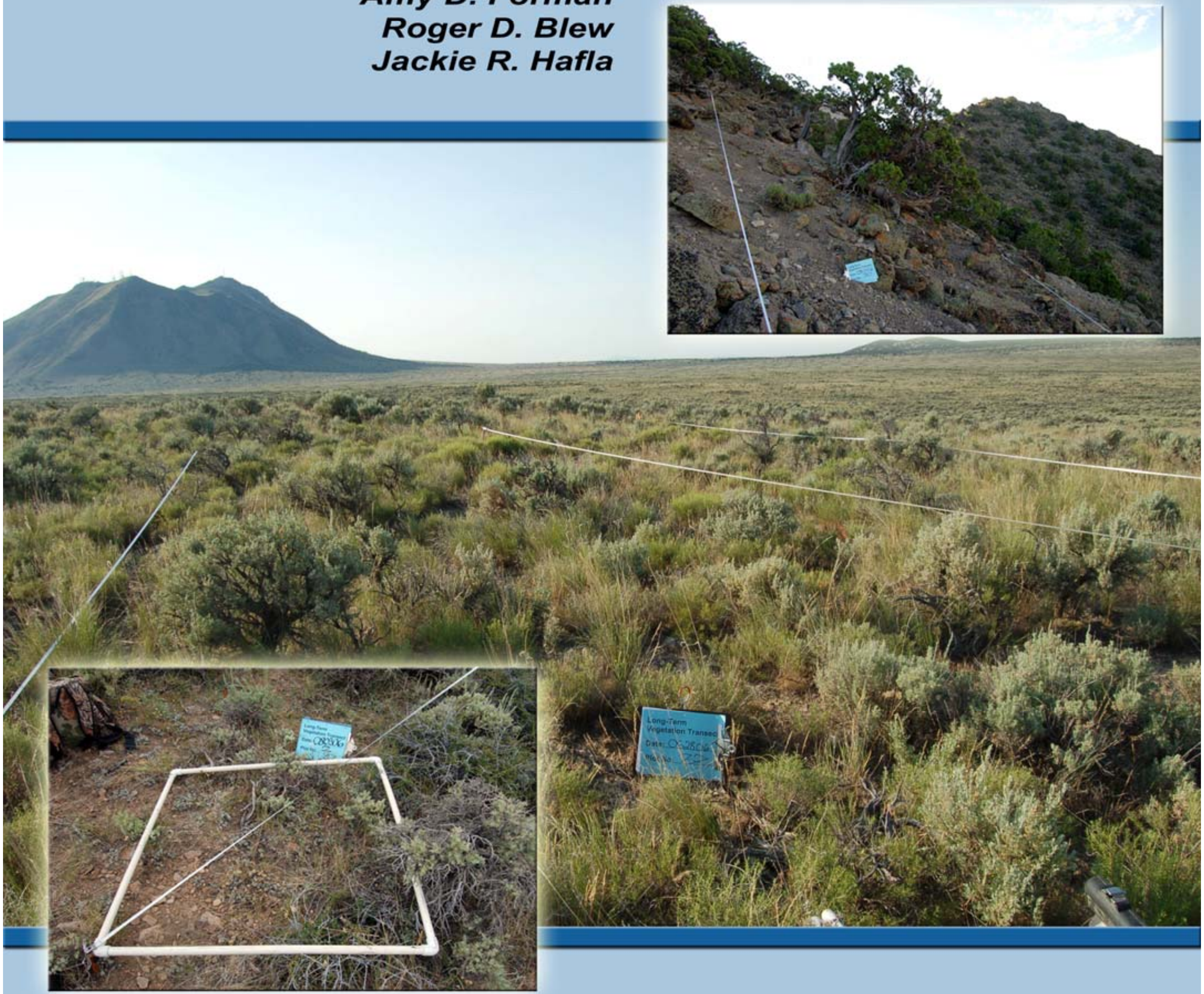
STOLLER-ESER-126

The Idaho National Laboratory Site Long-term Vegetation Transects: A Comprehensive Review

Amy D. Forman
Roger D. Blew
Jackie R. Hafla



S.M. Stoller Corporation
120 Technology Drive
Idaho Falls, ID 83401

The Idaho National Laboratory Site Long-term Vegetation Transects: A Comprehensive Review

Amy D. Forman
Roger D. Blew
Jackie R. Hafla

April 2010

S.M. Stoller Corporation
120 Technology Drive
Idaho Falls, ID 83401

Prepared for:

U.S. Department of Energy-Idaho Operations Office
Environmental Surveillance, Education and Research Program
Contract No. DE-AC07-06ID14680

ACKNOWLEDGEMENTS

Long-term vegetation data sets as complete and comprehensive as the INL Site LTV Project are rare, and certainly don't occur by accident. Numerous individuals over the past six decades have dedicated substantial time and energy to ensuring that LTV plot sampling was carried out in a consistent manner, maintaining data archives for future use, and contributing to the larger dialog on sagebrush steppe ecology through peer-reviewed publications and technical reports. Early researchers, such as the group led by D.L. Goodwin, conceptualized and implemented a sampling program robust enough to be considered applicable and pertinent today. During the first 25 years of data collection, when the LTV Project had not yet gained the momentum associated with a significant long-term resource, researchers like Roy Harniss, Neil West, Richard Jeppson, and Karl Holte recognized the potential importance of the project and provided continuity through a critical time period. Research teams led by Jay Anderson and Richard Inouye continued and improved data collection efforts, began synthesizing data archives in a fully electronic format, and ultimately contributed manuscripts pivotal to a contemporary understanding of sagebrush steppe dynamics. Steve Bunting and Beth Colket continued to improve the electronic data archives while interpreting the LTV data within the context of wildland fire through the 2001 sample period. We are grateful for the meticulous work of the field crew leaders and data managers associated with each of the research teams and sample periods, and would especially like to thank Blake Jones and Josh Ellis for their capable leadership of the 2006 field effort. Wendy Purrington provided thoughtful insights and guided us through much of the design process for the current iteration of the LTV Database. Maps and other GIS-based products were provided by Jeremy Shive. We would like to thank Brande Hendricks and Alana Jensen for organizing and formatting the report and designing the cover. Dozens of graduate students, interns, technicians, and data management support staff have contributed to the LTV Project since 1950, and although we can't possibly list every name, we recognize that the input from every individual has contributed to the ongoing success of the project. We would also like to recognize that the local scientific community; academics, agency personnel, INL Site scientists, and DOE technical leads, have continued to support and encourage ongoing data collection efforts. The most recent sampling and reporting effort was funded by the U.S. Department of Energy-Idaho Operations Office under the Environmental Surveillance, Education and Research Program, Contract No. DE-AC07-06ID-14680.

Table of Contents

List of Figures

List of Tables

1.0 INTRODUCTION

The Long-Term Vegetation (LTV) Transects and associated permanent vegetation plots (Figure 1-1) were established on what is now the Idaho National Laboratory (INL) Site, in 1950 for the purpose of assessing the impacts of nuclear energy research and production on surrounding ecosystems (Singlevich et al. 1951). Vegetation abundance data were first collected in 1950 for inclusion in an ecological characterization of the Site. Samples of plant and animal tissues were also collected from these plots and analyzed for radionuclide concentrations on an annual basis for several years. The effort to collect tissue samples was eventually discontinued because the effects of fallout from nuclear reactors were determined to be negligible (Harniss 1968), at least in terms of radionuclide concentrations in the environment. However, collection of vegetation abundance data has continued on a regular basis for nearly sixty years.

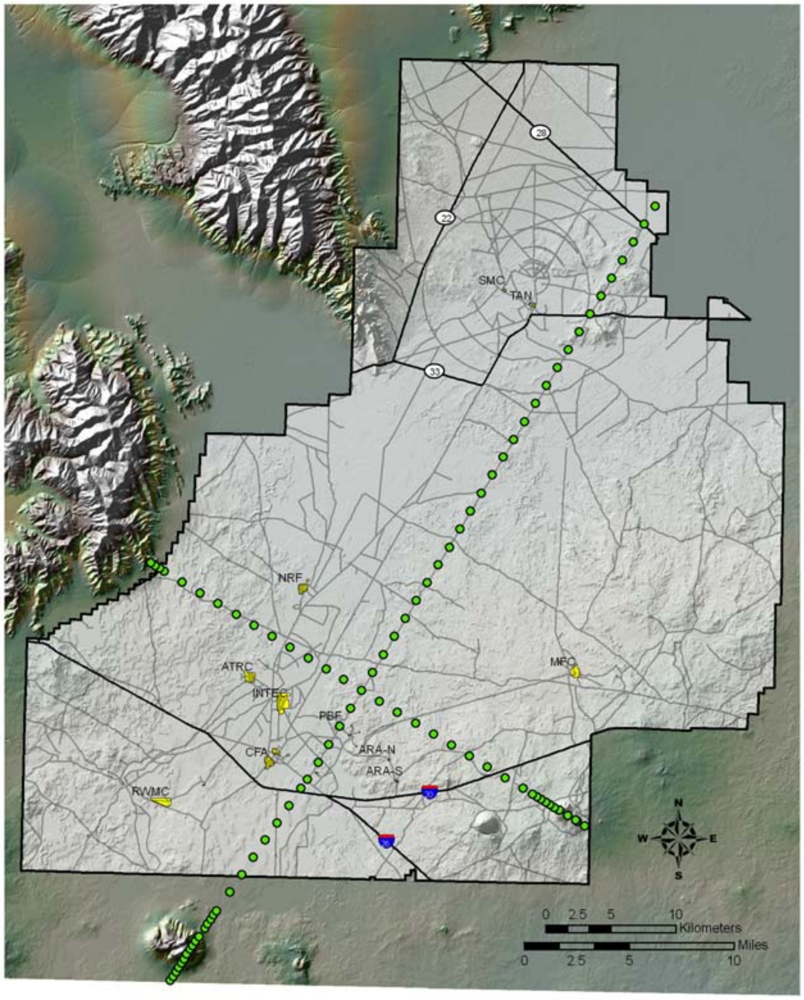


Figure 1-1. Long-Term Vegetation Plots on the Idaho National Laboratory Site.

The data generated from the LTV Transects comprises one of the oldest, largest, and most comprehensive vegetation data sets for sagebrush steppe ecosystems in North America. Since their establishment, the LTV Transects have been used extensively for various tasks to support the INL Site mission and have been the basis for major milestones in understanding practical and theoretical ecology of sagebrush steppe vegetation dynamics. Applications of the LTV data include:

- Plant community classification and mapping,
- Assessing the effects of drought and livestock grazing,
- Understanding fire history and recovery,
- Characterizing species invasion patterns,
- Testing theories of vegetation succession and change,
- As a basis for habitat suitability modeling for sensitive species,
- Supporting NEPA processes,
- Making appropriate land management recommendations, and
- Developing specific revegetation recommendations.

In addition to the functions listed above, the LTV data set is still used to assess the impacts of energy development on the environment, as was intended in 1950. However, impacts beyond radioactive fallout, such as exotic species invasion, habitat fragmentation, and global climate change are of current interest.

The eleventh LTV data set was collected during the summer of 2006. Three primary tasks were undertaken in association with the 2006 data collection. The first task involved a major effort in updating and describing the data archives. The second includes a thorough documentation of data collection methods and recommendations for standardizing the process for future data collection efforts on the LTV plots. The third task incorporates summarization and analysis of the 2006 and all previously collected abundance data.

This report is divided into chapters that address the significant tasks completed as components of the 2006 sampling effort. Chapter 2 is a history of the Long-Term Vegetation Transects and documents the origin of the study as part of the beginnings of the radiological surveillance program at what is now the INL Site. This chapter also traces the chronology of the ten preceding LTV data collections and the scientists responsible for those efforts. Also documented in this chapter are the major research findings derived from the growing database.

Chapter 3 provides documentation of the procedures used to collect the various data types at the LTV plots. The primary goal of this chapter is to provide a guide to future researchers who may be collecting data from the LTV plots or who are using the extensive database for exploring changes in the vegetation communities of the INL Site.

Chapter 4 describes and provides supporting documentation for utilizing the LTV database. Updating the data management system for the LTV to take advantage of modern developments in data management architecture and functionality was a significant accomplishment of the 2006 effort. This database has already proved invaluable to outside researchers studying sagebrush steppe vegetation communities. It is likely that having the database available in a modern and standardized format will make the LTV even more valuable to the larger scientific community.

Chapter 5 summarizes results from the eleventh LTV data collection and analyzes trends in community composition since the study was initiated in 1950. This includes characterizing general plant abundance and community composition trends, similar to analyses described in previous LTV reports as well as characterizing spatial patterns of exotic species invasion and the relationships between distribution and abundance patterns of non-native species occurrence over more than 50 years

Literature Cited

Harniss, R. O. 1968. Vegetation changes following livestock exclusion on the National Reactor Testing Station, Southeastern Idaho. Utah State University, Logan, UT.

Singlevich, W., J. W. Healy, H. J. Paas, and Z. E. Carey. 1951. Natural radioactive materials at the Arco Reactor Test Site. Radiological Sciences Department, Atomic Energy Commission, Richland, WA.

2.0 HISTORY OF VEGETATION STUDIES ON THE IDAHO NATIONAL LABORATORY

2.1 The Long-Term Vegetation Transects

The Long-Term Vegetation (LTV) Transects were established in 1950 for the purpose of assessing the impacts of nuclear energy research and production on surrounding ecosystems. The Atomic Energy Commission (AEC) and their contractor, General Electric Company, tasked a group at Idaho State College (now Idaho State University) led by D. L. Goodwin with conducting an ecological survey of the region. The ecological survey was part of a larger effort to characterize weather patterns, background radionuclide concentrations, and general biotic and abiotic attributes of what was known as the Arco Reactor Test Site (now the Idaho National Laboratory Site). The initial ecological survey included sampling to estimate the abundance of various vascular plant, bird, and small to mid-sized mammal species. Soils, along with several plant and animal species, were also sampled and processed for the purpose of establishing background radionuclide concentrations (Singlevich et al. 1951).

The baseline ecological surveys were conducted by sampling plots established along two macro-transects. The macro-transects, one 39 km in length and the other 71 km in length, were placed perpendicular to one another and intersected near the center of the Arco Reactor Test Site. One transect was oriented southeast to northwest and the other was oriented southwest to northeast. Both transects crossed the entire length and extended somewhat beyond the boundaries of the Arco Reactor Test Site. Several soil types, plant communities, and geological features were represented along each transect. Over one hundred permanent plots were established along the macro-transects during the sampling effort in 1950. Plots were placed at approximately one mile intervals across most of the length of each transect. When transects crossed geological features with abrupt elevation changes, such as East and Big Southern Butte and the foothills of the Little Lost River Range, plots were placed at approximately ¼ mile intervals. Early records indicate that between 107 and 110 plots were marked during the initial sample period (Singlevich et al. 1951). However, vegetation abundance data can only be verified for 83 of those plots. Whether only 83 of the original plots were sampled for vegetation abundance in 1950 or some of the original data were lost is unknown.

In addition to the plots established for the ecological survey of Arco Reactor Test Site, 20 plots were located near Wedgetop Butte, about 20 miles north of Shoshone, to provide background data once nuclear reactors became operational at the Site. No published documents beyond mention in a 1951 report (Singlevich et al.) can be found for these plots. It remains unclear whether these plots were sampled in identical manner to those located along the macro-transects of the Arco Reactor Test Site, although notes from Idaho State College sample notebooks indicate that tissue samples were collected and photographs were taken of the Wedgetop Butte plots at least once in the early 1950s. It is likely that the plots were sampled for plant and animal tissues annually for several years during the early 1950s while establishing a baseline for background radionuclide concentrations. Neither the photographs, nor the paper datasheets from this project were archived with the historical LTV data.

Samples of plant and animal tissues continued to be collected from the macro-transect plots at the Arco Reactor Test Site and analyzed for radionuclide concentrations on an annual basis for several years. This activity was eventually discontinued because the effects of fallout from nuclear reactors and activities associated with nuclear energy production were determined to be negligible (Harniss 1968), at least in terms of radionuclide concentrations in the environment. Nevertheless, collection of vegetation abundance data has continued for nearly sixty years using the plots established along the original ecological survey macro-transects. Thus, the macro-transects are now commonly referred to as the Long-Term Vegetation Transects.

The data generated from the LTV Transects comprises one of the oldest, largest, and most comprehensive vegetation data sets for sagebrush steppe ecosystems in North America. Since their establishment in 1950, the LTV Transects have been used extensively for various tasks to support the INL Site mission and have been the basis for major milestones in understanding practical and theoretical ecology of sagebrush steppe vegetation dynamics. Applications of the LTV data are too numerous to list in their entirety, but include: plant community classification and mapping (McBride et al. 1978), assessing the effects of drought and livestock grazing (Harniss 1968, Anderson and Holte 1981, Anderson 1986, Anderson and Inouye 1988, Anderson 1999, Anderson and Inouye 1999, Anderson and Inouye 2001, Colket 2003, Colket and Bunting 2003), understanding fire history and recovery (Colket and Bunting 2003), characterizing species invasion patterns (Anderson and Inouye 1999), testing theories of vegetation succession and change (Anderson and Holte 1981, Anderson 1986, Anderson and Inouye 1988), as a basis for habitat suitability modeling for sensitive species (Gabler 1997), supporting NEPA processes (Anderson 1991), making appropriate land management recommendations (Vilord et al. 2005, Blew et al. 2006), and developing specific revegetation guidelines (Blew et al. 2002a). In fact, the LTV data set is still used to assess the impacts of energy development on the environment, as was intended in 1950. However, impacts beyond radioactive fallout, such as exotic species invasion, habitat fragmentation, and global climate change are of current interest.

The first use of the LTV Transects, beyond assessing the concentrations of radionuclides in the environment, was in 1957. At that time the AEC tasked a group led by D.L. Goodwin with resampling the plots established in 1950 for vegetation abundance data. The purpose of the second data collection was to assess changes in vegetation abundance and composition over the seven year period. By 1957, efforts on an initial vegetation map of the Site had begun, and AEC personnel discovered that several vegetation types occurring on the Site (known during this period as the National Reactor Testing Station) were not represented in the plots sampled by the LTV Transects. Therefore, additional plots, representative of additional vegetation types, were established during the 1957 sampling period (McBride et al. 1978). A total of 38 plots were added to the LTV data set in 1957. These plots are now referred to as the century series. Although data have been archived from the macro-transect plots and the century series plots in 1957, there are no records of data analyses or technical reports to address questions of plant community change between the 1950 and 1957 sample periods.

The first published document to address temporal changes in INL Site plant communities using the LTV data was a thesis completed by R.O. Harniss (1968) from Utah State University subsequent to a third sampling effort in 1965. During this sampling effort, most of the plots along the original macro-transect lines were resampled, as were many of the plots in the century series. The last confirmed sample date for the plots in the century series is 1965.

The primary objective of Harniss' thesis was to quantify the effects of livestock exclusion on vegetation at the Site. Many of the plots along the LTV macro-transects occur within either 111,000 acres that were withdrawn from grazing in 1950 or an additional 58,000 acres that have been withdrawn from grazing since 1957. Prior to the closure of grazing, the land acquired for the establishment of the National Reactor Testing Station was thought to have been subject to heavy use by sheep and cattle. Much of the Snake River Plain, including the Site, was used to trail cattle between Oregon and eastern markets and was used to hold sheep until summer ranges became available. The competition for use of the rangeland in the Snake River Plain resulted in overgrazing. Hence, Harniss tested for vegetative differences among sample periods in plots open to grazing, in plots ungrazed since 1950, and in plots ungrazed since 1957. He concluded that recovery from overgrazing was a very slow process and that many changes in vegetation during the sample periods were due to variation in precipitation at least as much as they were due to recovery from overgrazing. Subsequent peer-reviewed contributions from Harniss and West (1973) were based on the LTV data collected through 1965 and further describe trends in vegetation change throughout the study period.

The next data collection effort on the LTV macro-transects was initiated in 1975. Surveys and reports were completed by a team of researchers at Idaho State University (ISU) lead by K.E. Holte (Jeppson and Holte 1976) and J.E. Anderson (Anderson and Holte 1981). Data were collected on as many of the original macro-transect plots as could be located. Many of the plot markers were upgraded during this time to make them more permanent and easily located. Because weather conditions during the 1975 sampling effort were abnormally cool and wet, a subset of plots were resampled in 1978. This subset of plots is often referred to as the "core" plots. The number and identity of the plots included in analyses utilizing core plots have changed throughout the history of the LTV project, but included 38 plots from the central portion of the INL Site in 1978. Only 36 plots were reported to have been used in the analyses from 1978, but 38 plots are contained in the data set. The reasons for excluding two plots from analysis are unknown. Data from both the 1975 and 1978 sample efforts were included in the final analyses for this study period to ensure that short-term weather patterns didn't overly influence conclusions about long-term vegetation change at the INL Site.

The data collected in 1975 and 1978 were used in combination with data from the first three annual LTV data sets to test hypotheses about vegetation succession in the sagebrush steppe ecosystem. Anderson and Holte (1981) found that several important changes in vegetation cover and composition had taken place over the 25-year study period. Cover of perennial grasses and shrubs increased significantly from 1950 through the mid-1970s. Additionally, variability in the cover of some species, like green rabbitbrush (*Chrysothamnus viscidiflorus*), increased throughout the study period. Because changes in vegetation cover and species composition were neither directional, nor predictable, the authors suggested that changes in sagebrush steppe ecosystems through time cannot be described by classical successional theory, nor can plant associations resulting from these changes be understood within the traditional definition of a climax community.

A group from ISU led by J.E. Anderson collected data on the LTV plots again in 1983. However, during this sampling effort only line intercept data were collected on a subset of core plots. One publication resulted from analyses subsequent to this sampling effort. In that paper, Anderson (1986) documented decreases in sagebrush and perennial grass cover when compared to the 1975 and 1978 sample periods. Although cover of dominant species varied greatly from one sampling period to the next throughout the history of the LTV, the identity of the dominant species in a given plot remained remarkably stable through time. These results failed to indicate directional changes in cover or serial replacement of species over the study period. Thus, Anderson again concluded that data from the LTV plots did not support traditional models of succession and climax community, and instead presented the concept of inertia as a framework for understanding changes in species abundance and composition of sagebrush steppe ecosystems over several decades. He further postulated that the inertia of the ecosystem was largely influenced by the individuals, and propagules, already present at a given location.

In 1985 a complete set of data were collected on all of the plots that could be located. An additional method for estimating cover was implemented on most of the LTV plots during that field season and has been used for every data collection effort since. J.E Anderson and R. Inouye analyzed data and reported results for the1985 and previous data sets (Anderson and Inouye 1988). The authors reported continued decreases in sagebrush cover and increases in species richness of all functional groups at the scale of individual plots. They also documented an increase in the distribution of cheatgrass (*Bromus tectorum*) since the inception of the LTV study.

A detailed analysis of actual and estimated precipitation patterns from the early 1900s through the 1985 sample period indicated that drought conditions persisted through much of the 1930s and 1940s. Therefore, the poor condition of INL Site plant communities recorded during the first LTV sampling period were likely due to a combination of grazing and drought, not just grazing as has been previously reported. Anderson and Inouye also emphasize that when considering the entire 35-year data set, shrub and perennial grass cover have fluctuated dramatically (100-500%) over the span of a decade in the absence of any major disturbance, indicating that weather patterns exert a large influence on species abundance and plant community composition. They concluded that variability in climate seasonally, annually, and over longer time periods, as well as variability biotic and abioic resources probably prevent plant communities on the INL Site from converging on a relatively uniform climax community.

The LTV data collected during the 1990 field season were collected in conjunction with site-specific vegetation data to support an Environmental Impact Statement for a New Production Reactor. The rationale for combining the two data collection efforts was to facilitate an understanding of the plant communities around the proposed reactor in terms of plant communities across the INL Site. A vegetation map was also developed as part of the overall effort to characterize the distribution of plant communities. Consequently, analyses of the LTV data in 1990 focused on the spatial dynamics of vegetation at the Site, but also included some general trend analyses as well. LTV data were collected on only the core subset of plots in 1990.

J.E. Anderson analyzed the data for short-term trends and used ordination and clustering techniques to classify plant communities into vegetation types (Anderson 1991). He reported significant increases in total plant cover, shrub cover, perennial forb cover, cheatgrass cover, and the cover of some species of perennial grasses between 1985 and 1990. A handful of vegetation types were described for the INL Site based on results from the ordinations. However, Anderson emphasized that vegetation at the INL Site "forms a continuum" based on continuously varying environmental conditions, rather than a "mosaic of discrete 'types.'"

Three publications resulted from the 1995 data collection effort including a peer-reviewed paper in *Ecological Monographs* (Anderson 1999, Anderson and Inouye 1999, Anderson and Inouye 2001). The *Monographs* paper (Anderson and Inouye 2001) analyzed landscape-scale changes in sagebrush steppe plant communities over 45 years, and is widely considered one of the most comprehensive articles on the dynamics of sagebrush-dominated vegetation in the absence of major disturbance. Species abundance data were collected on 88 plots in 1995 and those data were analyzed in conjunction with all of the data collected during previous sampling efforts. Several hypotheses about vegetation change in response to time, grazing, precipitation, and biodiversity were tested and results were described in one or more of the three publications from this period.

The first set of hypotheses tested with the entire 45-year data set addressed general temporal trends in plant community composition and structure. The authors reported an increase in shrub and perennial grass cover from 1950 through 1975, at which point cover of those functional groups fluctuated from one sample period to the next. Precipitation was not a straightforward predictor of those cover fluctuations, but sample frequency made specific relationships difficult to quantify. The only directional trends in abundance and species composition that can be generalized from the data set include; a sharp decrease in sagebrush cover subsequent to 1975 (due to widespread mortality), an increase in green rabbitbrush cover since 1950, and increases in species richness and heterogeneity at the plot level. Negative correlations between shrub and perennial grass cover during growing seasons having above average precipitation also suggested the potential for competitive interaction, at least in wet years.

Anderson and Inouye (2001) found little support for either traditional models of rangeland succession or more contemporary state and transition successional models in the LTV data set. Traditional models included assumptions about directional and predictable changes in plant communities through time, as well as convergence on relatively homogenous climax communities. Conversely, state and transition models predict that depauperate communities resulting from overgrazing, such as those that existed on the INL Site in the 1950s, will remain in such a condition, and a major disturbance is needed to push the community across a threshold into another state. Since trends in species abundance weren't directional or predictable, nor were they static, neither model could easily be used to describe patterns of vegetation change at the INL Site.

Although the authors compared, and found no difference in trends between the plots in grazing allotments with those in areas excluded from grazing, they strongly caution against considering the LTV plots a grazed versus ungrazed study. The reasoning is twofold. The plots that have been excluded from grazing since the 1950s tend to be lower in elevation and sample different plant communities than those located in grazing allotments, thereby statistically confounding any potential analyses. Additionally, many of the plots within allotments are inaccessible to livestock and grazing history and intensity have never been measured on any of those plots, making assumptions about the level and timing of use impossible.

The second set of hypotheses Anderson and Inouye (2001) tested subsequent to the 1995 data collection effort contributed to the debate concerning the effects of biodiversity on productivity, stability, and invasibility. They reported a positive correlation between species richness and absolute vegetative cover. Furthermore, they found that plots with higher cover had less variability when compared to the mean than plots with lower cover. Finally, they established that absolute cover, but not necessarily species richness, of native, perennial species is negatively correlated with the abundance of non-native species. These results have important management implications for sagebrush steppe ecosystems, namely that higher cover of native species may promote productivity and stability while rendering a community more resistant to exotic species invasions. Thus, maintenance of a healthy community of native, perennial plants is crucially important for preserving sagebrush steppe ecosystems.

LTV data were collected again on 89 plots in 2001 by E.C Colket and S.C. Bunting at the University of Idaho (Colket 2003, Colket and Bunting 2003). They analyzed cover data from 1985 through 2001 and focused reporting efforts on general trends and vegetative changes subsequent to several large fires that burned between 1994 and 2000. A decrease in shrub cover and an increase in grass cover were documented for the study period beginning in 1985. However, it should be noted that abundance data were analyzed in terms of relative cover rather than absolute cover, precluding comparisons with analyses by previous investigators. Colket and Bunting (2003) found an increase in native forb diversity on burned areas, but concluded that precipitation likely had a greater influence on diversity than fire. They caution that introduced annuals and biennials may be replacing native species in the same functional groups and trends should be closely monitored. Overall, the authors concluded that precipitation, rather than fire was the primary factor influencing plant community composition on the INL Site.

The most recent data collection effort on the LTV plots was completed during the summer of 2006 and results will be reported herein. The 2006 effort was led by A.D. Forman, R.D. Blew, and J.R. Hafla from the Environmental, Surveillance, Education and Research (ESER) Program, as contracted to S.M. Stoller Corporation by the Department of Energy (DOE). Three tasks were undertaken in association with the 2006 data collection. The first task involves a major effort in updating and describing the data archives. The second entails describing past data collection efforts and producing a standardized process for future data collection on the LTV plots. The third task includes summarization and analysis of the 2006 and all previously collected abundance data.

The last attempt at organizing and archiving the LTV data was completed in the early 1980s (Wilkosz and Anderson 1983). Although care has been taken to format and store data collected since 1983 in a manner consistent with the protocol established at that time, the data archives have become outdated. The software available for archiving and processing data have improved substantially over the past 25 years, necessitating an update of the LTV data files. A considerable amount of the work associated with entry and summary of the 2006 data included designing and populating a relational database for all of the LTV data from 1950-2006. Additionally, a specific sampling protocol was developed and a thorough history was included for the LTV as part of the reporting effort.

Analyses on the 2006 and previous data can be summarized under two focus areas. The first included characterizing general plant abundance and community composition trends, similar to analyses described in previous LTV reports. The second group of analyses concentrated on characterizing patterns of exotic species invasion and the effects of invasion on native plant communities.

2.2 Other Vegetation Studies

Several vegetation studies unrelated to the LTV project have also been conducted on the INL Site through ESER or equivalent programs predating ESER and will be mentioned here briefly as a resource for future investigators. The earliest vegetation project undertaken outside of the LTV was a vegetation map based on aerial photo interpretation. The map was begun in the 1950s and progressed through several iterations before it was finalized and published in 1978 (McBride et al.). An attempt to characterize the effects of radiation exposure on vegetation, beyond the original scope of the LTV, was also initiated in the mid-1950s. The plots established for that study, often referred to as the Q Plots, were sampled on a handful of occasions over a twenty-year period (French and Mitchell 1983). As with the LTV study, the investigators found no quantifiable effects of radiation, but did find substantial change in plant community abundance and composition through time.

Around the time J.E. Anderson became involved with the LTV project, in the mid- to late 1970s, he also designed an exclosure study to determine the impacts of native animal and livestock grazing on INL Site plant communities. The plots remain mostly intact and hard copies of the data have been archived from this project, however, there were no reports or publications generated. Two additional vegetation studies were undertaken in the late 1970s and early 1980s. They include a rare plant survey (Cholewa and Henderson 1984) and a study to determine the impacts of prescribed fire on vegetation, as well as other taxa (Floyd and Anderson 1983). Both of these efforts are documented as reports and/or theses.

In the 1980s, disposal of radioactive and hazardous waste became an important issue on the INL Site which provided impetus for research in landfill capping. A large component of the landfill-capping research that was initiated during this time period focused on the utility of using plant species to influence water balance on alternative landfill cover designs (Anderson et al. 1993). A diverse body of vegetation research accompanied studies of landfill cover performance. Various research topics included: physiology of individual species and plant communities (Anderson et al. 1987, Anderson and Forman 2002), distribution of species based on physiological constraints (Shumar and Anderson 1986), nutrient cycles associated with various natural and artificial plant communities (Morris 2001), the effects of soil texture profiles and various precipitation regimes on plant community dynamics (Anderson and Forman 2002, Janzen et al. 2007), and the performance of several cap designs and vegetation scenarios on landfill covers in terms of water balance (Anderson and Forman 2002, Forman and Anderson 2005, Janzen et al. 2007).

One additional vegetation data collection effort was undertaken in an attempt to characterize the effects of changes in precipitation regime and nutrient inputs on native and introduced plant communities. This monitoring program included data for vegetation, soil moisture, nitrogen mineralization, and small mammal and bird abundance. The study site was located at and adjacent to an irrigation center pivot used to apply processed waste water to vegetation. The data from this project were used primarily to meet the requirements of reporting for a state of Idaho permit for land application of wastewater (Forman et al. 2003b, 2005).

Associated with the interest in using vegetation to control water balance on landfill covers and wastewater disposal areas, was an increased focus on revegetation, particularly with native species. Thus vegetation studies geared toward understanding and improving revegetation success were undertaken beginning in the mid 1980s. One such experiment involved establishing an experimental garden of native species and culminated in the first formal revegetation guidance document for the INL Site (Anderson and Shumar 1989). Shortly thereafter revegetation test plots were established on areas slated for use as borrow material for landfill covers as well as for other purposes (Majors and Blew 2000). The test plots were to be used to assess the success of revegetation using various species, techniques, soil amendments, etc. (Blew and Horman 2000). Analysis and reporting were not completed since expected funding was not forthcoming at the time. The data have been archived in the ESER electronic data files. A similar situation occurred on revegetation monitoring plots established in a 1996 burn near the Materials and Fuels Complex (Blew 1999).

During the 1990s, a complete flora of the INL Site was published (Anderson et al. 1996). The flora was produced subsequent to the 1990 LTV data collection and the associated vegetation studies conducted for the New Production Reactor Environmental Impact Statement described here previously. This flora publication is predated by a species list published in 1970 (Atwood 1970). The INL Site Flora included a complete vascular species list, description of major plant communities, discussion of geologic and recent INL Site history, and an accounting of the cultural history and significance of numerous plant species to people indigenous to the INL Site. The publication also presented a final version of the Landsat-based map created during the vegetation studies to support the EIS.

Many of the vegetation data collection efforts of the 2000s were completed in support of Environmental Assessments (EAs) and EISs. These studies included assessment of the impacts of fire suppression activities (Blew et al. 2002b), description of the affected environments of the Sagebrush Steppe Ecosystem Reserve (Forman et al. 2003a), and characterization of plant communities with the potential to be impacted by construction activities (Vilord et al. 2005, Blew et al. 2006).

Finally, two research efforts to support land management activities on the INL Site were initiated in the early 2000s. One was the Tin Cup Fire Recovery Study which was undertaken by ESER scientists in conjunction with the Bureau of Land Management (BLM) and The Nature Conservancy (TNC). The purpose of the study was to characterize the trajectory of plant community recovery subsequent to fire. A report was completed, but not yet published at the time this was written. The report included analyses and results summarizing short-term and long-term species abundance and composition data, their relationships to predictions based on current models of rangeland succession, the effects of aerially seeding big sagebrush on reestablishment, spatial recruitment patterns of big sagebrush, and a discussion of statistical approaches for such studies.

The second research effort initiated during this time period was a sagebrush demography study. The intent of the sagebrush demography study was to provide a basis for understanding and predicting sagebrush stand health and condition in conjunction with the habitat requirements of sensitive sagebrush obligate species (Forman and Blew 2004). A complete data set was collected for the study, however, samples and data have not been processed or analyzed.

Literature Cited

Anderson, J. E. 1986. Development and structure of sagebrush steppe plant communities. Pages 10-12 *in* P. J. Joss, P. W. Lynch, and O. B. Williams, editors. Rangelands: A resource under siege. Proceedings of the Second International Rangeland Congress. Australian Academy of Science, Canberra, Australia.

Anderson, J. E. 1991. Vegetation studies to support the NPR Environmental Impact Statement. Department of Biological Sciences, Idaho State University, Pocatello, ID.

Anderson, J. E. 1999. The Idaho National Engineering and Environmental Laboratory: an ecological treasure of the Upper Snake River Plain. Rangelands **21**:11-17.

Anderson, J. E., and A. D. Forman. 2002. The protective cap/biobarrier experiment: A study of alternative evapotranspiration caps for the Idaho National Engineering and Environmental Laboratory. STOLLER-ESER- 46, Environmental Surveillance, Education, and Research Program and Idaho State University, Idaho Falls, ID.

Anderson, J. E., and K. E. Holte. 1981. Vegetation development over 25 years without grazing on sagebrush-dominated rangelands in Southeastern Idaho. Journal of Range Management **31**:25-29.

Anderson, J. E., and R. Inouye. 1988. Long-term dynamics of vegetation in a sagebrush steppe of Southeastern Idaho. Department of Biological Sciences, Idaho State University, Pocatello, ID.

Anderson, J. E., and R. Inouye. 1999. Long-term vegetation dynamics in sagebrush steppe at the Idaho National Engineering and Environmental Laboratory. Center for Ecological Research and Education, Department of Biological Sciences, Idaho State University and Environmental Science and Research Foundation, Idaho Falls, ID.

Anderson, J. E., and R. S. Inouye. 2001. Landscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. Ecological Monographs **71**:531-556.

Anderson, J. E., R. S. Nowak, T. D. Ratzlaff, and O. D. Markham. 1993. Managing soil moisture on waste burial sites in arid regions. Journal of Environmental Quality **22**:62-69.

Anderson, J. E., K. T. Ruppel, J. E. Glennon, K. E. Holte, and R. C. Rope. 1996. Plant communities, ethnoecology, and flora of the Idaho National Engineering Laboratory. ESRF 005, Environmental Science and Research Foundation, Idaho Falls, ID.

Anderson, J. E., and M. L. Shumar. 1989. Guidelines for revegetation of disturbed sites at the Idaho National Engineering Laboratory. DOE/ID-12114, Radiological and Environmental Sciences Laboratory, U.S. Department of Energy, Idaho Falls, ID.

Anderson, J. E., M. L. Shumar, N. L. Toft, and R. S. Nowak. 1987. Control of the soil water balance by sagebrush and three perennial grasses in a cold-desert environment. Arid Soil Research and Rehabilitation **1**:229-244.

Atwood, N. D. 1970. Flora of the National Reactor Testing Station. *in* S. L. Welsh, editor. Brigham Young University Science Bulletin. Brigham Young University, Provo, UT.

Blew, R. D. 1999. Planting and irrigating effects on vegetation recovery from fire. Pages 70-71 *in* D. L. Weigmann and R. D. Blew, editors. Environmental Science and Research Foundation, Inc. Annual Technical Report to DOE-ID, ESRF-033. Environmental Science and Research Foundation, Idaho Falls, ID.

Blew, R. D., D. K. Halford, S. J. Vilord, A. D. Forman, and J. R. Hafla. 2006. Survey and review of potential impacts to ecological resources on the Idaho National Laboratory due to construction and operation of the National and Homeland Security Research and Development Range. STOLLER-ESER-95, Environmental Surveillance, Education and Research Program, Idaho Falls, ID.

Blew, R. D., and C. Horman. 2000. Research supporting development of guidelines for improved success of revegetation activities at the INEEL. *in* A. A. Luft and R. W. Warren, editors. Environmental Science and Research Foundation, Inc. Annual Technical Report to DOE-ID: Calendar Year 1999, ESRF-037. Environmental Science and Research Foundation, Idaho Falls, ID.

Blew, R. D., M. R. Jackson, and A. D. Forman. 2002a. Soil stabilization and revegetation at the INEEL: recommendations for improvement. STOLLER-ESER-89, Environmental Surveillance, Education and Research Program, Idaho Falls, ID.

Blew, R. D., S. Majors, and A. D. Forman. 2002b. A survey of vegetation recovery on wildfire containment lines and an ecological evaluation of pre-suppression firebreak construction on the INEEL. STOLLER-ESER-83, Environmental Surveillance, Education and Research Program, Idaho Falls, ID.

Cholewa, A. F., and D. M. Henderson. 1984. A survey and assessment of the rare vascular plants of the Idaho National Engineering Laboratory Site. Great Basin Naturalist **44**:140-144.

Colket, E. C. 2003. Long-term vegetation dynamics and post-fire establishment patterns of sagebrush steppe. University of Idaho, Moscow, ID.

Colket, E. C., and S. C. Bunting. 2003. Long-term vegetation dynamics and fire effects at the Idaho National Engineering and Environmental Laboratory. Department of Rangeland Ecology and Management, University of Idaho, Moscow, ID.

Floyd, D. A., and J. E. Anderson. 1983. Baseline vegetation data for a controlled burn site. Pages 182-197 *in* O. D. Markham, editor. Idaho National Engineering and Environmental Laboratory Radioecology and Ecology Programs; 1983 Progress Report. Idaho Operations Office, U.S. Department of Energy, Idaho Falls, ID.

Forman, A. D., and J. E. Anderson. 2005. Design and performance of four evapotranspiration caps. Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management **9**:263-272.

Forman, A. D., and R. D. Blew. 2004. Proposal to conduct: sagebrush demography on the Idaho National Engineering and Environmental Laboratory. Environmental Surveillance, Education and Research Program, Idaho Falls, ID.

Forman, A. D., R. D. Blew, and J. R. Hafla. 2003a. Sagebrush Steppe Ecosystem Reserve plant community classifications. STOLLER-ESER-73, Environmental Surveillance, Education and Research Program, Idaho Falls, ID.

Forman, A. D., R. D. Blew, S. J. Vilord, and J. R. Hafla. 2003b. Sewage wastewater application ecological impact study 2002. STOLLER-ESER-72, Environmental Surveillance, Education and Research Program, Idaho Falls, ID.

Forman, A. D., R. D. Blew, S. J. Vilord, and J. R. Hafla. 2005. Sewage wastewater application ecological impact study 2003. STOLLER-ESER-84, Environmental Surveillance, Education and Research Program, Idaho Falls, ID.

French, N. R., and J. E. Mitchell. 1983. Long-term vegetation changes in permanent quadrats at the Idaho National Engineering Laboratory Site. Bulletin Number 36, Forest, Wildlife, and Range Experiment Station, University of Idaho, Moscow, ID.

Gabler, K. I. 1997. Distribution and habitat requirements of the pygmy rabbit (*Brachylagus idahoensis*) on the Idaho National Engineering and Environmental Laboratory. Idaho State University, Pocatello, ID.

Harniss, R. O. 1968. Vegetation changes following livestock exclusion on the National Reactor Testing Station, Southeastern Idaho. Utah State University, Logan, UT.

Harniss, R. O., and N. E. West. 1973. Vegetation patterns of the National Reactor Testing Station, southeastern Idaho. Northwest Science **47**:30-44.

Janzen, B. C., M. J. Germino, J. E. Anderson, and A. D. Forman. 2007. PCBE revisited: Long-term performance of alternative evapotranspiration caps for protecting shallowly buried wastes under variable precipitation. STOLLER-ESER-101, Environmental Surveillance, Education and Research Program and Department of Biological Sciences, Idaho State University, Idaho Falls, ID.

Jeppson, R. J., and K. E. Holte. 1976. Long-term vegetation analysis of the INEL site. Pages 160-165 *in* O. D. Markham, editor. 1975 Progress Report Idaho National Engineering Laboratory Site Radioecology-Ecology Programs. Idaho Operations Office, U.S. Energy Research and Development Administration, Idaho Falls, ID.

Majors, S. J., and R. D. Blew. 2000. Species suitability study for revegetation activities at Spreading Area B: First year report. ESRF-044, Environmental Science and Research Foundation, Idaho Falls, ID.

McBride, R., N. R. French, A. D. Dahl, and J. E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. IDO-12084, Environmental

Sciences Branch, Radiological and Environmental Sciences Laboratory, Idaho Operations Office, U.S. Department of Energy, Idaho Falls.

Morris, A. N. 2001. The effects of changes in timing and amount of precipitation on vegetation dynamics and nitrogen mineralization in a sagebrush-steppe ecosystem. Idaho State University, Pocatello, ID.

Shumar, M. L., and J. E. Anderson. 1986. Gradient analysis of vegetation dominated by two subspecies of big sagebrush. Journal of Range Management **39**:156-160.

Singlevich, W., J. W. Healy, H. J. Paas, and Z. E. Carey. 1951. Natural radioactive materials at the Arco Reactor Test Site. Radiological Sciences Department, Atomic Energy Commission, Richland, WA.

Vilord, S. J., C. L. Jenkins, D. K. Halford, J. R. Hafla, A. D. Forman, R. D. Blew, W. Purrington, and M. R. Jackson. 2005. Survey and review of potential impacts to ecological resources on the INL due to construction of a road as described in the draft Environmental Impact Statement for the proposed Consolidation of Nuclear Operations Related to Production of Radioisotope Power Systems DOE/EIS-0373D. STOLLER-ESER-87, Environmental Surveillance, Education and Research Program, Idaho Falls, ID.

Wilkosz, R. J., and J. E. Anderson. 1983. Idaho National Engineering Laboratory vegetation data file. Pages 147-156 *in* O. D. Markham, editor. Idaho National Engineering Laboratory Radioecology and Ecology Programs; 1983 Progress Report, IDO-12098. Idaho Operations Office, U.S. Department of Energy, Idaho Falls, ID.

3.0 DESCRIPTION OF DATA COLLECTION METHODS FOR THE LONG-TERM VEGETATION TRANSECTS

The purpose of this chapter is to provide sufficient detail of the data collection process to ensure that successive data collection efforts result in a high degree of data comparability to previously collected data. As these plots continue to be surveyed, the need to provide continuity becomes all the more important. The information provided here is intended to guide both future data collection and to provide documentation on how these data were collected and archived during the 2006 survey.

3.1 Plot Markings, Identification, and Setup

Each plot is marked by a steel fence post and rock crib. The post has a metal tag attached with the label “VEG TRANS” and the plot number. Originally each plot consisted of two transects, each 15.24 m (50 ft) long and parallel to the macrotransect (Figure 3-1). The first transect of the two is offset 15.24 m (50 ft) from the macrotransect and the second transect is 4.57 m (15 ft) from the first. In 1985, a third transect was added to all of the core plots and about half of the peripheral plots including Plots 13 through 15, 17 through 57, and 71 through 98. The third transect is 4.57 m (15 ft) from the second transect and is 20 m (65.6 ft) long. Each transect is marked with a steel rebar stake at each end. The plots are located to the northwest of the macrotransect that runs southwest to northeast and to the southwest of the macrotransect that runs southeast to northwest.

Prior to data collection, each plot is to “set up” by fastening a taut metal measuring tape between the steel rebar stakes at the endpoints of each of the three transects. The tapes used are graduated in both centimeters and inches.

3.2 Field Sampling Methods

Vegetation surveys on the LTV plots were conducted during June, July and August of 2006. The centermost plots have traditionally been sampled first, and sampling has progressed along the macrotransects toward the peripheral plots as the field season progresses. Centrally located plots are sampled first because the center of the INL Site is generally at a lower elevation than the periphery; thus, phenology is optimal for identification near the intersection of the macrotransects earlier in the growing season.

Sampling details can be found in the LTV plot sampling protocol (Appendix A). A general discussion of the sampling strategy is provided here. Because there is the potential for excessive foot traffic through the plot and along the transects, the order in which various sampling techniques are presented and completed has been designed to preserve as much information as possible for those data types that could be influenced by trampling.

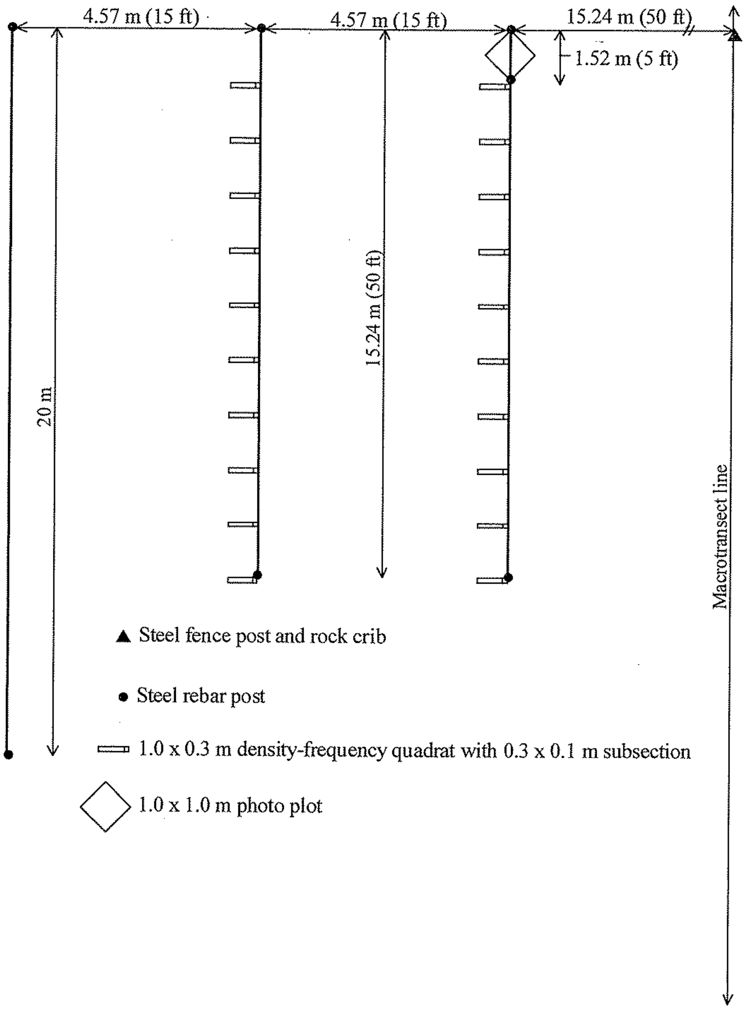


Figure 3-2. Long-Term Vegetation Plot layout showing the two 15.24-m (50-ft) long transects and the 20-m long transect parallel to the marcortransect line. Figure from Colket and Bunting (2003).

3.2.1 Photographic Documentation

Following setup, two photographs are taken at each plot. A Nikon D50 camera and a Nikon 18-55mm f/3.5 lens were used for the images captured during the 2006 sampling period. Detailed procedures for taking the LTV documentation photographs have been developed and can be found in Appendix A. The sampling protocol describes camera, lens, and tripod setup, and includes information about recording the setting details of each photograph. Generally, using the largest f-stop and slowest shutter speed possible for the given light and wind conditions produces the greatest depth of field, which is useful for bringing as much of the photo as possible into focus. The first photo is taken of a 1 m X 1 m frame placed at the starting point of the first transect. This photograph provides a detailed close-up of the same 1 m^2 photoplot for each year the plots are surveyed. The second photograph is a photopoint taken from the same location except that the camera is turned up to include the horizon. This photo captures the condition of the larger plot as well as the surrounding landscape.

For each plot, a Photo Plot ID Label is prepared and placed next to the photoplot and in the center foreground of the photopoint. The label records the plot number and date. Details of this photo label and an example are in the sample protocol (see Appendix A). Blue or beige paper with heavy black marker tends to work well for photo labels. Bright white paper may produce glare. Before removing the frame for the photoplot, a sketch is made to record the location and species of each plant within the frame. A space for the sketch is provided on the reverse side of the Photo Plot ID Label.

3.2.2 Vegetation Cover Methods

Cover is measured using two different methods. Point interception is used to estimate cover at all plots that have the third transect line added in 1985 as described above. The point sighting frame was developed by Floyd and Anderson (1982). The frame is 1 m x 0.5 m with a grid of intersecting lines at 0.1-m intervals resulting in 36 points per frame. The frame is held level above the vegetation on tripod legs. A small bubble level is attached to the frame to facilitate leveling. At each of the sighting points in the frame, the observer looks down through the point and records the species of all vegetation or other entity (e.g., bare ground) occurring beneath that point. Points are recorded for canopy cover of shrubs and forbs and basal cover of grasses.

The frame is centered lengthwise over the metal tape transect line with the first frame on the transect starting at the zero point on the metal tape. The frame is then moved at 1.0 m-intervals along the tape. Fifteen frames are surveyed along each of the two 15.24 m transects and 20 are surveyed on the 20 m transect, for a total of 50 frames per plot.

The crown cover of shrubs and the basal cover of perennial grasses are also estimated using line interception (Canfield, 1941). Line intercept sampling is completed along both 15.24 m transects on all plots. Forbs and annual grasses are not sampled using line interception techniques.

3.2.3 Density and Frequency

Density and frequency are estimated using 1 m x 0.3 m quadrats placed at 1.52 m (5 ft) intervals beginning at 1.52 m (5 ft) along the two 15.24 m (50 ft) transects. A total of 20 quadrats are surveyed at each plot. Counts of perennial species are conducted within the entire 1 m x 0.3 m quadrat. Tillers of rhizomatous grasses are counted as individuals. Annual species are counted within a 0.1 m x 0.1 m subsection of each quadrat.

3.3 Electronic Data Collection

In 2006, data were recorded using field rugged pocket pcs. An electronic data form was designed using a spreadsheet application. The data form contains four worksheets (or datasheets), one for each data collection technique (photographic documentation, point interception, line interception, and density/frequency). One data form, containing four datasheets, was completed at each plot. Examples of the datasheets contained within the data form are shown in Table 3-1. The electronic datasheets were designed and formatted with the structure of the database tables in mind, so that data transfer is as seamless as possible. Data entry effort was reduced in the field by pre-populating static fields (e.g. point location on the point frames) and by entering repetitive data (e.g. date, observer, plot, line, etc.) only if or when it changes and using an “autofill” macro to populate empty cells during data processing.

Table 3-1. Examples of the spreadsheet (or datasheet) templates used for electronic data collection during the 2006 sample period.

A. Electronic datasheet template used for recording photographic documentation data.

Date	Plot #	Photoplot or Photopoint	Photographer	Lens Length (mm)	Shutter Speed	f-stop	Filename (Camera)	Filename (Projects)	Comments

B. Electronic datasheet template used for recording point interception data.

Date	Observers	Plot	Line	Frame	Point	Entity 1	Entity 2	Entity 3
			1	1	A1			
			1	1	A2			
			1	1	A3			
			1	1	A4			
			1	1	A5			

C. Electronic datasheet template used for recording line interception data.

Date	Observers	Plot	Line	Code	Start	End

D. Electronic datasheet template used for recording density/frequency data.

Date	Observers	Plot	Line	Frame	Code	Count

The spreadsheet-based forms described above and database-style forms containing drop-down pick lists were both considered and tested prior to data collection. The rationale for choosing the spreadsheet application is twofold. First, it expedites the data entry process for the most common species. Field crews can often remember and type the codes for common species that occur in the majority of plots more efficiently than navigating through a series of pick lists, some of which may be quite extensive. Second, if the wrong species is chosen inadvertently from a pick list, it if often impossible to identify and recover that error since the database lookup tables recognize all of the species in the pick list. Conversely, if an error is made while typing a species code, the resulting value is often not recognized in the database lookup tables and can be flagged and fixed by querying the field data against a lookup table.

3.4 Quality Assurance/Quality Control and Data Archive

To support quality assurance/quality control goals, a checklist was developed to provide guidance to field crews and data managers and to meet data completeness criteria. The checklist can be found in Appendix A. The checklist includes information on plot number, date of survey, and the observers who collected the data. The order of data collection is noted on the checklist. The checklist requires the observer or field leader to initial each step to track responsibilities and to ensure that each step has been properly completed.

The checklist includes an "unknown species" log. Encountering unknown species is a common occurrence with any large vegetation survey like the LTV project. Unknown species are generally either rare species that are not often encountered or are more common species encountered in a phenology that is not commonly seen. It is important that these unknowns eventually be identified and the dataset properly corrected to include the correct identity. The sampling protocol (Appendix A) contains details regarding the collection, identification, and data management associated with an unknown species.

Downloading data from the cameras and pocket pcs was generally the responsibility of the field crew leader and was performed on a daily basis during the 2006 sampling period. The field checklist provides for documenting electronic data transfers from the field units to the file server. Hardcopy data are transferred concurrently with electronic data, and the checklist also provides documentation that the Photo Plot ID Label and Sketch are delivered from the field and appropriately filed. Once the checklist is complete, including final identifications on unknown species, it is delivered to the data manager.

Data processing, including performing QA/QC procedures and populating the LTV database are the responsibility of the vegetation data manager. As soon as possible after the data are transferred, generally the following day, the data files are given additional quality control checks for certain key parameters. First the spreadsheets are reviewed to for completeness to ensure that all data parameters, lines, quadrats and frames had been collected and recorded. Formatting required for importing the spreadsheets into the LTV Database iss completed and data are imported to the appropriate Database tables.

Data tables are then checked to ensure that the species codes recorded were from the list of known species on the INL and the data tables are populated with INL taxon codes. Queries are used to ensure that vegetation abundance summary values do not exceed expected value limits. Finally, final identification codes for unknown specimens are backfilled into the data table. Once the LTV Database tables are checked for quality, the Database is delivered to the ESER Natural Resources Data Management System to ensure long-term archive and availability.

Literature Cited

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry 39:388-394.

Colket, E.C. and S. Bunting. 2003. Long-term vegetation dynamics and fire effects at the Idaho National Engineering and Environmental Laboratory. Final Report. Task Order No. 2. Task Agreement No. 3628-005 with the S.M. Stoller Corporation. Idaho Falls, ID. 53 pp.

Floyd, D. A. and J. E. Anderson. 1982. A new point interception frame for estimating cover of vegetation. Vegetatio 50:185-186.

4.0 THE LTV DATABASE

The database includes seven raw data and metadata tables. The general structure of the database is depicted in Figure 4-1. The metadata tables include information about plant species on the INL Site, information about each of the permanent plots on the LTV Transects, and a record of which data types were collected on each plot during each sampling effort. The database also contains four data tables; three tables are comprised of vegetation abundance data and one includes information about plot photos. The abundance data tables contain density/frequency data, cover data estimated using line interception, and cover data estimated using point interception.

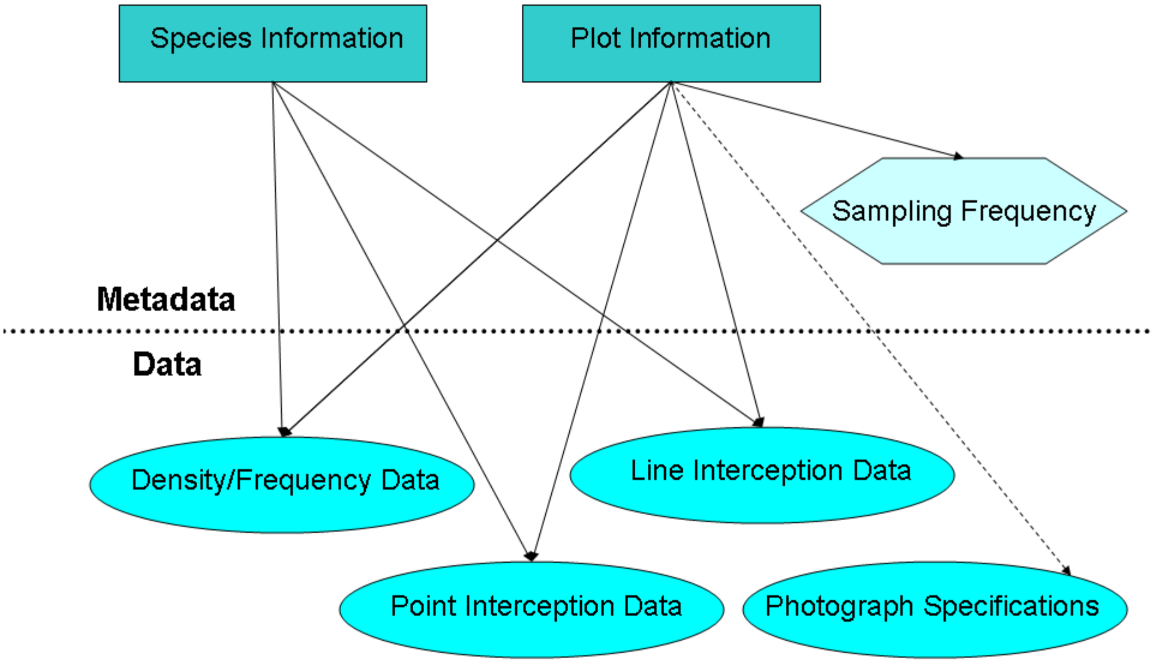


Figure 4-1. Conceptual model showing seven data and metadata tables and the relationships of those tables to one another in the LTV database.

4.1 Metadata Tables

The LTV database contains three metadata tables which are comprised of information about plant species occurring on the INL Site, information about the permanent LTV plots, and information about sampling frequency for various types of abundance data.

4.1.1 Master Species Table – Species Information

The master species table includes standardized information about all of the vascular plant species documented to occur within or in close proximity to the INL Site boundaries. The list of species represented in the master species table was compiled using previous LTV-related publications and the most recent INL Site flora. The purpose of the master species table is twofold. First, the master species table can be used to document taxonomic changes and maintain the consistency of scientific codes and names across all years in which data were collected. Second, the master species table will allow researchers to easily categorize species into functional groups based on one or several geographical/life history characteristics. Much of the information included in the master species table was populated and/or updated using the Plants National Database (USDA-NRCS 2005). The master species table was last reconciled against the Plants National Database in 2005. We recommend that the master species table be updated prior to every LTV data collection effort.

4.1.1.1 Data Fields in the Master Species Table

1. **Taxon Code** – The taxon code is a unique, permanent numerical code assigned to each species or non-vascular cover entity (i.e. bare ground). The taxon code is used to identify species or other entities in each of the abundance data tables. Thus, the taxon code is the key field linking the master species metadata table to the abundance data tables. Scientific names and their associated four-letter codes can be updated to reflect changes in taxonomy in the master species table without affecting the quality or consistency of the species identification data in the abundance data tables.

   The numeric taxon codes are specific to the INL Site and follow the following general numbering system:

   Table 4-1. Taxon code categories used for vascular plant species on the INL Site.

Entity Groups	Code Ranges
Non-vascular	<1000
Trees	1000-1990
Shrubs	2000-2990
Graminoids	3000-3990
Forbs	4000-5490
Succulents	5500-5990
Annuals	6000-6990
Biennials	7000-7990
Unknowns	8000-8990
Ferns	9000-9990

   The code ranges listed above are general guides, and occasionally, species have been assigned a code that is not consistent with the appropriate entity group. As such, the taxon code alone should not be used to group species into the functional groups listed in Table 4-1. Additionally, the taxon codes for two entities contain letters; therefore, the taxon code field is formatted as text in the species metadata table.

2. **INL Code** – The INL code is a one- to five-digit code used for data collection on the INL Site. The code generally contains the first two letters of the genus and the first two letters of the specific epithet for a given species. The code may also contain a fifth letter if the vascular plant has been or is commonly identified to the subspecies level, as for big sagebrush subspecies. The four-letter code may also be followed by a number if two species

have the same code. The more common of the two species will be identified simply by the appropriate four-letter code, while the less common of the two species will contain the number “2” after the four-letter code. Because the codes are specific to the INL Site, they do contain some idiosyncrasies that deviate from the general naming scheme discussed above and have been maintained by convention and passed on from one researcher to the next. For example the INL code for *Artemisia tripartita* is “ARTP,” rather than “ARTR2.”

Non-vascular entities such as bare ground or moss have also been assigned INL Site-specific codes. The codes for non-vascular entities are comprised of one to two letters that are usually quite intuitive. The INL code for bare ground is “B,” and the INL code for moss is “M.” The non-vascular codes are used only for point interception abundance data.

INL codes have been periodically updated to reflect changes in taxonomy. Vegetation field crews are generally provided a list of INL codes prior to any data collection effort.

3. **USDA Code** – The USDA code is a 4+ digit code for each species as assigned by the USDA, NRCS (2005). This field allows species, as identified at the INL Site, to be reconciled against a well-accepted national standard. The Plants National Database (USDA-NRCS 2005) may be queried using the USDA code for additional information about each species, including geographic range, life-history characteristics, classification information, conservation status, etc. USDA codes in the master species table have been updated periodically to reflect changes in taxonomy, as defined by the USDA.

4. **Scientific Name** – This field includes the full scientific name of each species or subspecies contained in the data table. The scientific name of each species is periodically updated using the Plants National Database (USDA-NRCS 2005). As such, nomenclature of the LTV database follows that of the Plants National Database (USDA-NRCS 2005).

5. **Common Name** – A common name for each species is included in this field of the master species table. The common name used for a given species is often the common name provided by the Plants National Database (USDA-NRCS 2005). However, in the event that a species has an additional common name that is used more often in a local or regional context, we have used the more locally accepted common name rather than the common name listed in the Plants National Database (USDA-NRCS 2005).

6. **Family** – This field includes the name of the family to which a given species belongs. The family field of the master species table has been updated periodically to reflect changes in nomenclature.

7. **Nativity** – The nativity field designates the origin of the species as it relates to the INL Site. A species is categorized as native if it was thought to occur inside or in close proximity to the INL Site boundary prior to settlement of the region. A species is identified as introduced if it invaded or was introduced from elsewhere within the last one-hundred-and-fifty or so years.

8. **Duration** – Duration refers to the seasonal longevity of a given species (i.e. annual, biennial, and perennial). Many forb species can be variable with regard to longevity; therefore, the duration most common for a particular species at the INL Site has been assigned to that

species in the duration field. If the lifespan of individuals of a certain species is truly variable at the INL Site, the species is labeled as "variable" in the duration field of the master species table.

9. **Growth Habit** – In the Growth Habit field, species are assigned a category (shrub, grass, forb, etc.) based on the predominant growth form of a given species at the INL Site.

10. **Graminoid Growth Form** – This field is used to specify the growth forms of the perennial graminoid species occurring on the INL Site. Field categories include bunch, rhizomatous, and stoloniferous. This field only contains data for grass and sedge species.

11. **Vascular Vegetation** – A researcher can use the Vascular Vegetation field to quickly sort or summarize point interception cover data. This field is especially useful for calculating total absolute vascular cover or the relative cover a species or functional group.

12. **Comments** – The comments field was designed to provide some continuity between the current iteration of the LTV database and the historical text-formatted electronic data files. The comments field primarily documents changes in taxonomy from one sample period to the next, but can be used for any additional pertinent notations. In terms of documenting taxonomy changes, the comments field was not complete at the conclusion of the 2006 sampling and reporting effort.

4.1.1.2 Additional Comments on the Master Species Table

Although slightly less than five hundred vascular plant species have been documented to occur within or adjacent to the INL Site, the master species table contains over six hundred records. Some of the additional records represent the non-vascular entities discussed above. However, many of the additional records can be attributed to various unknown species codes. Throughout the nearly sixty years that the LTV plots have been sampled, researchers have assigned a plethora of codes to species that were not identified while collecting plot abundance data. In order to maintain continuity between the historical data archives and the current version of the LTV database, all of the unknown species codes recorded in the data files had to be represented in the master species table.

In addition, a wide range of specificity occurs in unknown codes used throughout the sampling history of the LTV. In some cases, researchers used very general unknown codes such as "UNK 1," which doesn't identify the individual in question any more specifically than as a vascular plant. In other instances, an unknown code would identify the plant in question to the level of genus, but the species remained unknown. For example "ARTSP2" may have been used to indicate that the individual was a species in the genus *Artemisia*.

For unknown codes that identify an individual to the genus level, the associated record was assigned the appropriated nativity, duration, and growth habit so long as that information could be generalized from all of the species known to occur on the INL Site within that genus. In cases where life history characteristics differ among species within a genus, the corresponding fields in the master species table indicates that the information is not applicable (N/A). The data fields documenting life history characteristics of unknowns was populated as completely as possible so that appropriate species would be included in analyses that classify species into functional groups.

Codes for non-vascular species have not been used in an entirely consistent manner since the initiation of point intercept sampling in 1985. The non-vascular species codes have become increasingly more specific through time, often in response to specific hypotheses of interest. For example, in 1985 all dead shrubs were recorded under one INL code, “DS,” regardless of the presumed cause of death. Beginning in 2001, however, field crews began using the code “BS” to differentiate between shrubs that appear to have died as a result of wildland fire, as opposed to shrubs that died from other causes. Thus, current researchers should take into account the splitting of non-vascular groups into more specific categories through time when analyzing the LTV data.

The historical LTV data files only included species that had been recorded in the abundance data tables for the LTV project. Since the master species table was designed with the intention of using it on all INL Site vegetation projects, making the all vegetation data consistent and comparable to the LTV data set, several hundred species were added to the master species table in 2005. The master species table now includes all species occurring on or adjacent to the INL Site. The historical taxon code numbering system was not sufficient to contain the added species. Therefore, the historical taxon codes were multiplied by a factor of 10 and the species recently added to the table were assigned taxon numbers according to the general entity groups listed in Table 4-1. Thus, when comparing current abundance tables with the historic electronic files, researchers should note that the taxon code will differ by a factor of 10.

Finally, both taxonomy and the taxonomic level at which species of interest are studied have changed throughout the duration of the LTV project. Consequently, some species have been lumped under one scientific name and others have been identified to the subspecies level in more recent data collection efforts. For example, *Poa sandbergii*, Poa *nevadensis*, and *Poa secunda* were identified as separate species when data collection began on the LTV, but are now lumped under the name *Poa secunda*. Conversely, big sagebrush (*Artemisia tridentata*) has been identified to the subspecies level (i.e. *Artemisia tridentata* ssp. *wyomingensis* and *Artemisia tridentata* ssp. *tridentata*) only during the past few decades of data collection.

In cases where several species have been lumped into one, the original taxon codes remain the same in abundance data tables, but the scientific and common names have been changed in the master species table to reflect the change in taxonomy. Hence, some species are listed in the master species table more than once, but each record representing that species will have a different taxon code. Therefore, if an abundance table were queried for *Poa secunda* using its relationship to the master species table, all of the records that would correspond to the current definition of *Poa secunda* would be returned (including all records originally identified as *Poa sandbergii* or *Poa nevadensis*).

For occasions where a species has been identified to the subspecies level during one or more data collection periods, an additional character has been added to the taxon code. In the case of *Artemisia tridentata*, the letter “a” was added to the taxon code for the subspecies *Artemisia tridentata* ssp. *tridentata* and the letter “b” was added to the *Artemisia tridentata* ssp. *wyomingensis* for years in which big sagebrush was identified to the subspecies level. As a result, if an abundance data table were queried for one of the subspecies, results would only be returned for years in which big sagebrush was identified to subspecies. On the other hand, if a researcher wanted to query an abundance data table for big sagebrush, including all subspecies, the query would have to be written such that the taxon code field "contains" the numeric code that is common to the species and both subspecies.

4.1.2 Master Plot Table – Plot Information

The master plot table contains metadata for all of the plots currently and historically sampled as part of the LTV project. The plot metadata contained in the master plot table includes information about the location, history, land use, biotic, and abiotitic factors associated with each plot. The master plot table can be used to sort, categorize, or analyze plots according to any of the factors listed above.

4.1.2.1 Data Fields in the Master Plot Table

1. **Plot** – This field contains the unique plot number assigned to each LTV plot. The plot field is also used to identify the plot in each of the abundance data tables. As such, the plot is the key field linking the master plot table to the abundance data tables.

2. **Plot_Group** – For analytical purposes, plots have been assigned to various groups throughout the duration of the LTV project. Plot groups include core, peripheral, and century series plots. The plots in the "core" group were assigned by Anderson (see Chapter 2) and are comprised of plots that are located within the central areas of the INL Site. These plots are the most homogenous in terms elevation and species composition and they tend to be the most typical examples of sagebrush steppe plant communities on the INL Site. All of the other LTV plots located along the macro-transects were assigned to the "peripheral" plot group. These plots tend to be located on or near the buttes and foothills. The additional plots added in 1957 and 1965 which were not located along the macro-transects were assigned to the "century series" group. The century series plots were added to document plant communities that are not dominated by big sagebrush (see Chapter 2).

3. **Easting** – The easting is the geographic X coordinate of the plot. The eastings listed in the master plot table are in the projection UTM Zone 12N and datum NAD 83.

4. **Northing** – The northing is the geographic Y coordinate of the plot. The northings listed in the master plot table are in the projection UTM Zone 12N and datum NAD 83.

5. **Elevation** – The elevation field indicates the approximate elevation of each plot. The elevation data were derived from the National Elevation Dataset by the USGS. The USGS data are at a 7.5 minute scale and a 10 m resolution.

6. **Soil_Char** – The soil_char field contains the soil association represented at each LTV plot. The data were derived from soil map layers developed by Olsen et al. (1995).

7. **Soil_Group** – A description of combined soil groups occurring on each LTV plot are contained in the soil_group field. The data were derived from soil map layers developed by Olsen et al. (1995).

8. **McBride_Veg_Class** – The data in this field represent the plant community, as described by McBride et al. (1978), associated with each LTV plot.

9. **Fire** – The fire field lists years in which fires were know to have burned through a given LTV plot. The fire data were compiled from available geo-spatial data sets. The data are from various sources, are of varying accuracy, and were derived using a variety of methods. The fire data are more complete in more recent years (< 20) and very sporadic for older fires (>50). Accordingly, this field should be used with caution.

10. **Allotment** – This field indicates whether or not a plot is located within a BLM grazing allotment boundary. It also provides the name of the associated BLM allotment.

11. **Comment** – The comment field contains general information about each plot. The field includes data about plots that have been lost or damaged as well as the last sampling period in which a compromised plot was known to have been sampled.

4.1.2.2 Additional Comments on the Master Plot Table

Plots classified as "core" plots in the plot group field reflect the most recent definition of the core plots as assigned by Anderson and Inouye (1999). The core plots have historically been defined by land use, topography, and/or statistical parameters. The number of plots included in the core group has fluctuated between approximately 35 and nearly 50 depending on the principal investigators involved and hypotheses of interest during a particular study period. The current group of core plots was defined by a combination of topographic homogeneity, proximity, and similar plant community composition which was support by multivariate analyses, primarily ordination.

Location data were collected with a Garmin GPS 12XL by Colket (2003) during the 2001 data collection effort. The data are uncorrected and are estimated to have an accuracy of 3-10 m. GPS locations were only collected for the plots that were actively being sampled during the 2001 study period. Consequently, plots that have not been sampled during the past few decades do not have any associated location data. Plots that don't have associated location data also lack data for soils, fires, vegetation class and other spatially explicit information. We strongly recommend that historically sampled plots be located and their coordinates be documented if at all possible, before the physical plot markers are lost.

The data contained in both of the soils-related fields in the master plot table are from a 1995 status report (Olson et al.) The data were compiled using existing soil surveys. The data layers developed during this effort are the most complete and comprehensive soils maps created for the INL Site. However, the soil survey data used to develop the 1995 maps were from various sources with different scales and resolutions. Additionally, most polygons and soil classifications were extrapolated onto the INL Site based on surveys conducted on adjacent lands, and data is still lacking for some portions of the INL Site. Therefore, soils data in the master plot table should be used with an understanding of the limitations of those data.

The vegetation class field was populated with data from a GIS layer derived from the McBride et al. (1978) vegetation type map. The original McBride map has since been modified to reflect wildland fire boundaries and the resulting loss of sagebrush from recently burned plant communities. The vegetation class field in the master plot table also accounts for these changes. The vegetation class in the McBride map was typically named using the three most abundant species within a vegetation type polygon. If the vegetation class name contained big sagebrush, and the LTV plot has burned since the McBride map was finalized, sagebrush was removed from the vegetation class name. Nomenclature in the vegetation class categories reflects that of 1978. Aerial photographs and plot data used to create the map were collected for almost two decades before the map was produced. Thus some of the data reflected in the McBride vegetation map are nearly 50 years old. The age of the data coupled with the potential for vegetation composition to change over 50 years should be considered when using the vegetation class data for analysis.

Additionally, Anderson (1999) has strongly cautioned against making comparisons between aspects of plots located within grazing allotments to plots located outside of grazing allotments. First, plots that aren't located within grazing boundaries tend to be lower in elevation, drier, and dominated by different understory species than plots located within grazing boundaries. Hence, differences in abiotic factors and plant community composition would be confounding factors in analyses comparing the two sets of plots. Second, livestock class, stocking rates, utilization, and season of use vary greatly within and among allotments. This range of variability in use also makes grazed vs. ungrazed result of these comparisons difficult to interpret.

4.1.3 Sample Year Table – Sampling Frequency Information

The sample year metadata table contains information about which types of abundance data were collected on a given plot during a given sampling period. The data contained in the sample year metadata table are not entirely unique in that each of the abundance data tables can be queried separately as to which plots were sampled for that data type during a specific sampling period. The purpose of summarizing metadata related to sampling frequency in one database table is simply as a quick reference resource. The sample year table also houses information about sampling details.

4.1.3.1 Data Fields in the Sample Year Table

1. **Year** – This field denotes the year during which data were collected. This field facilitates data summarization based on a specific, user-defined sampling period.

2. **Plot** – This field contains the unique plot number assigned to each LTV plot. The Master Plot Table and the Sample Year Table are related through the plot field.

3. **Density_Freq** – This is a yes/no formatted field indicating whether or not a given plot was sampled for density during a given year.

4. **Line_Inter** – This is also a yes/no formatted field. It specifies whether or not cover data were collected using line interception methods on a given plot during a given year.

5. **Point_Inter** – This is also a yes/no formatted field. It specifies whether or not cover data were collected using point interception methods on a given plot during a given year.

6. **Comment** – The comment field provides details about deviations from the normal sample protocol such as the notation that only 40 point frames were sampled on plot 36 in 1990

instead of the 50 frames normally used for collecting point interception data. This information is important for calculating accurate summary statistics. For example, calculating absolute cover for a species or functional group in one plot is usually accomplished by dividing the number of “hits” recorded for that entity by 1800 (50 frames x 36 points per frame). In the case mentioned above, where only 40 frames were sampled, an accurate summary statistic for absolute cover would be calculated by dividing the number of “hits” by 1440 (40 frames x 36 points). Thus the comment field of the Sample Year Table should be referenced to ensure that abundance data are properly summarized for analysis.

4.2 Data Tables

The LTV database contains four data tables; three tables are comprised of vegetation abundance data and one is designed to document information about plot photographs.

4.2.1 Density Frequency Table

The density/frequency table contains all of the density data collected and archived on the LTV project beginning in 1950 through the 2006 sample period. Most of the density data were previously archived in a raw data format which has been preserved in the density table of the current project database. Because the data are available in a raw format, species frequency within a plot can also be derived from the density data table.

4.2.1.1 Data Fields in the Density Frequency Table

1. **Date** – The date listed in this field is the date on which a plot was sampled. The date field is maintained as a text-formatted field due to the uncommon nature of the date format used for sample dates on the LTV project. The date format historically used for the LTV data is yymmdd. This is not considered a standard date format in many software applications, but has been retained in the current project database as a measure of continuity between the historical data archives and the current database.

2. **Plot** – This field contains the unique plot number assigned to each LTV plot. The Density Frequency table is related to the Master Plot table through the plot field.

3. **Frame** – The frame field indicates from which of the 20 density frames sampled in each plot a given record came. Frames 1-10 are located along transect #1 and frames 11-20 are located along transect #2. See Chapter 3 for more information about density frame placement within a plot.

4. **Taxon_Code** - The taxon code is a unique, permanent numerical code assigned to each species or non-vascular cover entity (i.e. bare ground). The Density Frequency table is related to the Master Species table through the taxon_code field.

5. **Count** – This field contains the individual count data for each of the species encountered within a given 0.3 x 1.0m density frame. To estimate density in the standard format of individuals/m^2, the count field should be multiplied by 3.333.

6. **Year** – The year in which the data were collected is documented in this field. It was added to simplify data summarization because the Date field has not been maintained in a standard format.

4.2.1.2 Additional Comments on the Density Frequency Table

Annuals are counted within a subsection of the 0.3 x 1.0m density frame (see Chapter 3). The subsection originally measured 0.3 x 0.1m, or 1/10th of the total size of the frame. During a few of the sampling periods, however, the annuals subsection was increased to 0.3 x 0.3m, or 1/3rd of the total sized of the frame. Consequently, there has been some confusion about which subsection size was used in a particular sampling period and whether the counts of annual species were scaled up accordingly in the historical data archives. As part of the data verification/validation process associated with compiling the new LTV project database, count data were referenced against hard-copy datasheets and members of more recent field crews were contacted to determine which subsection size was used and annual counts were adjusted accordingly. Some annual counts appear in the density frequent table as multiples of 10 and others as multiples of 3.333, but all annual species have been scaled up appropriately so that the counts represent the number of individuals in an entire 0.3 x1.0 m frame. Perennial species were counted in the entire 0.3 x1.0 m frame during all sample periods. Thus, both annuals and perennial are represented on the same scale in the Density Frequency table.

The raw density data were lost for the 1995 sampling period; only an average density of each species within each plot was maintained in the historical data archives. This issue was addressed in the Density Frequency table of the LTV project database by dividing the available average by 20 and listing the resulting number in each of the 20 frames for each species within a plot. The resulting data in the count field aren't very intuitive in that fractions of individuals of a particular species often appear to occur within each frame of the plot. When the table is queried for average density of a given species in a given plot, however, an accurate summary statistic is returned. Unfortunately, it is impossible to derive frequency data from the 1995 density data. If a frequency query were run against the 1995 data, a frequency of 1.0 would be returned for every species in every plot.

4.2.2 Line Intercept Table

Cover has been measured on perennial grasses and shrubs using line interception since the initiation of the LTV project in 1950. The data have been maintained in the historical data archives as a sum of the amount of tape intercepted by a given species in a given plot. Within a plot, line interception data are collected on two transects each approximately 15m in length. See Chapter 3 for more information about line intercept sampling on the LTV plots.

4.2.2.1 Data Fields in the Line Intercept Table

1. **Date** – The date listed in this field is the date on which a plot was sampled. The date field is maintained as a text-formatted field due to the uncommon nature of the date format used for sample dates on the LTV project. The date format historically used for the LTV data is yymmdd. This is not considered a standard date format in many software applications, but has been retained in the current project database as a measure of continuity between the historical data archives and the current database.

2. **Plot** – This field contains the unique plot number assigned to each LTV plot. The Line Intercept table is related to the Master Plot table through the plot field.

3. **Taxon_Code** – The taxon code is a unique, permanent numerical code assigned to each species or non-vascular cover entity (i.e. bare ground). The Line Intercept table is related to the Master Species table through the taxon_code field.

4. **Cover** – The cover field contains the total amount of line (in cm) intercepted by a shrub or perennial grass in a particular plot. Absolute cover of a species or functional group within a plot can be calculated by dividing the cover of that species by 3000 – the total amount of line sampled (in cm).

5. **Year –** The year in which the data were collected is documented in this field. It was added to simplify data summarization because the Date field has not been maintained in a standard format.

4.2.2.2 Additional Comments on the Line Intercept Table

As indicated above, forb and annual grass cover has not been sampled using line interception. Additionally, it should be noted that cover has been measured on the canopy of shrubs and basal area of grasses. Prickly pear cactus (*Opuntia polyacantha*) has not been addressed consistently throughout the LTV project, but some measure of cover is available for most sample periods.

4.2.3 Point Intercept Table

Cover data collection using point interception methods began on the LTV plots in 1985 as a means of collecting cover data for all species on a common scale. Previously, cover data were only collected on perennial grass and shrub species. Furthermore, the only abundance data collected for annual species and forbs was density. Point interception techniques used on the LTV project are documented by Floyd and Anderson (1982) and consist of using 50, 36-point frames across three transects within a plot. Point intercept data is collected on a large subsample of the LTV plots. See Chapter 3 for more information about point intercept sampling on the LTV plots.

4.2.3.1 Data Fields in the Point Intercept Table

1. **Date** – The date listed in this field is the date on which a plot was sampled. The date field is maintained as a text-formatted field due to the uncommon nature of the date format used for sample dates on the LTV project. The date format historically used for the LTV data is yymmdd. This is not considered a standard date format in many software applications, but has been retained in the current project database as a measure of continuity between the historical data archives and the current database. Exact sample dates for point intercept sampling were not maintained in the historical data archive. Therefore, sample dates prior to the 2006 sample period only indicate the year in which the plot was sampled.

2. **Plot –** This field contains the unique plot number assigned to each LTV plot. The Point Intercept table is related to the Master Plot table through the plot field.

3. **Taxon_Code** – The taxon code is a unique, permanent numerical code assigned to each species or non-vascular cover entity (i.e. bare ground). The Point Intercept table is related to the Master Species table through the taxon_code field.

4. **Hits** – The hits field indicates the number of times a given species or non-vascular entity (if a vascular species wasn't present) was intercepted on a given plot during each sampling period.

5. **Year –** The year in which the data were collected is documented in this field. It was added to simplify data summarization because the Date field has not been maintained in a standard format.

4.2.3.2 Additional Comments on the Point Intercept Table

Point intercept data have been archived at the plot level. Consequently, cover data from point intercept sampling can only be summarized at the plot level. For example, absolute cover of a species or group of species can be obtained by dividing the number of "hits" on that species or group of species by the total number of points sampled across the entire plot. In most cases, 50 point frames are sampled per plot and each frame has 36 points, so a total of 1800 points are sampled. It should also be noted that occasionally more than 1800 "hits" are recorded for a plot as a result of a point intercepting multiple strata of vascular vegetation, however, the total number of points sampled is still 1800.

As with the line interception method discussed above, point intercept sampling has been used to estimate the cover of the canopy of shrubs and the basal area of grasses. Forbs have also been measured in terms of canopy cover using the point interception method. Grass cover has been estimated basally because one of the primary goals of the LTV project is to study changes in plant community composition through time rather than annual variability in production. Measuring aerial cover of grasses tends to estimate responses to weather patterns while measuring more stable parameters like basal cover tends to favor estimating long-term changes in populations.

Point frame placement within a plot and the total number of frames sampled in each plot differed from the specified sample protocol during the 1990 and 1995 sampling periods. In 1990, only 40 frames were sampled per plot, 20 along the each transect line on both of the 15m transects. Frame placement along each line also differed from the standard sampling protocol during this sample period, as frames were placed perpendicular and adjacent to the transect line rather than parallel to and centered along the transect line. During the 1995 sample period, only 20 frames were sampled on several plots, while a total of 50 frames were sampled on others. It is unclear how the frames were placed in the plots where only 20 frames were sampled. All of the deviations from the sample protocols are noted in the Sample Year metadata table. This table should be referenced to ensure accurate summary statistics when estimating cover from the Point Intercept table.

4.2.4 Photos-2006

The Photos-2006 data table is currently incomplete. It is included in the current LTV project database simply as a concept. We hope that it will eventually contain hyper-links to the actual plot photos as well as some additional information about the photos such as lens length, shutter speed, aperture setting, etc. All plot photos available from all sample periods were archived in a digital format in anticipation of completing historical photo data table in future sample periods.

Literature Cited

Anderson, J. E., and R. Inouye. 1999. Long-term vegetation dynamics in sagebrush steppe at the Idaho National Engineering and Environmental Laboratory. Center for Ecological Research and Education, Department of Biological Sciences, Idaho State University and Environmental Science and Research Foundation, Idaho Falls, ID.

Colket, E. C., and S. C. Bunting. 2003. Long-term vegetation dynamics and fire effects at the Idaho National Engineering and Environmental Laboratory. Department of Rangeland Ecology and Management, University of Idaho, Moscow, ID.

Floyd, D. A., and J. E. Anderson. 1982. A new point interception frame for estimating cover of vegetation. Vegitatio **50**:185-186.

McBride, R., N. R. French, A. D. Dahl, and J. E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. IDO-12084, Environmental Sciences Branch, Radiological and Environmental Sciences Laboratory, Idaho Operations Office, U.S. Department of Energy, Idaho Falls.

Olson, G. L., D. J. Jeppesen, and R. D. Lee. 1995. The status of soil mapping for the Idaho National Engineering Laboratory. INEL-95/0051, Idaho National Engineering Laboratory.

USDA-NRCS. 2005. The PLANTS Database (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

5.0 LONG-TERM VEGETATION TRENDS

5.1 Introduction

Sagebrush steppe in the semi-arid, western U.S is considered to be a severely impacted ecosystem across most of its range (Noss 1995). Declines in the extent and condition of sagebrush steppe plant communities are often attributed to fragmentation, exotic species invasion, altered fire regime, conversion to agriculture, and overgrazing by domestic livestock (Knick et al. 2003). As a result, it has become increasingly difficult to study the ecological patterns and processes inherent to native sagebrush steppe plant communities. The Long-Term Vegetation (LTV) plots at the Idaho National Laboratory (INL) Site provide a unique opportunity to study vegetation dynamics in sagebrush steppe across broad spatial and temporal scales. Many LTV plots have had limited exposure to anthropogenic disturbance over the past six decades and remain in relatively good ecological condition.

The LTV plots were sampled for the eleventh time since 1950 during the summer of 2006. The analysis of the 2006 and previously collected data can be summarized under two primary objectives. The first includes characterizing general plant abundance and community composition trends, similar to analyses described in previous LTV reports. The second group of analyses was directed toward characterizing spatial patterns of exotic species invasion and the relationships between distribution and abundance patterns of non-native species occurrence over more than 50 years.

5.2 Methods

5.2.1 Study Area

The Long-Term Vegetation (LTV) Transects and associated plots occur on and immediately adjacent to the INL Site within the Upper Snake River Plain, Idaho. Two macro-transects are located perpendicular to one another and intersect near the center of the INL Site. Both transects cross the entire length and extended somewhat beyond the boundaries of the INL Site. The INL Site is located on 2315 km^2 of land that was withdrawn from the public domain by the Department of Energy in 1950 and 1957.

The INL Site is positioned at the northern extent of the Great Basin and is characterized by cold desert sagebrush steppe vegetation. Plant communities on the INL Site have been classified into between eight and twenty vegetation types (McBride et al. 1978a, McBride et al. 1978b, Anderson et al. 1996a, Anderson et al. 1996b). Annual precipitation averages 208 mm, with May and June typically being the wettest months. Snow cover may persist for two weeks to several months in the winter. Mean annual temperature for the INL Site is 5.6 °C; however, high diurnal and seasonal temperature fluctuations are normal (Anderson and Inouye 2001b). Windy conditions are typical and closely restricted to two primary directions. Wind direction is predominately from the southwest, but changes to the northeast for a few early morning hours daily. Mean elevation of the INL Site is 1500 m. Surficial geology is strongly influenced by volcanic activity and soils include wind blown sand or loess over basalt and a few small alluvial deposits. Because soil movement patterns are influenced by abundant basalt outcrops and frequent windy conditions, transitions between soils types and textures may be quite abrupt. For a more thorough description of the environment see Anderson et al. (1996a).

5.2.2 Survey Methods

The original LTV plots consisted of two, 15.24-m transects that were placed parallel to one another and about 4.5 m apart. An additional transect, 20 m in length, was added to many of the plots in 1985; it was placed parallel to the original transects and about 4.5 m from the second original transect. Cover, density, and frequency were measured on all of the accessible LTV plots in 1950, 1957, 1965, 1975, 1985, 1995, 2001, and 2006. A subset of plots and/or abundance metrics was sampled in 1978, 1983, and 1990.

Density and frequency were measured using twenty, 0.3 x 1.0 m quadrats located along the original transects of each plot. Cover was estimated using line interception in all study years and point interception was used on most of the plots during the 1985 sample year and all sample periods thereafter. Line intercept data were collected along both original transects and point intercept data were collected using 50 point frames placed along all three transects. Density and frequency data and point interception data were collected for all taxa and line interception data were collected for perennial grasses and shrubs. Line interception measurements follow guidelines suggested by Canfield (1941) and point interception data were collected using a method developed by Floyd and Anderson (1982). See Chapter 3 for additional sampling details.

5.2.3 Data Analysis

Data were analyzed using regressions and one- and two-way ANOVAs (Zar 1999). Although a repeated measures design is the most appropriate statistical model given the permanent nature of the LTV plots, we were only able to use repeated measures ANOVAs for a limited group of analyses. Repeated measures tests are sensitive to balanced experimental designs, and in many cases data missing from the historical archives and inconsistencies in which plots were sampled from one sample period to the next led to unbalanced designs that were not amenable to repeated measures tests.

The first objective of this study period, updating analyses previously used to characterize trends in species abundance and community composition, was addressed using both point- and line-interception cover data on the core plots. The core plots are a subset of the LTV plots located in the center-most area of the INL Site which have been sampled in each of the 11 sample periods. These plots have had the least exposure to anthropogenic disturbance over the past 60 years and are considered to be the most homogenous, representative examples of sagebrush-dominated plant communities on the INL Site. See Anderson and Inouye (2001a) and Chapter 2 for details regarding the classification and definition of the core plots.

An updated cover by species table for 2006 was compiled using the point-interception data as it is the only cover metric that samples all taxa on a common scale. Long-term trends in functional groups of perennial species were characterized using line-interception data. Cover data for annual species were not collected prior to the initiation of point-interception methods in 1985, precluding cover analyses of those functional groups for the entire study period (1950-2006).

The consistency with which line intercept data were collected in the core plots allowed us to analyze long-term trends of the perennial functional groups using repeated measures ANOVA's. Significance was determined at the $\alpha = 0.05$ level and the Holm-Sidak method (Sidak 1967) was used for multiple comparisons.

We used simple linear regressions to update a comparison of plot-level species richness over the 56 years in which data were collected. This analysis is restricted to perennial species in the core plots. Since a regression was performed on each three functional groups, we applied a Bonferroni correction (Zar 1999), which established a significance level of $\alpha = 0.017$.

The second objective of the study period, characterizing the distribution and abundance patterns of non-native, annual species from 1950 through the current study period, was addressed using density/frequency data on all of the LTV plots sampled during each of 8 sample periods in which all available plots were sampled. The three sample periods during which only the core plots were sampled were omitted from the non-native species analyses because we were interested in invasion patterns over as large a spatial scale as possible. The distributions of plots in which non-native species and functional groups occurred were mapped by density class for each sample period. Each plot was assigned to a density class based on plot density of the target species or functional group and density class ranges were chosen to approximate logical breaks along an exponential growth curve. We further analyzed changes in the density and frequency of annual species over the 8 sample periods using one-way ANOVAs. Repeated measures designs could not be used due to inconsistencies among years in terms of which plots were sampled and represented in the historical data archives. The Holm-Sidak method was again used for multiple comparisons and significance was determined at the $\alpha = 0.05$ level.

5.3 Results and Discussion

5.3.1 Perennial Species Trends

5.3.1.1 Point-Interception Data

Table 5-1 shows the most common species and the mean cover of each summed into functional groups on the core plots during the 2006 sample period. Mean shrub cover was substantially higher than cover from any other functional group, and green rabbitbrush (*Chrysothamnus viscidiflorus*) was the most abundant shrub on the core plots. Wyoming big sagebrush cover was less than 5% and total big sagebrush cover (including basin big sagebrush) averaged just over 7% in 2006. Mean perennial grass cover was about half of that of shrubs, but it is important to note that basal cover measurements of grasses generally underestimate the importance of those species in a plant community in a given year (Anderson and Inouye 2001). Needle and thread (*Hesperostipa comata*) was the most abundant perennial grass species on the core plots in 2006.

Table 5-1. Mean percent cover of vascular plants sampled on 43 LTV plots using point-intercept methods during the 2006 sample period. Species are listed in order of descending cover values within each functional group. Cover is reported for each species having an absolute cover value > 0.1%. Constancy indicates the number of plots in which a species occurred and cover normalized by constancy indicates the mean cover of a species averaged across only the number of plots in which it occurred.

Plant Species	Absolute Cover (%)	Constancy	Cover (%) Normalized by Constancy
Shrubs			
Chrysothamnus viscidiflorus	6.902	41	7.238
Artemisia tridentata ssp. *wyomingensis*	4.885	30	7.002
Artemisia tridentata ssp. *tridentata*	2.495	11	9.753
Grayia spinosa	0.999	9	4.772
Linanthus pungens	0.807	18	1.929
Tetradymia canescens	0.415	7	2.548
Krascheninnikovia lanata	0.366	5	3.144
Ericameria nauseosa	0.101	5	0.867
Others (n = 5)	0.130		
Total Shrub Cover	**17.10**		
Perennial Graminoids			
Hesperostipa comata	3.238	31	4.491
Achnatherum hymenoides	1.159	38	1.311
Elymus lanceolatus	1.003	31	1.391
Agropyron desertorum	0.952	6	6.824
Elymus elymoides	0.935	29	1.387
Pascopyrum smithii	0.824	10	3.544
Poa secunda	0.450	28	0.690
Others (n = 6)	0.202		
Total Graminoid Cover	**8.76**		
Perennial Forbs			
Schoenocrambe linifolia	0.775	32	1.042
Phlox hoodii	0.453	26	0.750
Eriogonum ovalifolium	0.264	16	0.708
Astragalus lentiginosus	0.189	15	0.541
Stephanomeria spinosa	0.119	5	1.022
Others (n = 24)	0.836		
Total Perennial Forb Cover	**2.64**		
Succulents			
Opuntia polyacantha	**0.40**	33	0.52
Native Annuals and Biennials			
Lappula occidentalis	0.357	24	0.639
Eriogonum cernuum	0.249	16	0.670
Gayophytum diffusum	0.230	16	0.618
Eriastrum wilcoxii	0.167	19	0.377
Cordylanthus ramosus	0.121	6	0.870
Others (n = 13)	0.377		
Total Native Annual/Biennial Cover	**1.50**		
Introduced Annuals and Biennials			
Alyssum desertorum	2.672	26	4.419
Bromus tectorum	0.771	27	1.228
Salsola kali	0.525	10	2.256
Descurainia sophia	0.141	11	0.551
Sisymbrium altissimum	0.137	7	0.841
Halogeton glomeratus	0.121	6	0.870
Tragopogon dubius	0.006	3	0.093
Total Introduced Annual/Biennial Cover	**4.37**		
Total Vascular Plant Cover	**34.77**		

During the 2006 sample period, mean cover of introduced annuals and biennials was several times higher than mean cover of native annuals and biennials. Colket and Bunting (2003) cautioned that introduced annuals may be replacing native annuals at the INL Site. While the LTV data aren't sufficient to test this hypothesis due to the intermittent nature of the data collection and the potential influence of precipitation on the cover of annual functional groups, they do indicate that at least in some years, introduced annual species are more abundant than their native counterparts. Among introduced annuals, desert madwort (*Alyssum desertorum*) was the most abundant species, and it is notable that mean cheatgrass (*Bromus tectorum*) cover was below 1% on the core plots in 2006.

In addition to mean, absolute cover we also considered constancy and the cover of each species normalized by constancy in the analysis of the 2006 point-intercept cover data. Constancy was considered to be the number of plots in which a given species occurred out of the 43 core plots used in the analysis. Percent cover normalized by constancy was derived by averaging the cover of a species over only the number of plots in which it occurred, as opposed to averaging the percent cover of a species over all 43 plots. These metrics were used to assess abundance/distribution patterns of individual species, such as identifying which species tended to have wide distributions and low cover and which species tended to have more limited distributions but higher abundance in the communities where they occur.

The difference between mean absolute cover and cover normalized by constancy was greatest for basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) and crested wheatgrass (*Agropyron desertorum*). A relatively high difference between these two metrics indicates that a species has a patchy distribution across the core plots, but is locally abundant where it occurs. This result was expected for basin big sagebrush since stands dominated by this subspecies at the INL Site have been documented to have a patchy distribution related to abrupt changes in soil texture and depth (Shumar and Anderson 1986). Crested wheatgrass has not been planted on any of the LTV plots, so we did not anticipate the relatively high cover normalized by constancy value for this species.

Several core plots have been burned by wildland fire over the past 15 years, resulting in a loss of sagebrush from many of the affected plots. However, the cover of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) was only a few percent higher when normalized across only the plots that still contained this big sagebrush subspecies. There are two possible explanations for this result. The first is that some of the burned plots were not excluded from the constancy metric because they did contain at least a few Wyoming big sagebrush shrubs, either as a result of unburned islands or as individuals that were recruited post-fire. The other possibility is that the core plots with no sagebrush recorded in the point intercept data lack sagebrush cover due to causes other than fire. These possibilities are not mutually exclusive and will be explored in greater detail using results from additional analyses discussed below.

A final pattern worth noting in the 2006 point-intercept data is related to the abundance and distribution of cheatgrass. Constancy of this species was relatively high in 2006; it occurred in nearly two-thirds of the core plots, only three plots fewer than Wyoming big sagebrush. Interestingly, absolute cover of this species was quite low, especially when compared to other species and functional groups. The combination of high constancy and low cover indicates that cheatgrass was widely distributed but was not a dominant component of the plant community across the core plots in 2006.

Comparing the 2006 point-intercept data table (Table 5-1) with a similar table generated from the 1995 point-intercept data (Table 5-2, reproduced from Anderson and Inouye 2001) revealed that, in general, total cover values across the major functional groups only varied by a few percent between the two study periods. An obvious exception is in the native annuals and biennials functional group; total cover was lower in 2006 than in 1995 by nearly five-fold. The lack of variability in the total cover of the introduced annuals and biennials functional group between the two sample periods is remarkable when compared to the magnitude of change in equivalent functional group of native species.

Table 5-2. Mean percent cover of vascular plants sampled on 47 LTV plots using point-intercept methods during the 1995 sample period. Species are listed in order of descending cover values within each functional group. Cover is reported for each species having an absolute cover value > 0.1%. Table reproduced from Anderson and Inouye (1995).

Plant Species	Absolute Cover (%)	Relative Cover (%)
Shrubs		
Artemisia tridentata ssp. *wyomingensis*	9.448	25.152
Chrysothamnus viscidiflorus	7.655	20.132
Artemisia tridentata ssp. *tridentata*	1.699	4.465
Linanthus pungens	0.539	1.417
Grayia spinosa	0.417	1.100
Atriplex confertifolia	0.352	0.926
Tetradymia canescens	0.347	0.914
Krascheninnikovia lanata	0.273	0.718
Others (n = 4)	0.148	0.423
Total Shrub Cover	**19.74**	**51.88**
Perennial Graminoids		
Elymus elymoides	1.460	3.838
Hesperostipa comata	1.376	3.617
Elymus lanceolatus	0.985	2.588
Agropyron desertorum	0.567	1.492
Achnatherum hymenoides	0.405	1.066
Pascopyrum smithii	0.253	0.665
Poa nevadensis	0.181	0.475
Pseudoroegneria spicata	0.149	0.392
Poa secunda	0.139	0.367
Others (n = 6)	0.118	0.311
Total Graminoid Cover	**5.63**	**14.81**
Perennial Forbs		
Phlox hoodii	1.136	2.986
Astragalus lentiginosus	0.306	0.805
Astragalus filipes	0.236	0.621
Erigeron pumilus	0.154	0.404
Astragalus ceramicus	0.148	0.388
Psoralea lanceolata	0.130	0.342
Phacelia hastata	0.128	0.336
Others (n = 36)	0.617	1.622
Total Perennial Forb Cover	**2.85**	**7.50**
Succulents		
Opuntia polyacantha	**0.50**	**1.31**
Native Annuals and Biennials		
Descurainia pinnata	0.748	1.967
Gayophytum diffusum	0.707	1.858
Lappula redowskii	0.573	1.507
Gilia sinuata	0.522	1.373
Cordylanthus ramosus	0.517	1.358
Collomia tenella	0.369	0.969

Eriastrum sparsiflorum	0.293	0.771
Machaeranthera canescens	0.273	0.718
Eriogonum cernuum	0.232	0.609
Chenopodium leptophyllum	0.204	0.537
Cryptantha scoparia	0.182	0.479
Chaenactis fremontii	0.167	0.438
Others (n = 16)	0.264	0.693
Total Native Annual/Biennial Cover	**5.05**	**13.28**
Introduced Annuals and Biennials		
Bromus tectorum	2.280	5.994
Sisymbrium altissimum	0.710	1.868
Descurainia sophia	0.656	1.724
Alyssum desertorum	0.563	1.479
Others (n = 5)	0.053	0.14
Total Introduced Annual/Biennial Cover	**4.26**	**11.21**
Unknowns	0.008	0.021
Total Vascular Plant Cover	**38.04**	**100.00**

In both data tables, species were listed in descending order of abundance within their respective functional groups and only species with greater than 0.1% cover were included individually. Therefore, the position of a species on the list represents the rank of that species with regard to its importance within a given functional group. Although most of the species represented in the 1995 cover table were also included in the 2006 cover table, the rank of species within most functional groups changed dramatically between the two study periods. Consequently, the general stability in functional group cover from one sample period to the next did not appear to be a result of stability in the cover of individual species between the two sample periods.

The long-lived nature and woody growth habit of shrubs would presumably render species of that functional group the least susceptible to short-term cover variations. However, by the 2006 sample period, Wyoming big sagebrush cover fell by nearly half of its 1995 value on the LTV core plots. Green rabbitbrush replaced Wyoming big sagebrush as the most abundant shrub in the point-intercept data in 2006. When cover of both big sagebrush shrub subspecies is combined, total sagebrush cover is only a few tenths of a percent greater than that of rabbitbrush.

Other notable changes in cover and rank of species between the two sample periods occur within the perennial graminoids and introduced annuals and biennials functional groups. The mean absolute cover of some perennial grass species including needle and thread, Indian ricegrass (*Achnatherum hymenoides*), and western wheatgrass (*Pascopyrum smithii*) more than doubled across the core plots between the two sample periods, which resulted in a change of rank among graminoid species between 1995 and 2006. Anderson and Inouye (2001) suggested that the species in the perennial grasses "guild," or functional group, respond individualistically to temporal environmental variation, a pattern which is supported by the differences in grass cover between the two sample periods. Cover differences between perennial graminoids and the introduced annual, cheatgrass, were also apparent across the core plots between the sample periods. In 1995, cheatgrass was the most abundant grass species in the point-intercept data across the core plots. A modest decrease in cheatgrass cover coupled with slight cover increases in many of the native, perennial grass species over the 11-year period led to cheatgrass being ranked as the 7th most abundant grass species across the core plots in 2006. Three native perennial bunchgrasses two native, perennial rhizomatous grasses, and crested wheatgrass were all more abundant than cheatgrass in 2006.

5.3.1.2 *Line-Interception Data*

Line-interception cover data were used to assess changes in perennial functional groups across the core plots over the 56-year timeframe in which these data were collected. Several time-series analyses presented in previous LTV reports were revisited as a component of this reporting effort (Anderson and Inouye 1988, Anderson and Inouye 1999).

Total cover of native perennial species continued to fluctuate within the previously documented range of variation through the 2006 sample period (Figure 5-1). Changes in mean cover within the shrub and native grass functional groups also remained well within the range of historical variation across the core plots. One-way ANOVAs confirmed statistically significant differences in mean cover values among sample years for total cover and for each of the functional groups. Generally, a few years with the lowest cover values in a given group were significantly different than a few of the years with the highest cover values in the same group (ANOVA results are detailed in Appendix B). Results from similar analyses described in previous LTV reports were interpreted to indicate that although mean cover of functional groups has been anything but static, trends in abundance failed to follow clear, directional trends through time (Anderson and Inouye 1999). This interpretation continues to accurately describe changes in the mean cover of native, perennial functional groups through the 2006 sample period.

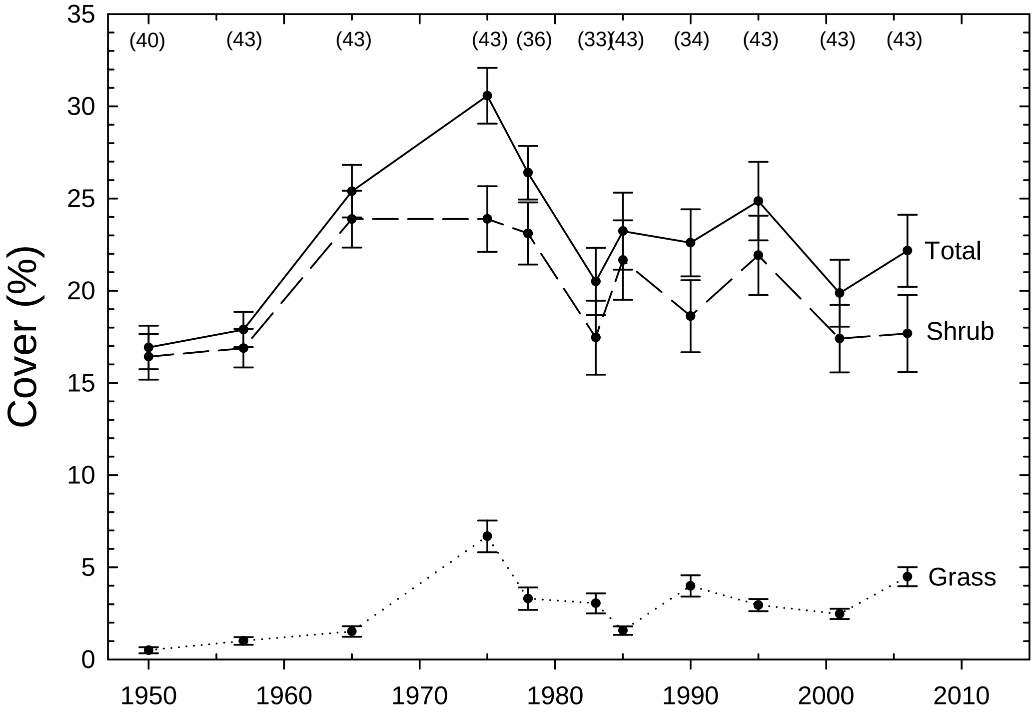


Figure 5-1. Trends in total native perennial species cover, shrub cover, and native perennial grass cover from 1950 to 2006 for the "core" subset of plots on the Long-Term Vegetation Transects at the Idaho National Laboratory Site. Data were collected using line-interception methods and are represented here as means ± 1 SE. Numbers in parentheses at the top of the frame indicate the number of plots for which data were available in each sample year.

Although directional trends in mean cover were not apparent in the shrub functional group over 56-year dataset, we observed obvious trends in a few shrub species. In 2006, sagebrush (*Artemisia tridentata*) cover estimates were slightly higher for line-interception data (about 8%) than they were for point-interception data (about 7% for both subspecies combined). Nevertheless, the general decline in sagebrush cover over the core plots from the 1995 sample period through the 2006 sample period, as summarized in the point interception data (Table 5-1 and Table 5-2), was also discernable in the line-interception data (Figure 5-2). In fact, the line-intercept data indicate that sagebrush cover has been declining since about 1965. ANOVA results confirm that mean sagebrush cover across the core plots was significantly lower in 2006 than it was in either 1965 (the highest value reported) or in 1950 (Appendix B).

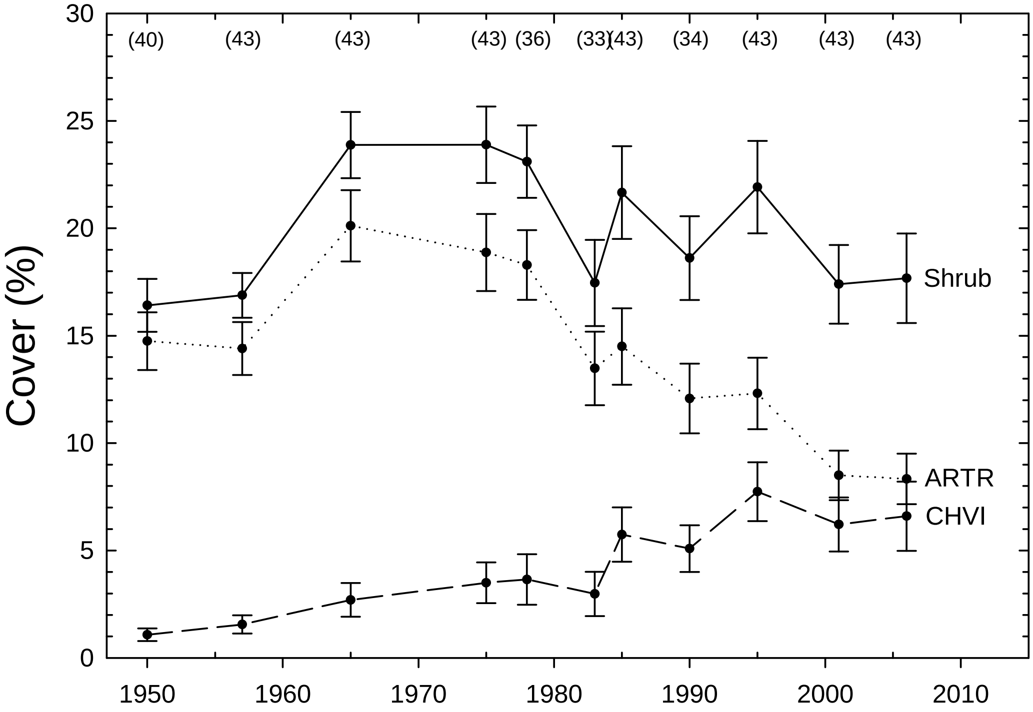


Figure 5-2. Trends in total shrub cover, *Artemisia tridentata* cover, and *Chrysothamnus viscidiflorus* cover from 1950 to 2006 for the “core” subset of plots on the Long-Term Vegetation Transects at the Idaho National Laboratory Site. Data were collected using line-interception methods and are represented here as means ± 1 SE. Numbers in parentheses at the top of the frame indicate the number of plots for which data were available in each sample year.

In direct contrast to the declining trends in big sagebrush cover, mean green rabbitbrush cover has been increasing across the core plots over the study period (Figure 5-2). Green rabbitbrush cover was significantly higher in 2006 than in 1950, 1957, and 1965 (Appendix B). Mean sagebrush cover was significantly greater than mean rabbitbrush cover in each of the first nine sample periods. However, mean cover of these two shrub species were statistically indistinguishable from one another in 2001 and 2006.

We were interested in determining whether more recent declines in big sagebrush cover and concomitant increases in green rabbitbrush cover were related to fire and/or other processes which may have altered local vegetation dynamics over the past few decades. To address this issue, we reanalyzed the shrub species trend data without plots that had burned. Specifically, one core plot that burned in 1996 and six core plots that burned in 2000 were removed from the 2001 and 2006 datasets for the analysis. Three core plots have also exhibited a marked increase in crested wheatgrass cover since 1985 (see discussion below), which may alter ecological processes affecting shrub species composition in those plots. Accordingly, we removed the three plots affected by crested wheatgrass from the analysis as well.

Results for mean big sagebrush cover were similar between the analysis in which plots affected by fire or crested wheatgrass were removed and the analysis using all of the core plots (Figure 5-3). Results from the analysis in which affected plots were removed still indicated a general downward trend in mean cover, and sagebrush cover was significantly lower in 2006 than in 1950 through 1978 (Appendix B). Because removing burned plots did not appreciably change the trend or statistical results, the declining trend in sagebrush cover is not easily explained by losses due to fire and other factors should be considered as possible causes for the continuing decline in sagebrush cover across the core plots.

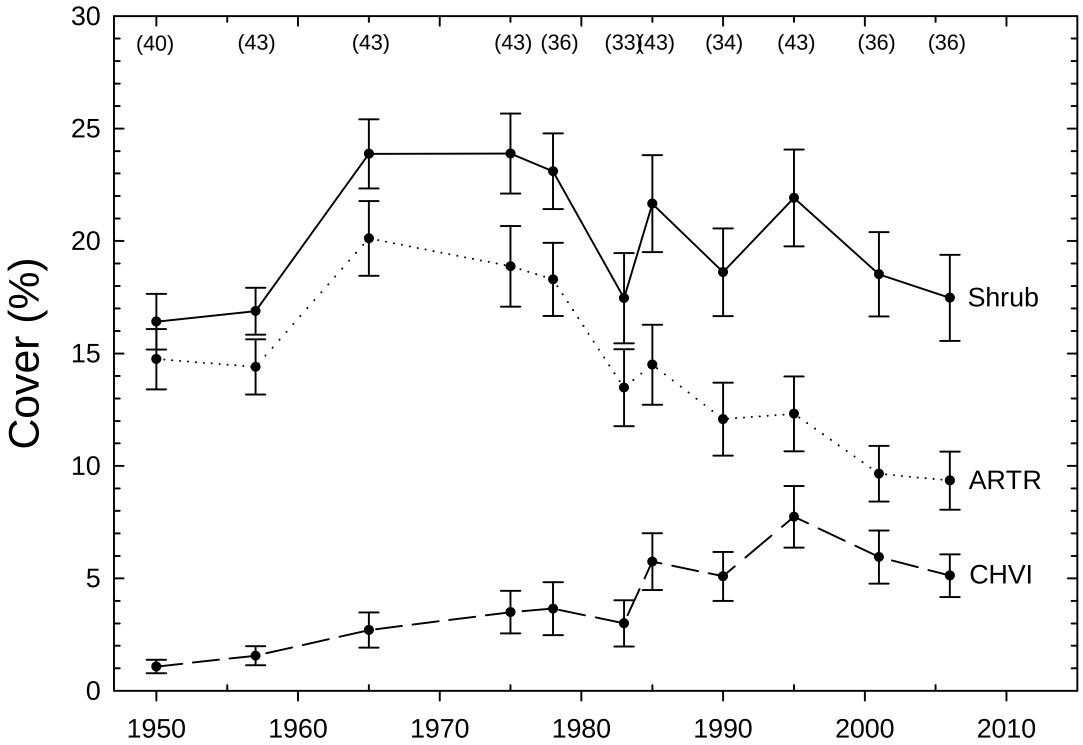


Figure 5-3. Trends in total shrub cover, *Artemisia tridentata* cover, and *Chrysothamnus viscidiflorus* cover from 1950 to 2006 for the "core" subset of plots on the Long-Term Vegetation Transects at the Idaho National Laboratory Site. Plots that were burned in wildland fires were removed from cover estimates for all sample dates subsequent to the fire. Plots in which *Agropyron desertorum* was recorded were also removed from cover estimates after 1995. Data were collected using line-interception methods and are represented here as means ± 1 SE. Numbers in parentheses at the top of the frame indicate the number of plots for which data were available in each sample year.

Removing the plots affected by fire and crested wheatgrass did result in a change in the trend of green rabbitbrush cover (Figure 5-3). Green rabbitbrush exhibited a decline from 1995 through 2006 in the analysis where affected plots were removed, whereas green rabbitbrush cover did not follow a directional change over the same time period in the analysis using all of the core plots. Furthermore, in the analysis where affected plots were removed, 2006 green rabbitbrush cover was not significantly different than cover in any other sample year. Since removing affected plots did change the general trend in rabbitbrush cover across the core plots in the past few decades, it is reasonable to assume that fire and/or crested wheatgrass may have influenced trends in green rabbitbrush cover over that time period.

A comparison of the constancy of both big sagebrush and green rabbitbrush in the core plots through the 56-year data record shows that the number of core plots in which sagebrush occurs has declined slightly in the past two survey periods, but remains relatively high overall (Figure 5-4). This result further supports the conclusion that the declines in cover documented in the line-interception data are likely a result of decreasing trends across many of the plots rather than a loss of big sagebrush from a handful of core plots. The number of plots in which green rabbitbrush occurs has generally trended upward over the entire study period, indicating that green rabbitbrush has become established in more of the core plots through time. Constancy values between the two shrub species differed by about 40% in 1950 and differed by only a few percent in 2006.

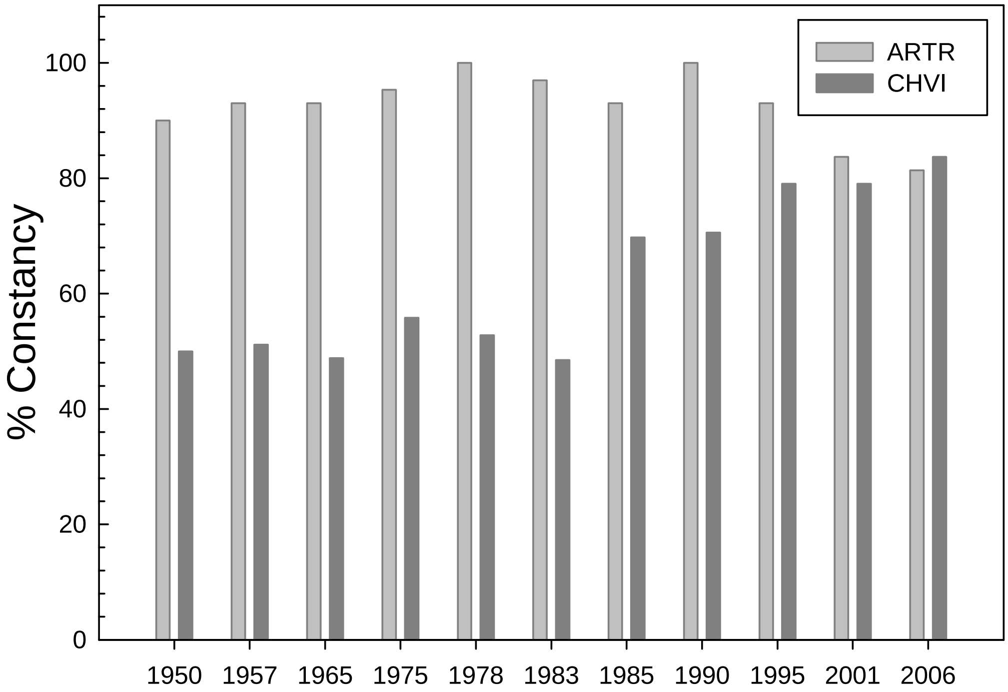


Figure 5-4. Percent constancy for *Artemisia tridentata* and *Chrysothamnus viscidiflorus* in the line interception data from 1950-2006 for the “core” subset of plots on the Long-Term Vegetation Transects at the Idaho National Laboratory Site.

Within the native grasses functional group, Anderson and Inouye (2001) reported dramatic fluctuations in total cover over 45 years; cover values from one sample period to the next often varied several-fold. This pattern has continued through the 2006 sample period and further analysis failed to attribute these fluctuations to changes in the cover of specific functional groups based on the growth form of grass species (Figure 5-5). Mean cover of both bunch grasses and rhizomatous grasses differed significantly from one sample period to another, but no consistent, directional trends were apparent in either functional group (Appendix B). In about half of the sample periods since 1950, bunch grasses had significantly higher (P<0.001) mean cover across the core plots than rhizomatous grasses, and the direction and magnitude of change in cover from one sample period to the next was not consistent between the functional groups based on growth form. The lack of consistency between bunch and rhizomatous grasses suggests that they function differently within a sagebrush steppe plant community and that they are likely responding to different combinations of environmental conditions.

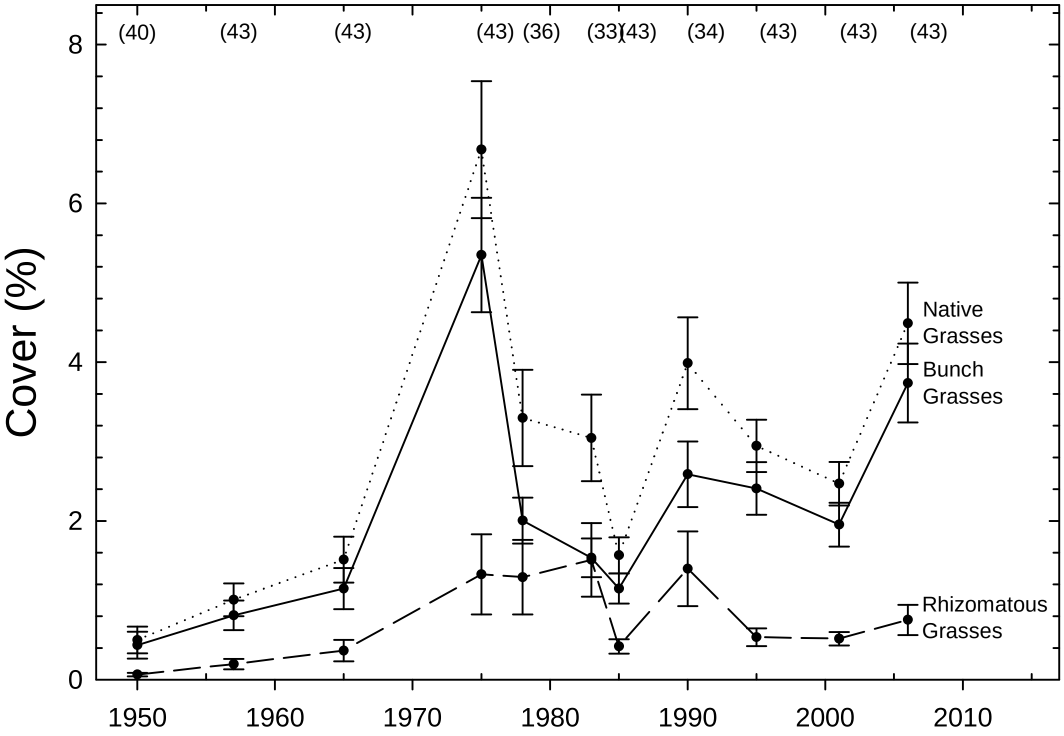


Figure 5-5. Trends in total native perennial grass cover, native perennial bunchgrass cover, and native perennial rhizomatous grass cover from 1950 to 2006 for the “core” subset of plots on the Long-Term Vegetation Transects at the Idaho National Laboratory Site. Data were collected using line-interception methods and are represented here as means ± 1 SE. Numbers in parentheses at the top of the frame indicate the number of plots for which data were available in each sample year.

Prompted by the high cover values for crested wheatgrass when cover was averaged across the only plots in which occurred, as reported in the point-interception data discussed above (Table 5-1), we compared native and introduced perennial grass cover over the 56-year point-interception data set. We found no appreciable introduced perennial grass cover in the line-interception data prior to 1985, after which a positive, linear increase became apparent (Figure 5-6). Average cover of introduced perennial grasses in the line-interception data across the core plots was less than 1% in 2006; however, the linear increase in the absolute cover values from 1985 through 2006 were driven entirely by crested wheatgrass in three plots. The cover differences in crested wheatgrass from one year to the next were not statistically significant (Appendix B), but variability for the cover estimates in each sample period was quite high since crested wheatgrass was present in only three of the 43 core plots.

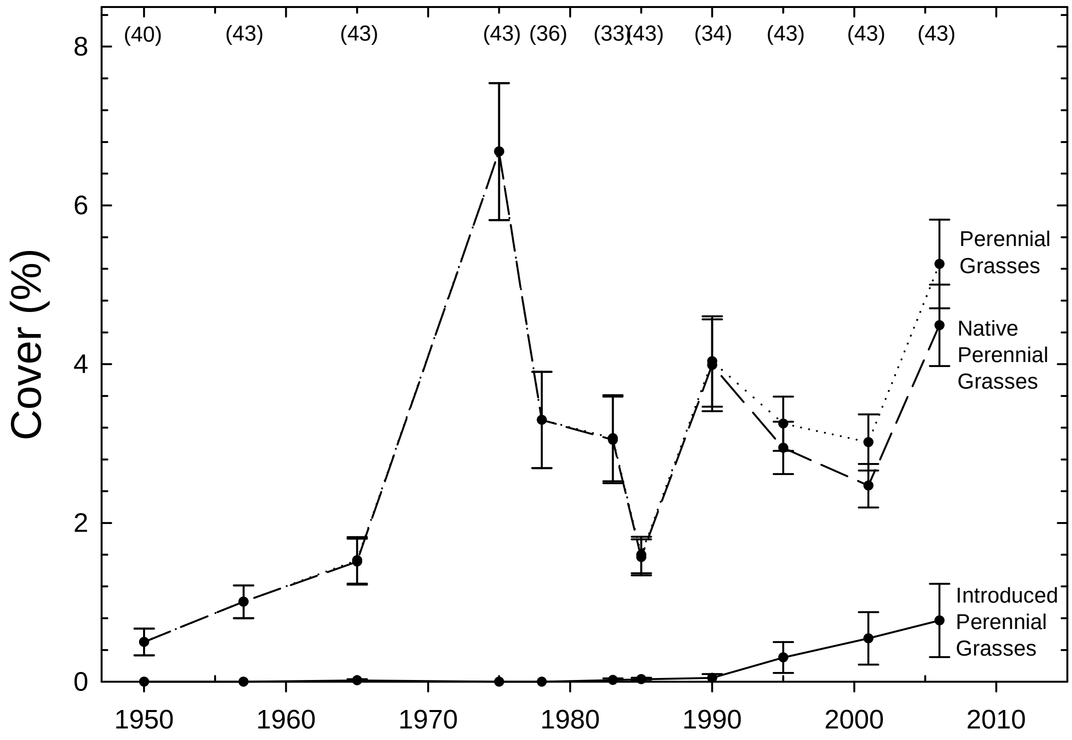


Figure 5-6. Trends in total perennial grass cover, native perennial grass cover, and introduced perennial grass cover from 1950 to 2006 for the “core” subset of plots on the Long-Term Vegetation Transects at the Idaho National Laboratory Site. Data were collected using line-interception methods and are represented here as means ± 1 SE. Numbers in parentheses at the top of the frame indicate the number of plots for which data were available in each sample year.

Because crested wheatgrass was present in only a fraction of the core plots and the increasing trend of this species was noticeable even when averaged across all of the core plots, crested wheatgrass is likely increasing dramatically within those plots where it occurs. An analysis of functional group trends in the three plots where crested wheatgrass occurred confirmed an increase in crested wheatgrass cover from about half a percent in 1985 to over 11% in 2006 (Figure 5-7). Trends in native functional groups also differed in these three plots when compared to trends across all of the core plots. For example, native perennial grass cover generally increased from 1985 to 1990 and remained above 1985 levels through the most recent study period when averaged across the core plots (Figure 5-5). In the three plots with crested wheatgrass, mean native perennial grass cover declined after 1985 and was almost nonexistent in those plots by 2006. Trends in mean total shrub cover are also characterized by a marked decline after 1985 in the plots where crested wheatgrass occurred, as opposed to total shrub cover across all of the core plots, which fluctuated but did not change directionally during the same time period (Figure 5-1). Prior to the 2001 sample period, shrub cover was significantly higher than cover of introduced and native grasses in each of the sample years on the three plots with crested wheatgrass (Appendix B). In the 2001 and 2006 sample periods, mean shrub cover was not statistically different from the other two functional groups.

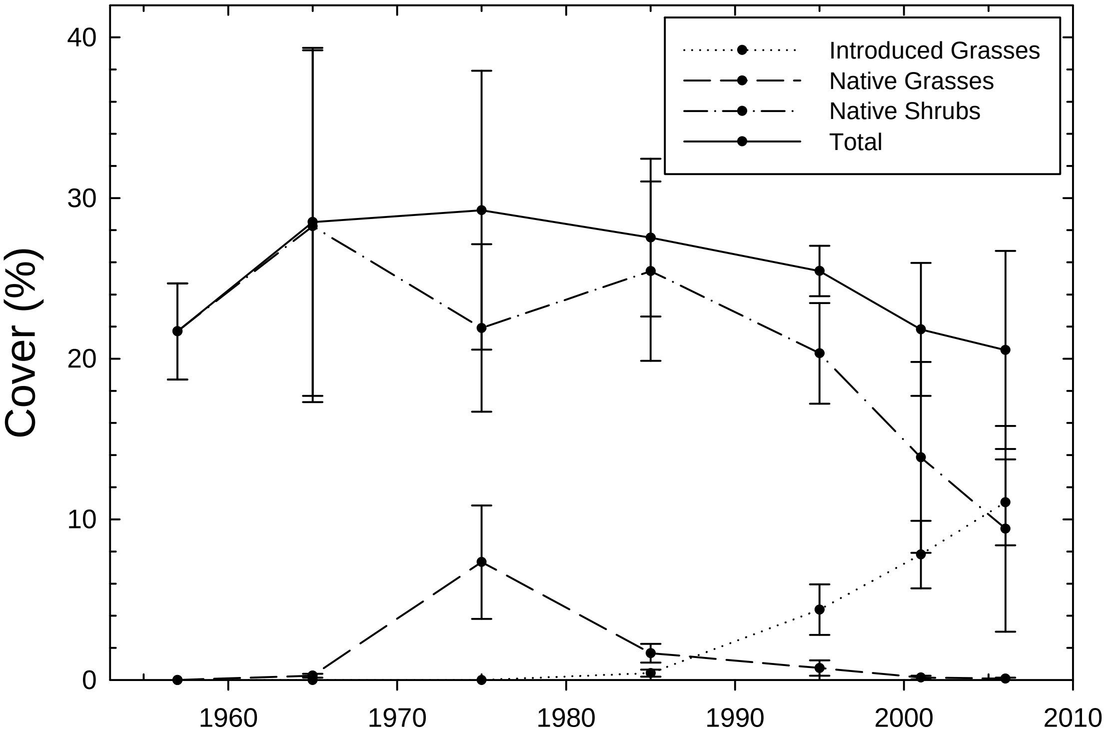


Figure 5-7. Trends in total perennial vegetation cover, introduced perennial grass cover, native perennial grass cover, and shrub cover from 1957 to 2006 for the three of the core plots in which *Agropyron desertorum* has become established. The plots are located on the Long-Term Vegetation Transects at the Idaho National Laboratory Site. Data were collected using line-interception methods and are represented here as means ± 1 SE.

Anderson and Inouye (2001) reported strong positive relationships between time and the mean species richness of native, perennial grasses and shrubs sampled in the line-interception data across the core plots. We updated these analyses with mean species richness of the native, perennial functional groups in 2001 and 2006 to assess whether the strength of the relationships continued to persist over the past decade (Figure 5-8). Regression results indicate that the relationship between time and species richness remains positive and significant for native perennial grasses and shrubs when the latest two sample periods were included in the analysis.

The R^2 values for these relationships also remained high throughout the entire 1950-2006 study period. Overall, total species richness was slightly lower in 2006 than in the previous three sampling periods, but not enough to substantially change the relationship. Lower total species richness in the line-interception data was primarily a result of lower mean native grass species richness within the core plots in 2006.

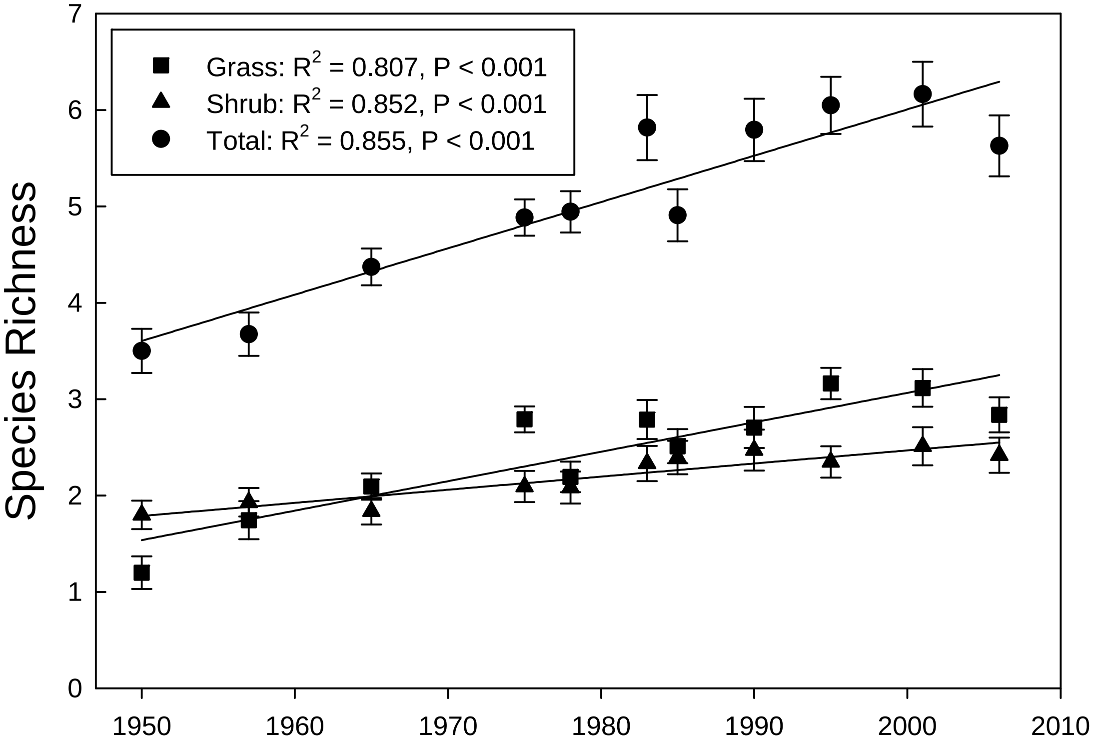


Figure 5-8. Trends in mean total, shrub, and perennial grass species richness in the line-interception data from 1950 to 2006 for the “core” subset of plots on the Long-Term Vegetation Transects at the Idaho National Laboratory Site.

5.3.2 Annual and Biennial Species Trends

5.3.2.1 Density/Frequency Data

The second primary objective related to the 2006 sampling and reporting effort was directed at assessing and characterizing changes in the distribution and abundance of introduced annuals over the entire data set both spatially and temporally. We used density/frequency data for these analyses since it is the only set of abundance data in which annual species were sampled on all plots through the entire 56-year study period. We analyzed trends for introduced annual grasses and introduced annual forbs separately. We also analyzed trends for native annual forbs to provide a standard against which we could compare the distribution and abundance trends of introduced annual species.

Cheatgrass is the only species represented in the introduced annual grass functional group. Anderson and Inouye (2001) reported that cheatgrass was recorded in peripheral plots on and around the buttes beginning in 1950, but it wasn’t recorded in the LTV plots near the central portion of the INL Site until 1975, after which cheatgrass distribution continued to increase. Based on these observations and on reported patterns of cheatgrass invasion elsewhere (Mack 1981, D'Antonio and Vitousek 1992), we hypothesized that we would be able to detect distinct directional, though not necessarily linear, increases in abundance and distribution of cheatgrass through time. We plotted cheatgrass presence and density on a map of the LTV plots from 1950 through the current data collection effort to assess the changes in the spatial pattern of distribution and density through the 56-years over which data were collected (Figure 5-9).

We confirmed that cheatgrass was well represented in some of the peripheral plots by the first sampling effort in 1950 (Figure 5-9a) and that the distribution of cheatgrass across the LTV plots did not change appreciably between the 1950 and 1965 sample periods (data for 1957 and 1965 not shown). Cheatgrass distribution changed dramatically by the 1975 sample period, at which time it was recorded in a handful of peripheral plots where it had not been previously documented and it was recorded in several of the core plots for the first time (Figure 5-9b). From 1975 through 2001, the distribution of cheatgrass across the LTV plots generally increased (Figure 5-9b – Figure 5-9e).

The pattern of increase in abundance and distribution from one sample period to the next was not as predictable as we had expected. We did not find an obvious, directional spatial trend, or "invasion front," where we could systematically follow a pattern of cheatgrass becoming present in plots adjacent to those with cheatgrass presence during the prior sample period. A predictable abundance trend was also unapparent in the analysis of the distribution maps. Although mean cheatgrass density generally increased across the LTV plots between 1975 and 2001, coincident with the increase in distribution, mean cheatgrass density within a given plot wasn't necessarily predictable from one sample period to the next. In some of the LTV plots, cheatgrass density increased from one density class to the next relatively systematically from one sample period to the next, however, mean cheatgrass density declined and cheatgrass even became undetectable in some of the plots over time (Figure 5-9a – 5-9e). Interestingly, the density, and to some extent the distribution, of cheatgrass across the LTV plots declined slightly between the 2001 and 2006 sample periods (Figure 5-9e – Figure 5-9f).

The variability in pattern of cheatgrass distribution and abundance through time can be easily illustrated by following a given plot through time (Figure 5-9a – Figure 5-9f). For example, Plot 36, a plot which hasn't been subject to fire or other known disturbances since the beginning of the LTV data collection effort, lacked cheatgrass in 1950. By 1975, cheatgrass was present in Plot 36 but mean density was less than five individuals per square meter. Cheatgrass density remained less than five individuals per meter squared through the 1985 sample period, but increased to about 160 individuals per square meter by the 1995 sample period and remained at roughly the same abundance level through 2001. From 1950 through 2001, the increasing trend in cheatgrass density on Plot 36 was expected. However, between the 2001 and 2006 sample periods, cheatgrass density decreased to approximately 30 individuals per meter squared, indicating that at the plot level, increases in cheatgrass abundance were reversible during the extended study period.

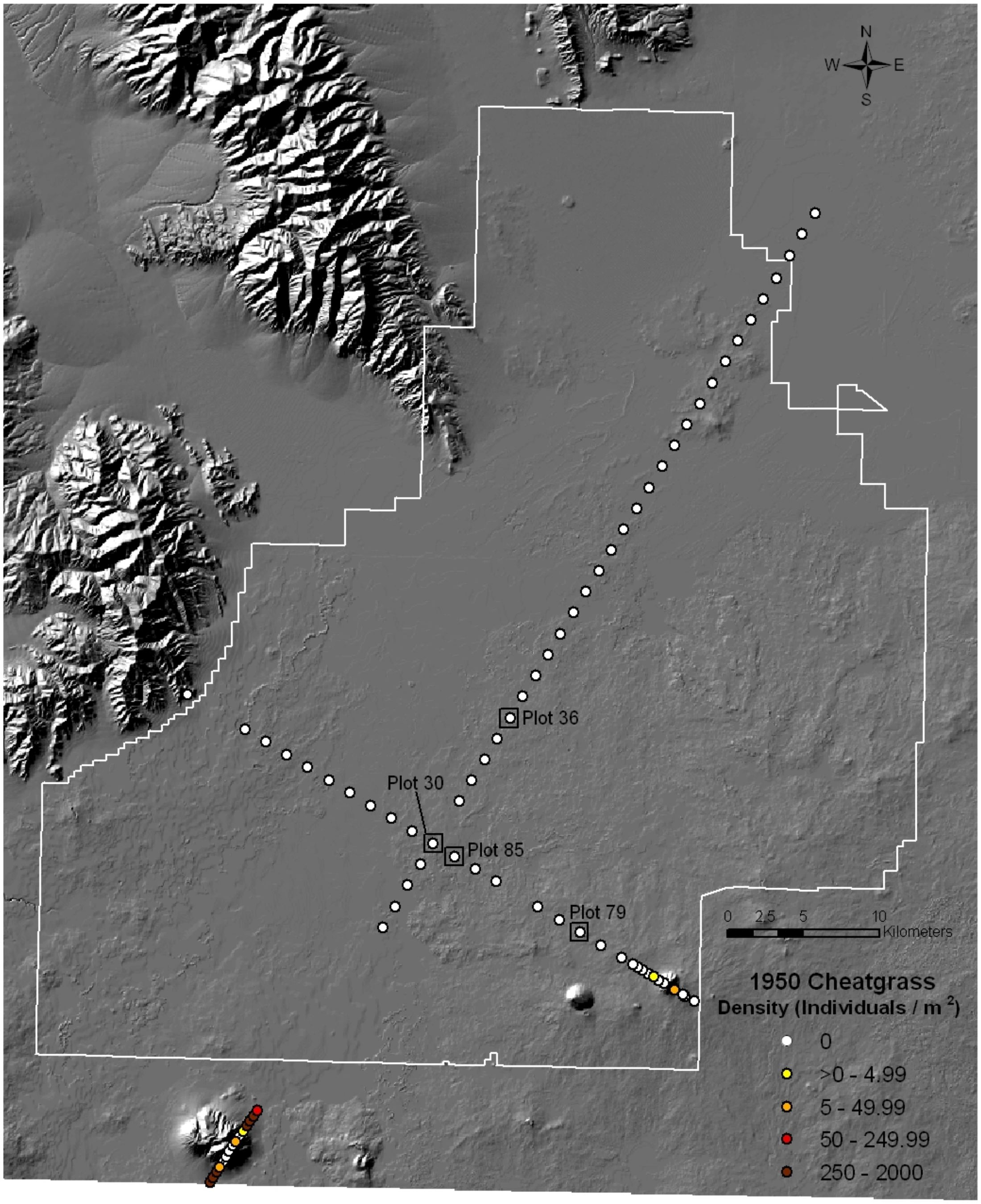


Figure 5-9a. *Bromus tectorum* distribution by density class on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site in 1950.

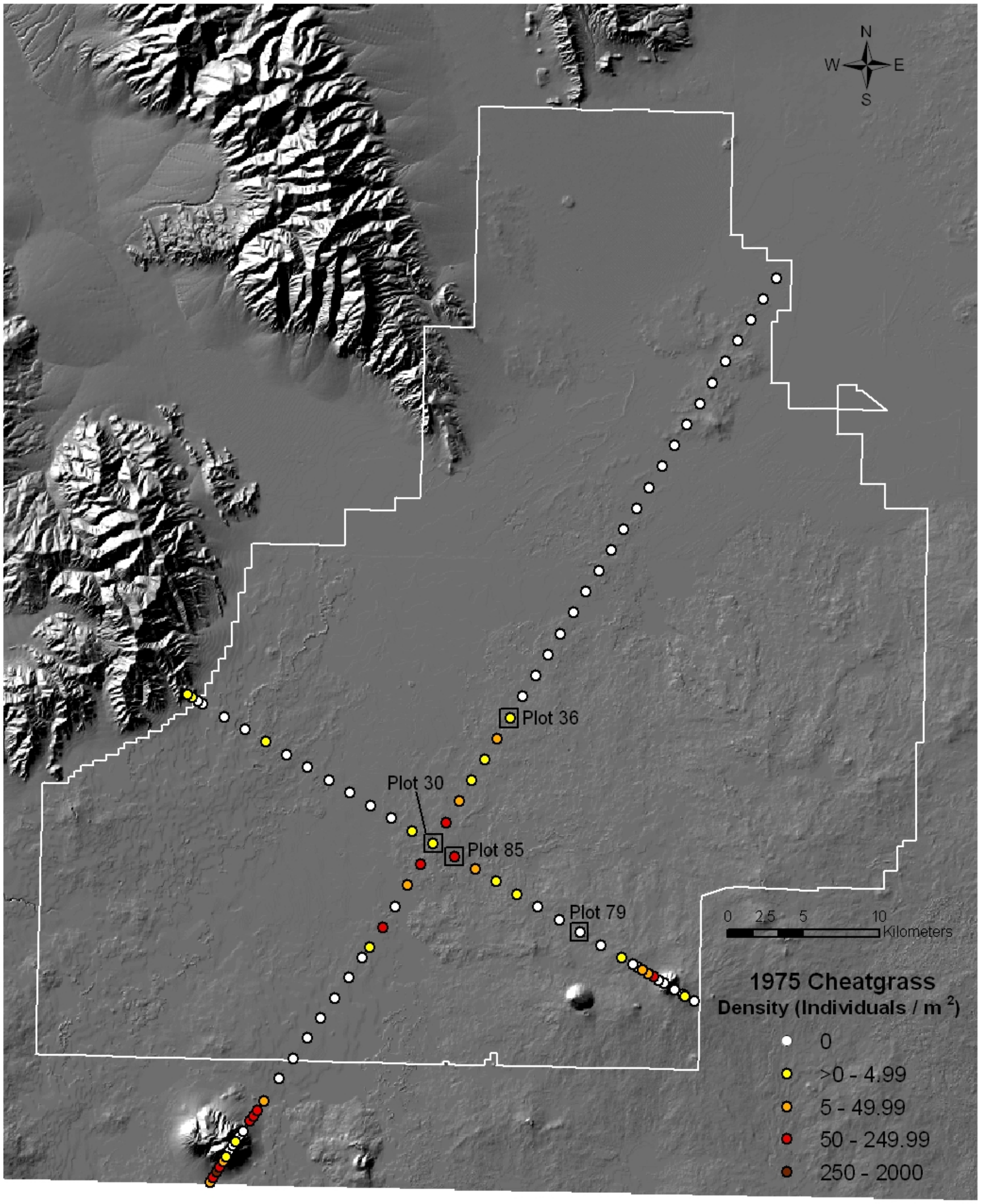


Figure 5-9b. *Bromus tectorum* distribution by density class on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site in 1975.

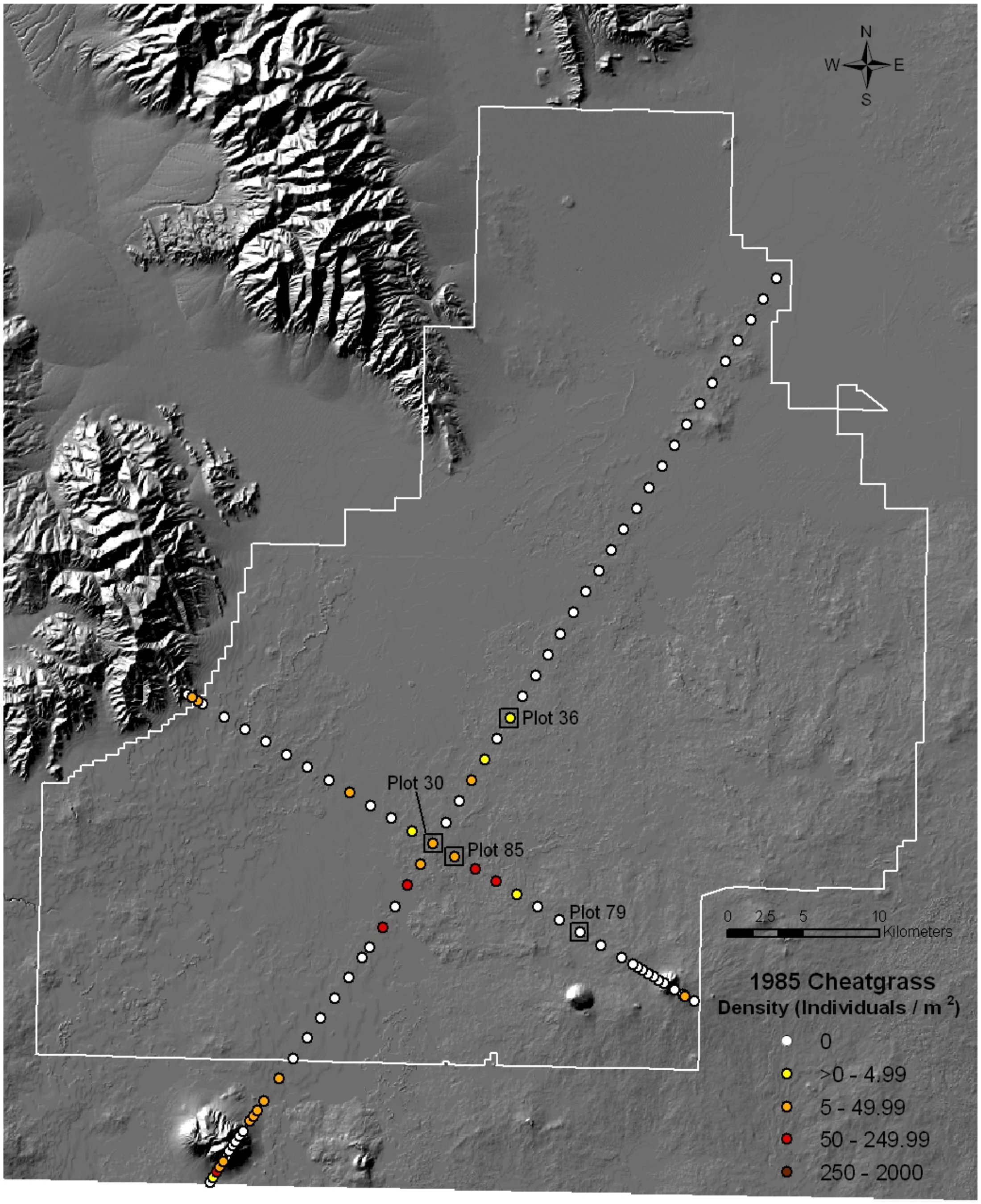


Figure 5-9c. *Bromus tectorum* distribution by density class on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site in 1985.

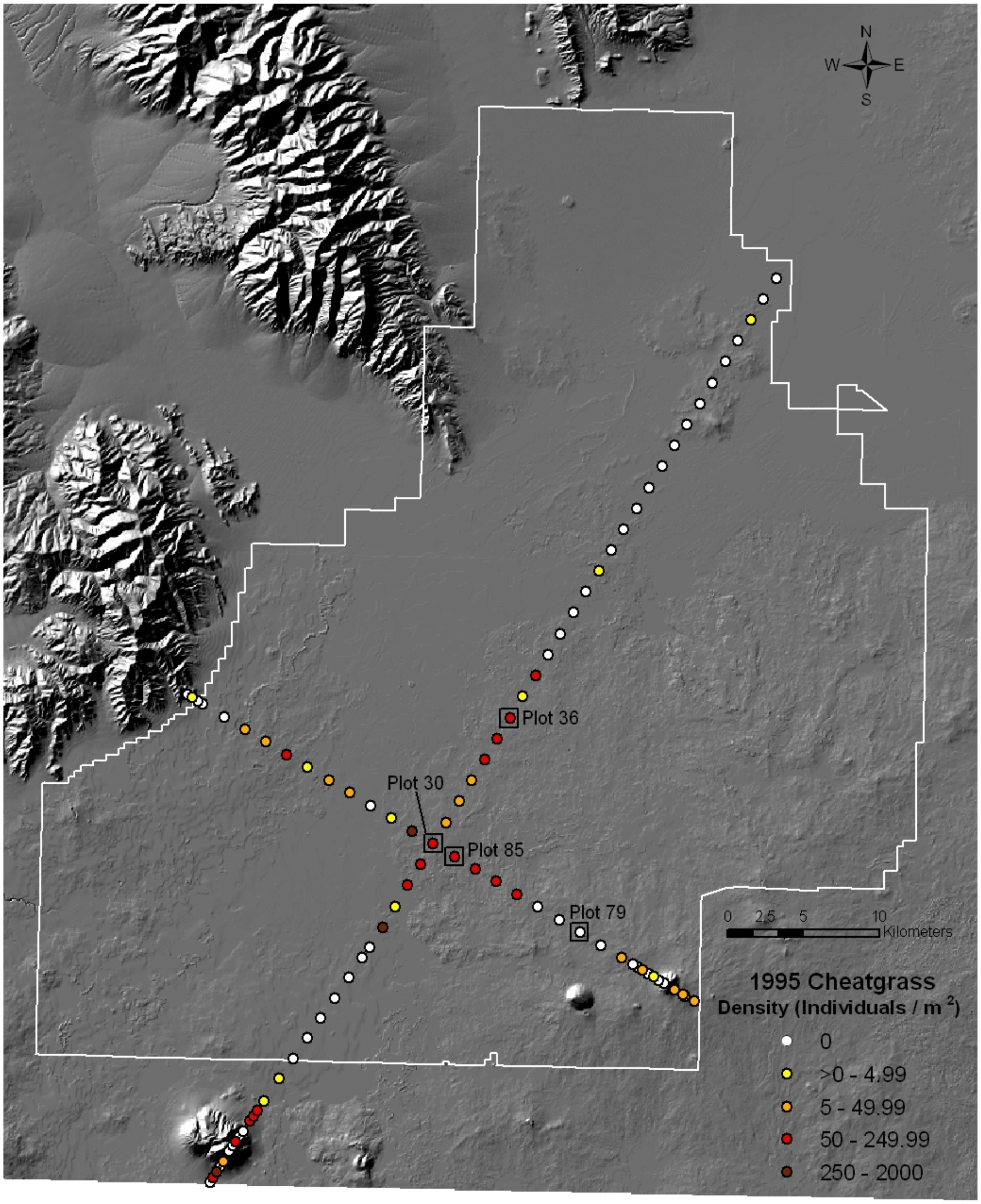


Figure 5-9d. *Bromus tectorum* distribution by density class on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site in 1995.

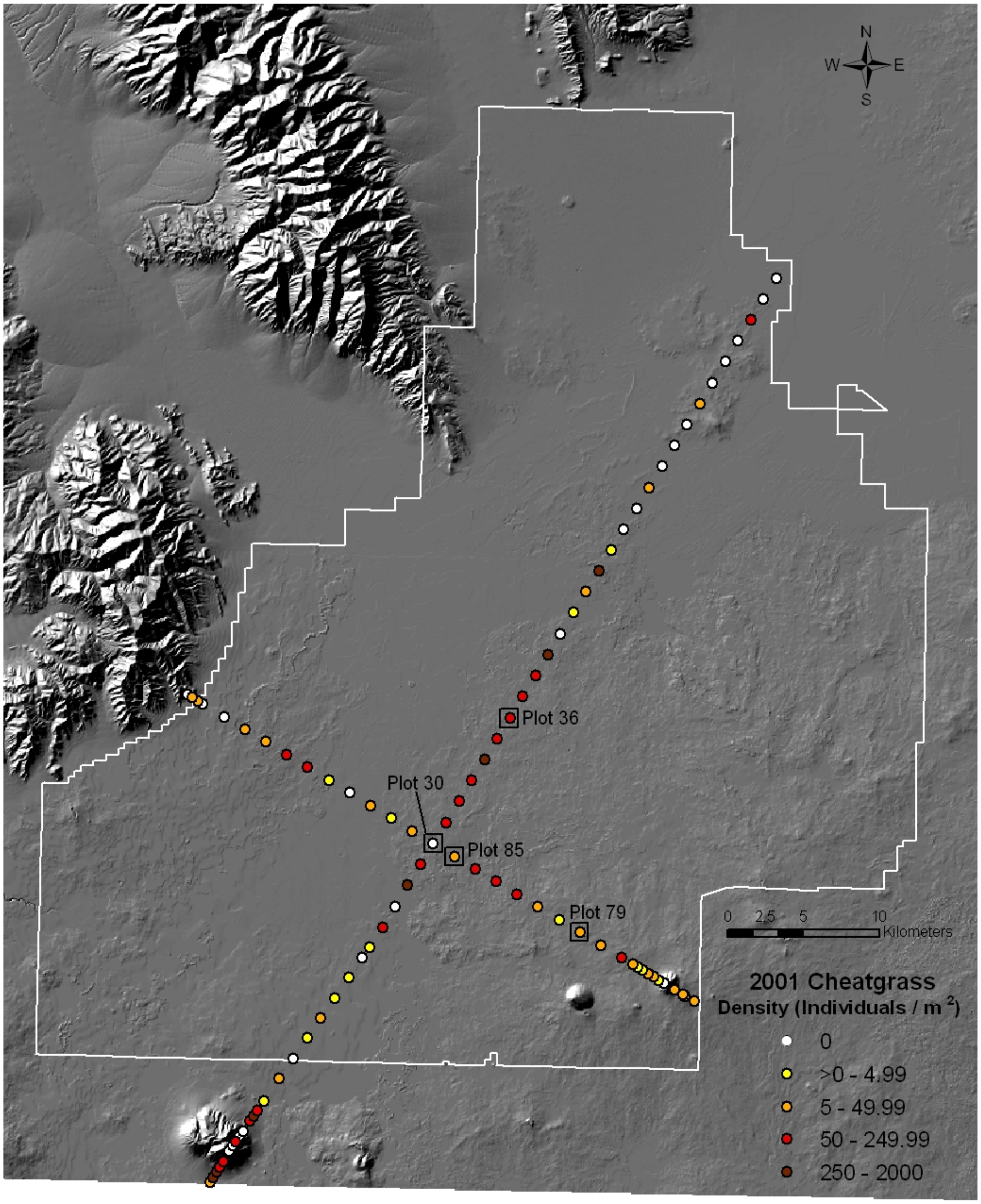


Figure 5-9e. *Bromus tectorum* distribution by density class on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site in 2001.

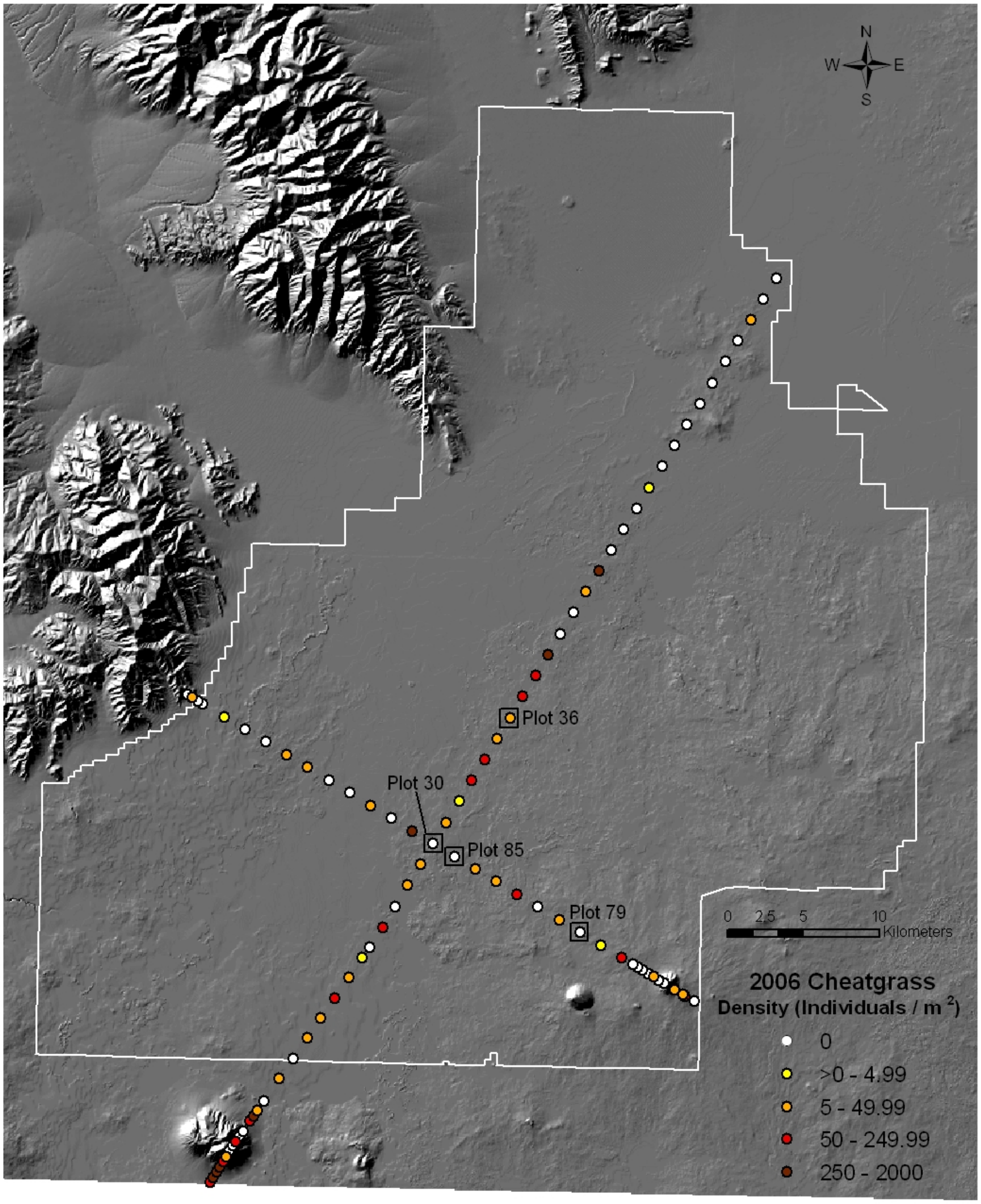


Figure 5-9f. *Bromus tectorum* distribution by density class on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site in 2006.

Furthermore, this pattern was not unique to the relatively undisturbed, Plot 36. Decreases in cheatgrass abundance also occurred on some LTV plots subsequent to fire. Plot 30, which burned in 2000, showed steady increases in cheatgrass density from 1975 through 1995. In an unexpected reversal of trend, however, cheatgrass was not abundant enough in plot 30 during the 2001 or 2006 sample periods to have been recorded in the density frames. Vegetation on plots 79 and 85 also burned in the decade prior to the 2006 data collection and decreases in cheatgrass density occurred on those plots during the sample periods subsequent to the respective fire. Cheatgrass density decreased to undetectable levels in the sample year immediately after the fire in plot 85. In plot 79, cheatgrass became established on the plot after the last sample period pre-fire, but prior to the first sample period post-fire; however, cheatgrass density decreased in abundance by the second sample period after the fire. In short, numerous LTV plots, regardless of fire history, experienced changes in mean cheatgrass density of at least an order of magnitude from one sample period to the next, and on several occasions those changes were decreases rather than increases.

The overall increase in cheatgrass distribution across the LTV plots suggests that by 2001 cheatgrass was widely distributed across the INL Site. However, this general increase coupled with the sporadic nature of cheatgrass presence and the magnitude of change in density in given plot from one sample period to the next indicates that distribution and abundance may fluctuate in response to stochastic environmental factors. Additionally, these combined results suggest that although cheatgrass may become established in a given plot, that plot is not necessarily destined to become dominated by cheatgrass over a given time period. Moreover, a dramatic increase in cheatgrass abundance over one or even several sample periods is reversible. Thus, trends in cheatgrass distribution and abundance across the INL Site appear to be much more stochastic and far less directional and systematic than we had hypothesized, and the susceptibility or resilience of a plot to cheatgrass invasion may be based on very specific conditions at very local scales.

An analysis comparing mean cheatgrass density and mean cheatgrass frequency (the percentage of density frames per plot in which cheatgrass is present) over the 56-year study period confirmed a departure from our hypothesized pattern of increase in abundance through time. Mean density, that is the mean number of individuals per square meter estimated in each plot and averaged across all LTV plots, did tend to track changes in distribution through time. As with cheatgrass distribution, mean density of cheatgrass followed a generally increasing trend from 1975 through 2001 but was slightly lower in the 2006 study period than it was in 2001. Frequency values also appear to track changes in the distribution and mean density of cheatgrass through time. The only pair-wise comparison of sample periods for which mean cheatgrass density was significantly different was between 1985 and 2001 (Appendix B). Mean density of cheatgrass was not significantly different between 1950 and 2006 across the LTV plots (Figure 5-10). In fact, mean cheatgrass density was only about 12 individuals per square meter greater in 2006 than it was in 1950. In 2006, mean cheatgrass density was about 60 individuals per square meter. For comparison cheatgrass densities have been reported to average 10,000 individuals per square meter in cheatgrass-dominated stands (Young and Longland 1996).

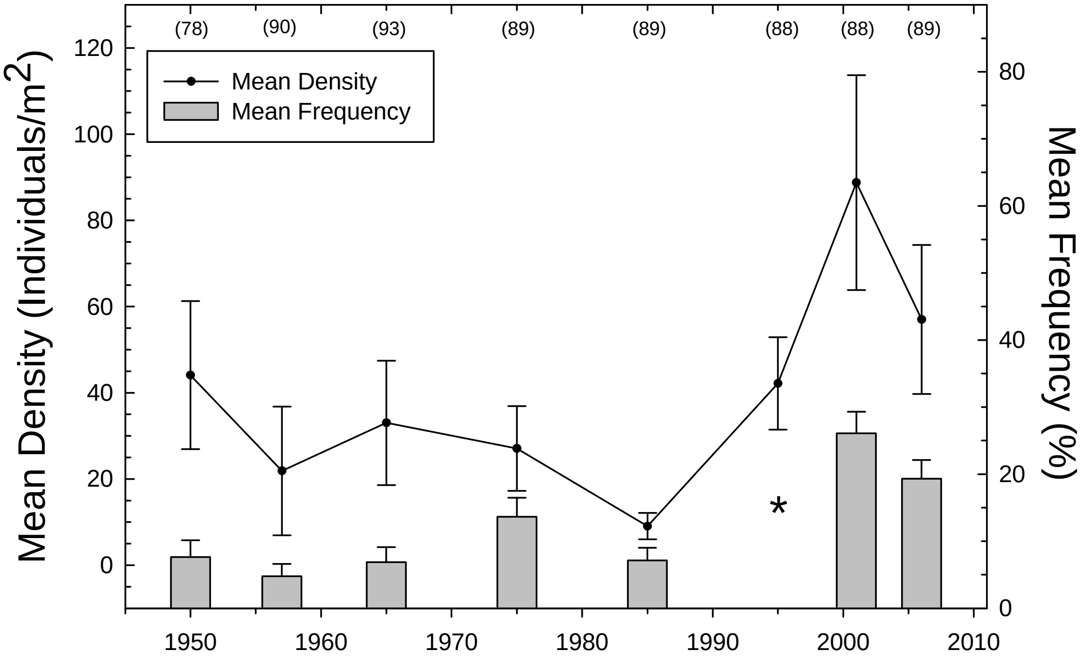


Figure 5-10. Density and frequency trends for *Bromus tectorum* on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site from 1950 to 2006. Data are means ± 1 SE. *Frequency data are missing from the 1995 data archives.

Taken together, the distribution, density, and frequency data demonstrate that changes in cheatgrass occurrence over the 56-year study period were complicated and could not be easily summarized by simple trend analyses. Cheatgrass distribution and abundance on the INL Site appears to be quite dynamic, and changes are not necessarily directional from one sample period to the next. A few generalizations that can be made from these results are that the distribution of cheatgrass has increased across the INL Site, it is currently present and widely distributed across the LTV study site, its mean density has not increased markedly over the past 56 years, though the increase in distribution indicates that seed is now widely available and susceptible plant communities are at risk of invasion.

Similar distribution, density, and frequency analyses were completed for the introduced annual forbs functional group. The most abundant species in this functional group in 2006 included desert madwort, Russian thistle (*Salsola kali*), saltlover (*Halogeton glomeratus*), and several mustard species (Table 5-1). Introduced annual forbs were present in a handful of LTV plots in 1950 and these plots were sporadically distributed along the macro-transects (Figure 5-11a). Notable changes to this pattern did not occur until the 1995 sample period (1957 – 1985 data not shown). Between the 1985 and 1995 sample periods, the distribution of species represented by this functional group expanded considerably (Figure 5-11b) and the distribution continued to increase through the 2006 sample period (Figure 5-11c – Figure 5-11d).

The increasing distribution of introduced annual forbs across the LTV plots from 1995 through 2006 was also reflected in the mean density and frequency data (Figure 5-12). Mean density of species in this functional group has increased quasi-exponentially since 1995. Mean density of introduced annual forbs was significantly greater in 2006 than in all other sample years (Appendix B). Mean frequency also trended upward during the same time period and was significantly higher in 2006 than all other sample periods as well (Appendix B).

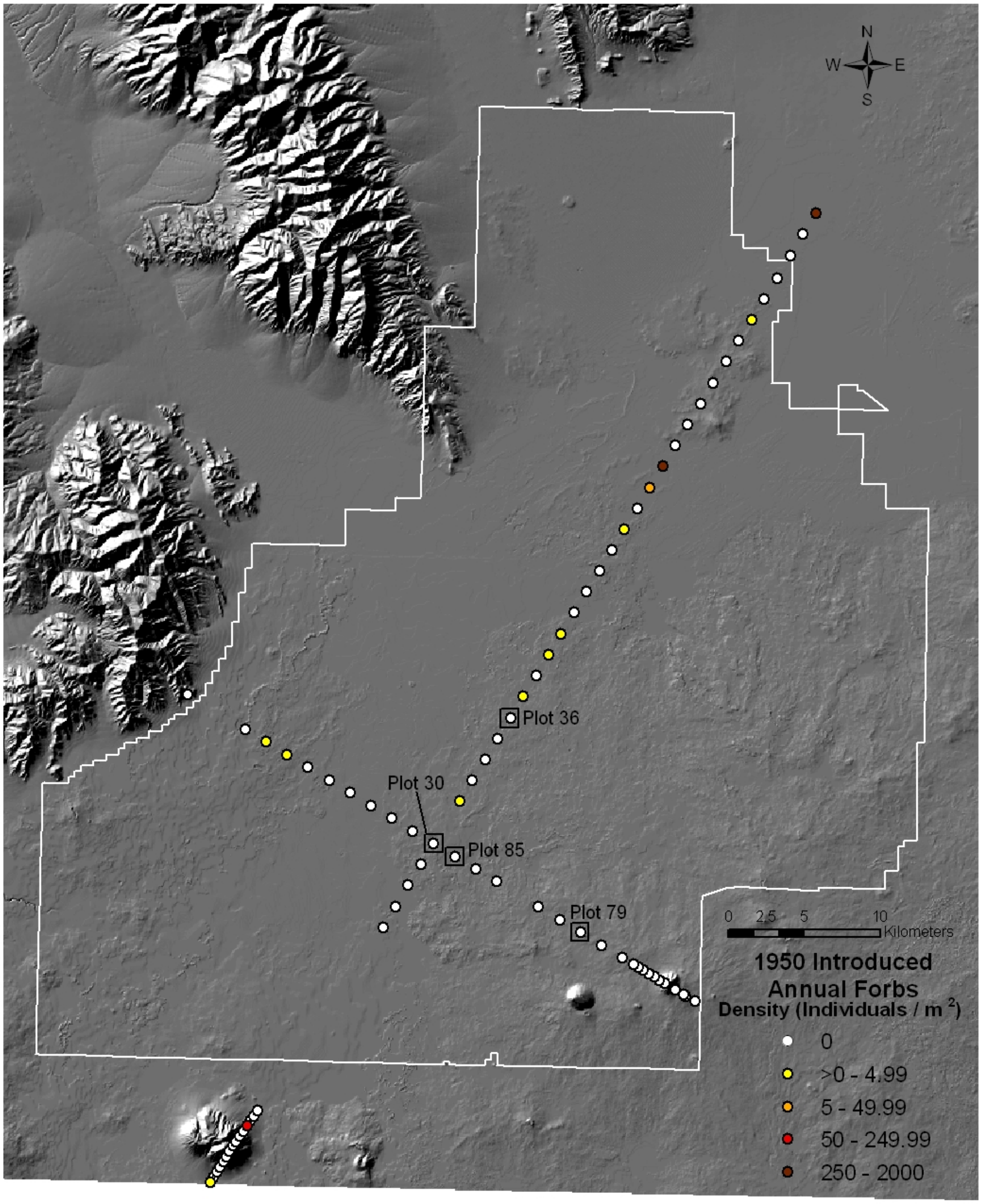


Figure 5-11a. Introduced annual forb distribution by density class on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site in 1950.

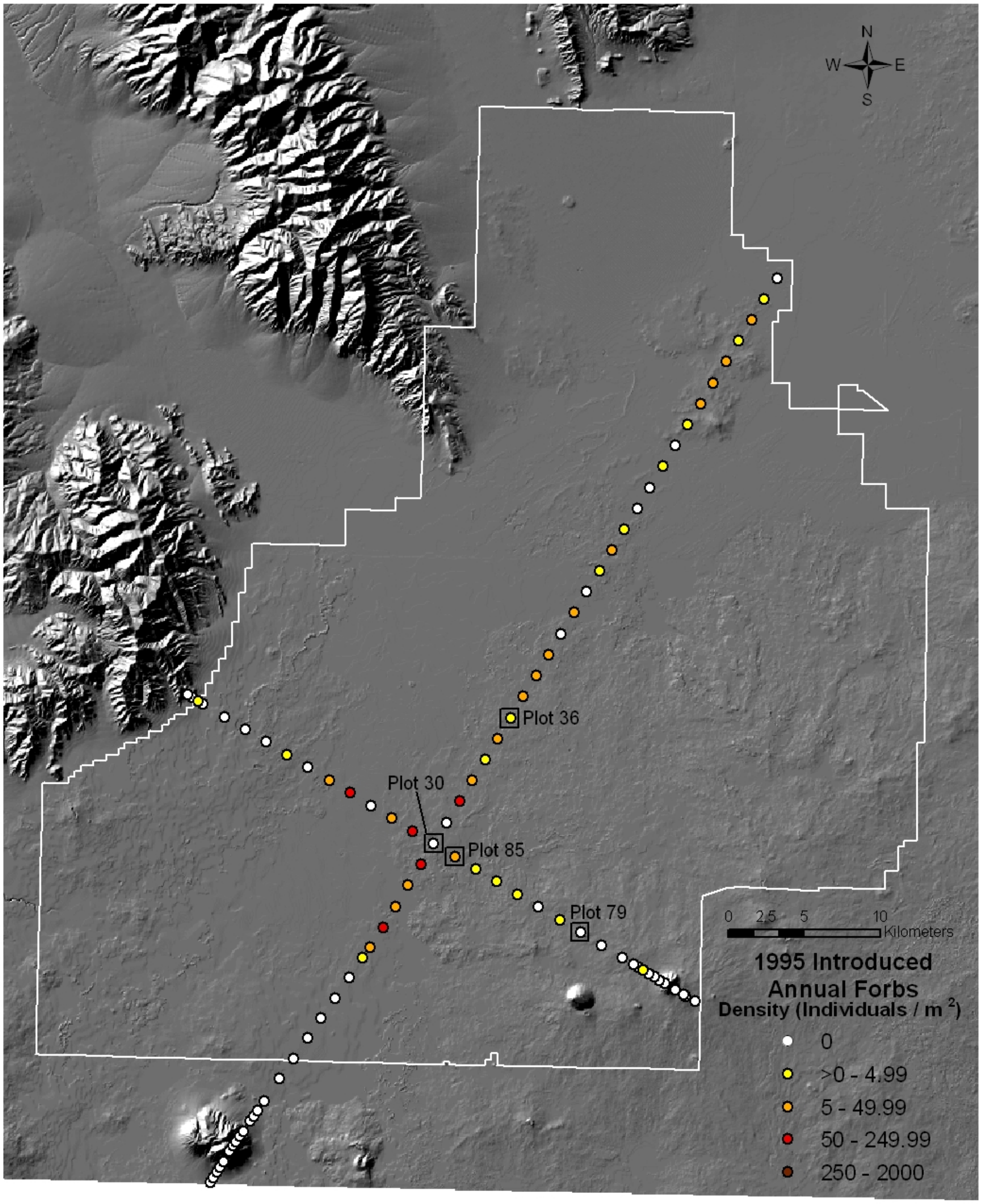


Figure 5-11b. Introduced annual forb distribution by density class on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site in 1995.

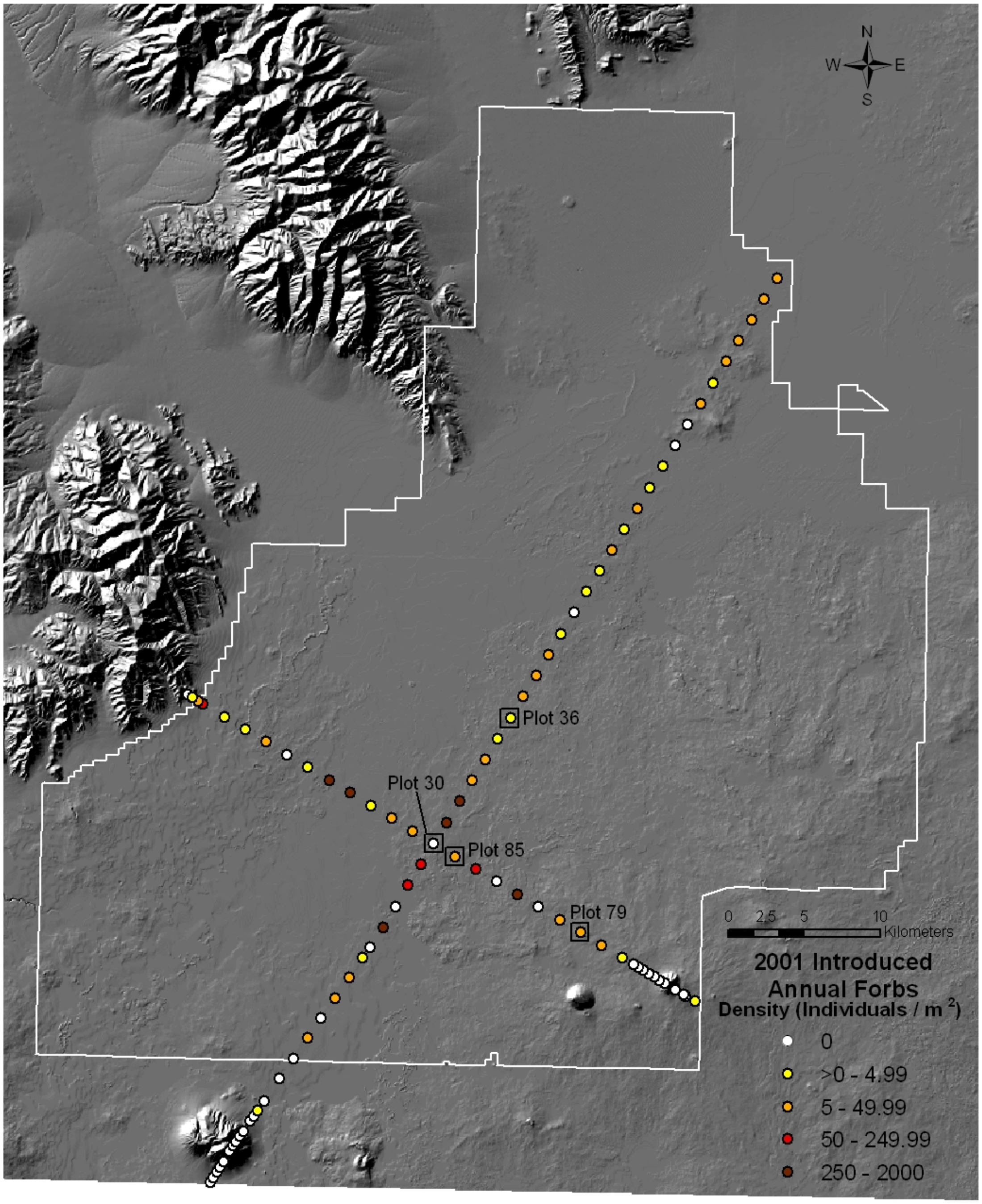


Figure 5-11c. Introduced annual forb distribution by density class on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site in 2001.

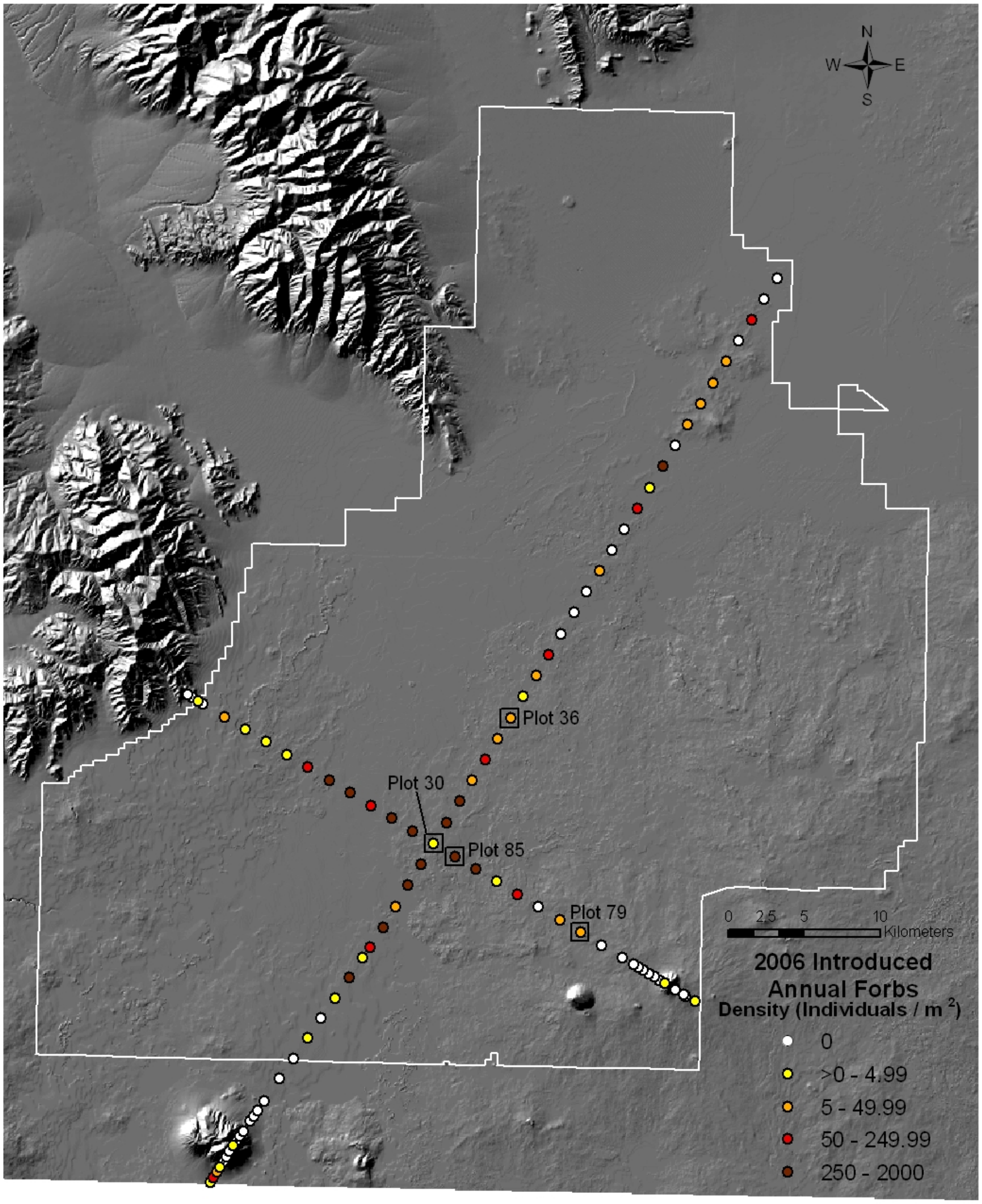


Figure 5-11d. Introduced annual forb distribution by density class on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site in 2006.

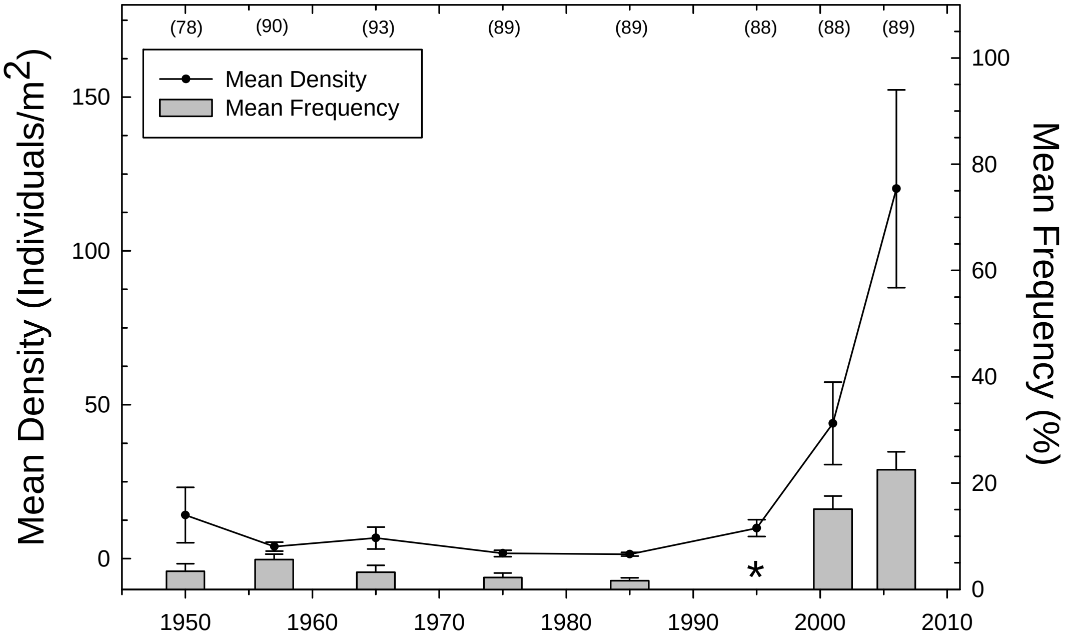


Figure 5-12. Density and frequency trends for introduced annual forbs on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site from 1950 to 2006. Data are means ± 1 SE. *Frequency data are missing from the 1995 data archives.

We analyzed trends in the mean annual density and frequency of native annual forbs in order to have some context within which to compare the trends apparent in introduced annual forbs. Both mean density and mean frequency of native annual forbs fluctuated several-fold over the study period (Figure 5-13). For both metrics, a few years with high mean values were significantly different from a few years with low mean values, but there were no directional trends (Appendix B). The sample years with highest mean density and frequency values for native annual forbs, 1975 and 1995, coincided with the wettest summers. Anderson and Inouye (1999) reported the summer of 1975 as being abnormally wet and they noted that 1995 had the wettest growing season on record. If mean density of native annual forbs is responding to summer precipitation, those species would appear to be functioning as ephemerals. Because the rapid changes in native annual forbs from one sample period to the next were not directional, as they were with introduced annual forbs, introduced annual forbs are probably not functioning similarly to their native counterparts in sagebrush steppe plant communities. The consistent and directional increases in the density and frequency of introduced annual forbs through time support the idea that they are not ephemeral in nature and increases in the abundance of species in this functional will likely continue to trend upward.

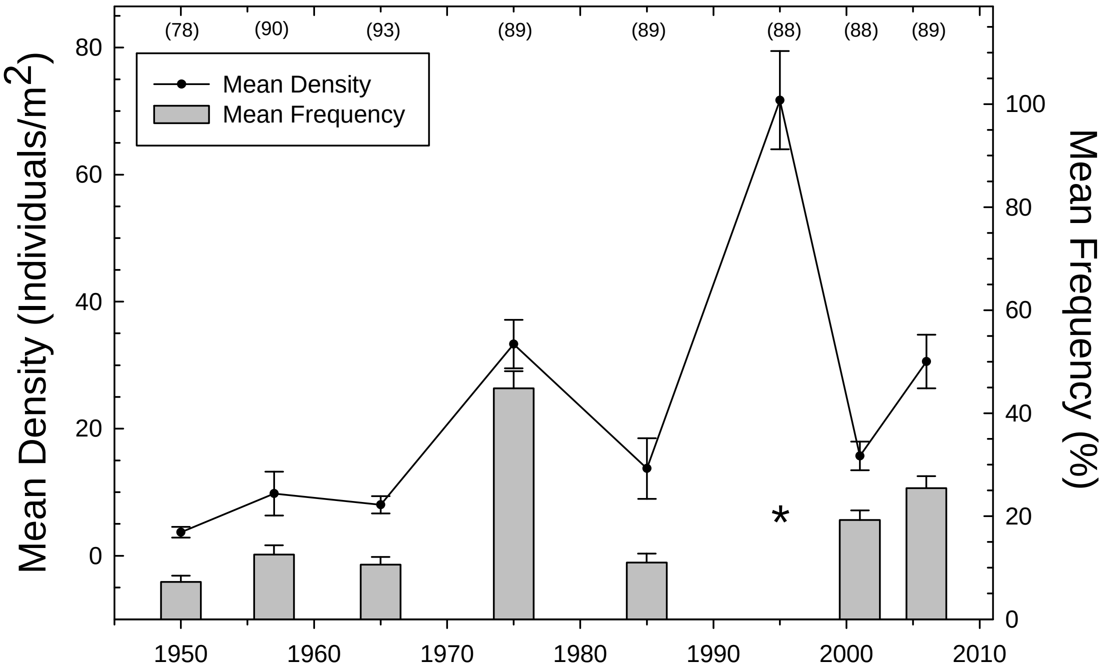


Figure 5-13. Density and frequency trends for native annual forbs on the Long-Term Vegetation Transect permanent plots at the Idaho National Laboratory Site from 1950 to 2006. Data are means ± 1 SE. *Frequency data are missing from the 1995 data archives.

5.4 Conclusions

Several generalizations can be made about trend, or lack thereof, in changes in abundance metrics of several species and functional groups from the analyses of the LTV plot data through the 2006 sample period. First, although cover of most major functional groups remains relatively stable through time, the species composition, or relative abundance of those species within a given functional group in very dynamic and can vary dramatically over just a decade. The overall relationship between the species richness of the native perennial functional groups and time is still positive and significant, but the mean species richness of native perennial grasses at the plot level decreased between the last two sample periods.

With regard to perennial species, sagebrush cover continues to decline across the core LTV plots, and the decline cannot be directly attributed to sagebrush losses in plots that have burned over the past few decades. Conversely, green rabbitbrush cover continues to increase across the core plots. At least some of the increase in green rabbitbrush can be attributed to increases in cover on plots that have recently burned. The mean cover of crested wheatgrass, which was not planted on the LTV plots, is steadily increasing at a localized scale and has the potential to substantially change the composition of plant communities in which it becomes established.

In terms of annual species, the distribution of cheatgrass has increased over the 56-year study period, but average density and frequency have not changed significantly between 1950 and 2006. The distribution of introduced annual forbs has increased considerably over the study period, specifically within the past decade. The density and frequency of species in this functional group has increased quasi-exponentially over the same time period. Finally, introduced annual forbs and native annual forbs appear to function very differently in sagebrush steppe plant communities at the INL Site.

Literature Cited

Anderson, J. E., and R. Inouye. 1988. Long-term dynamics of vegetation in a sagebrush steppe of Southeastern Idaho. Department of Biological Sciences, Idaho State University, Pocatello, ID.

Anderson, J. E., and R. Inouye. 1999. Long-term vegetation dynamics in sagebrush steppe at the Idaho National Engineering and Environmental Laboratory. Center for Ecological Research and Education, Department of Biological Sciences, Idaho State University and Environmental Science and Research Foundation, Idaho Falls, ID.

Anderson, J. E., and R. S. Inouye. 2001a. Landscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. Ecological Monographs **71**:531-556.

Anderson, J. E., and R. S. Inouye. 2001b. Lanscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. Ecological Monographs **71**:531-556.

Anderson, J. E., K. T. Ruppel, J. E. Glennon, K. E. Holte, and R. C. Rope. 1996a. Plant communities, ethnoecology, and flora of the Idaho National Engineering Laboratory. ESRF 005, Environmental Science and Research Foundation, Idaho Falls, ID.

Anderson, J. E., K. T. Ruppel, J. M. Glennon, K. E. Holte, and R. C. Rope. 1996b. Plant communities, ethnoecology, and flora of the Idaho National Engineering Laboratory. Environmental Science and Research Foundation, Idaho Falls, Idaho, USA.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry 39:388-394.

Colket, E. C., and S. C. Bunting. 2003. Long-term vegetation dynamics and fire effects at the Idaho National Engineering and Environmental Laboratory. Department of Rangeland Ecology and Management, University of Idaho, Moscow, ID.

D'Antonio, C. M., and P. M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics **23**:63-87.

Floyd, D. A., and J. E. Anderson. 1982. A new point interception frame for estimating cover of vegetation. Vegitatio **50**:185-186.

Knick, S. T., D. S. Dobkin, J. T. Rotenberry, M. A. Schroeder, W. M. Vander Haegen, and C. Van Riper III. 2003. Teetering on the edge or too late? Conservation and research issues for avifauna of sagebrush habitats. The Condor **105**:611-634.

McBride, R., N. R. French, A. D. Dahl, and J. E. Detmer. 1978a. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. IDO-12084, Environmental

Sciences Branch, Radiological and Environmental Sciences Laboratory, Idaho Operations Office, U.S. Department of Energy, Idaho Falls.

McBride, R., N. R. French, A. H. Dahl, and J. E. Demeter. 1978b. Vegetation types and surface soils of the Idaho National Engineering Laboratory site. IDO-12084, Radiological and Environmental Sciences Laboratory, U.S. Department of Energy, Idaho Falls, Idaho, USA.

Mack, R. N. 1981. Invasion of *Bromus tectorum* L. into western North America: An ecological chronicle. Agro-ecosystems 7:145-165.

Noss, R. F., E. T. LaRoe III, AND J. M. Scott. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. USDI, National Biological Service Biological Report 28, Washington, DC.

Shumar, M. L., and J. E. Anderson. 1986. Gradient analysis of vegetation dominated by two subspecies of big sagebrush. Journal of Range Management **39**:156-160.

Sidak. Z. 1967. Rectangular confidence regions for the means of multivariate normal distributions. Journal of the American Statistical Association **62**:626-633.

Young, J. A., and W. S. Longland. 1996. Impact of alien plants on Great Basin rangelands. Weed Technology 10:384-391.

Zar, J. H. 1999. Biostatistical Analysis. Prentice Hall, Upper Saddle River, New Jersey.

Appendix A

Sample Protocol

LTV Plot Sampling and Data Transfer Protocol

1. Plot Setup

- **A.** Minimize plot trampling while completing setup.
- **B.** Locate rebar stakes marking the endpoints of each of the plot transects.
- **C.** Establish the plot transects by fastening metal tapes to the appropriate rebar stakes (see plot drawing) ensuring that the tapes are taut.
- **D.** Record the plot number, date, and observers on the plot checklist.

2. Electronic Data File Setup

- **A.** Open the electronic data form template, enter the plot number on at least one datasheet and save the file with the appropriate file name.
- **B.** Name the electronic data form files according to the following convention:
  - **i.** Acronym of the project (in this case “ltv”).
  - **ii.** Date in mmddyy (6 numbers and no symbols).
  - **iii.** Plot number preceded by the letter “p.”
  - **iv.** Initials of recorder.
  - **v.** Letter indicating which pocket pc was used.
  - **iv.** Example:

ltv062806p1afa

indicates that the data file is from the Long-Term Vegetation Transects on June 28, 2006. Plot 1 was sampled by Amy Forman using pocket pc “a.”

3. Plot Photos

- **A.** Ensure the camera has been properly setup. For the Nikon D50:
  - **i.** SD Card has been downloaded.
  - **ii.** SD Card is installed.
  - **iii.** Battery is charged and installed.
  - **iv.** Mode Dial is set to M
  - **v.** Shooting Menu
    - **a.** Optimize Image **ON**
    - **b.** Image Quality **RAW+B**
    - **c.** White Balance **A** (or as appropriate, see manual)
    - **d.** ISO **200**
  - **vi.** Custom Settings Menu (pencil)
    - **a.** Autofocus **AF-A** (or **AF-S**)
    - **b.** AF-Area Mode **Single Area**
  - **vii.** Tools Menu
    - **a.** Time and date are correct
- **B.** Capture the image of the photoplot (1 m x 1 m photo frame).
  - **i.** Set frame over photoplot. The frame is placed such that one corner is against the rebar stake and the opposing corner is on the transect line (the measuring tape).
  - **ii.** Set tripod with feet about 15cm from frame.
  - **iii.** Attach camera and lens to tripod.

- **iv.** Set camera height so that approximate center of the focal plane is 1.35 m above ground.
- **v.** Place photo identification label at top of frame, lying flat on the ground.
- **vii.** Aim camera at center of plot. Be sure to include photo identification label in picture.
- **vii.** Turn camera On.
- **viii.** Set camera to allow Manual Exposure settings.
- **ix.** Check that zoom is set to 18mm.
- **x.** Adjust aperture to highest f-stop.
- **xi.** Adjust shutter speed so that light meter centers. Do not go below 1/60th of a second shutter speed. If meter will not center at 1/60th, leave at 1/60th and adjust aperture to smaller f-stop until meter centers. If vegetation is moving because of wind, use a faster shutter speed and lower f-stop.
- **xii.** Adjust focus to a mid point between the top of the tallest vegetation and soil surface. If camera and lens are set to AutoFocus, it may be necessary to use Focus Lock to avoid autofocusing on upper canopy or soil surface.
- **xiii.** Release shutter.
- **xiv.** Review photo to check for proper focus and exposure.
- **xv.** Record the details about the camera settings and file name in the electronic datasheet .

C. Capture the image of the photopoint (entire plot plus some of the horizon).

- **i.** With camera and tripod still in place, rotate the tripod head up to a general view of the entire plot. Try to include some sky in the photo. Doing so will show some horizon and allow for better relocation of the same shot during the next sample period year.
- **ii.** Place the photo identification label standing upright in the middle foreground.
- **iii.** Make sure the zoom is still adjusted to 18 mm.
- **iv.** Adjust the f-stop to the highest possible value for the given conditions.
- **v.** Adjust shutter speed so that light meter needle centers. Do not go below 1/60th of a second shutter speed. If meter will not center at 1/60th, leave at 1/60th and adjust aperture to smaller f-stop until meter centers. If vegetation is moving because of wind, use a faster shutter speed and lower f-stop.
- **vi.** Adjust the focus so as much of the plot a possible is in focus.
- **vii.** Release the shutter.
- **viii.** Review photo to check for proper focus and exposure.
- **ix.** Turn camera Off.
- **x.** Record the details about the camera settings and file name in the electronic datasheet .

D. Complete a sketch of the photoplot in the space provided on the back of the photo identification label.

E. Mark the plot checklist to indicate that both photos were taken, the electronic datasheet was populated, and the plot sketch (drawing) was completed.

4. Point Intercept Sampling (plots 13-57 and 71-98).

A. Keep foot traffic and trampling associated with placing and reading the point frames limited to the side of the transect opposite of where density frames will be placed (see plot drawing).

B. Center the long axis of the point frame parallel to and directly over the first transect line between the 0 and 1 m marks. Make sure the frame is level.

C. Read the point frame and record “hits” of vascular vegetation or other recognized entities (moss, litter, rock, etc.). All vegetative structures (non-reproductive) intercepted by shrubs and forbs are considered “hits.” Only interceptions at the basal area of graminoids are considered to be “hits.” Record non-vegetation entities only if a vegetative layer is not present at a given point. Record more than one “hit” for a point if more than one species is present under a point (i.e. multiple vegetation layers).

D. Record data in the electronic datasheet using standardized INL Site species codes.

E. Move the frame down to the next 1 m section of the transect line and repeat the procedure until all 50 frames have been sampled across all three transects.

F. Mark the plot checklist to indicate that point intercept sampling has been completed.

5. Line Intercept Sampling

A. Keep foot traffic and trampling associated with collecting line intercept data limited to the side of the transect opposite of where density frames will be placed (see plot drawing).

B. Estimate the points where individuals (or groups of individuals) intercept the tape using a plumb bob. The same side of the tape used for placing density frames should also be used for line interception.

C. Only the vegetative structures of shrubs and the basal areas of perennial graminoids should be recorded using line interception techniques. Treat succulents as shrubs.

D. Ignore gaps in shrub canopies that are less than 2 cm. Treat overlapping individuals of the same species as a continuous entity.

E. Record data in the electronic datasheet. Record beginning and end interception points in cm to the nearest half cm, and use standardized INL Site species codes to identify individuals or overlapping groups of individuals.

F. Complete line intercept sampling along the length of both 15.24 m (50 ft) transects.

G. Mark the plot checklist to indicate that point intercept sampling has been completed.

6. Density/Frequency Sampling

A. Place the density frame along the first transect beginning at 1.52 m (5 ft). The short axis of the frame should abut the transect line (the long axis of the frame should be perpendicular to the transect line) and the 0.1 m x 0.3 m subsection of the frame should be adjacent to the transect line. Density frames are located opposite the macrotransect line (see plot drawing).

B. Count all individuals of perennial species in the entire frame. All individuals rooted at least 50% within the boundary of the frame should be counted. Tillers of rhizomatous grasses are counted as individuals.

C. Count all individuals of annual species within the 0.1 m x 0.3 m subsection of the density frame.

D. Record data in the electronic datasheet using standardized INL Site species codes.

E. Move the density frame so that it begins at the 3.04 m (10 ft) mark along the tape marking the transect line and repeat the procedure until 10 frames along each of the 15.24 m (50 ft) transects have been sampled (a total of 20 frames).

F. Mark the plot checklist to indicate that density/frequency sampling has been completed.

7. Unknown Species Log

A. Any individual that cannot be readily identified to the species level during the plot sampling process should be collected for identification in the laboratory using the INL Site Reference Herbarium collection and/or appropriate flora keys.

B. Use a unique unknown code to identify the unknown individual in the electronic datasheet. Codes that make reference to identifying characteristics of an individual are particularly helpful. For example "UNKFYelFlow" could be used to denote an unknown forb with a yellow flower.

C. Every attempt should be made to collect a specimen outside the LTV plot boundary. If an individual cannot be located adjacent to the plot, then photos should be taken of the unknown individual. Photos should capture as many details of leaf shape, flower anatomy, etc. as possible to facilitate the identification process.

D. Once a specimen has been located outside the plot boundary, as much of the individual as possible should be collected, including; roots, stems, leaves, flowers, and/or fruit. The specimen should be placed in either a plastic bag or plant press. A plastic bag may be used if the specimen will be identified within a day or two of collection. A plant press should be used if more than a few days will pass between collection and identification.

E. Label the plastic bag or the corner of the blotter paper in the plant press with the plot number and the unknown code used in the electronic datasheet.

F. Complete the unknown species log on the plot checklist indicating where the individual was located within the plot, a brief description of the individual, and the unknown code used to designate the individual in the electronic data form. The "Final ID" section of log will be completed once a positive identification has been made in the laboratory.

8. Data Transfer

A. Electronic and hardcopy data will be transferred on a daily basis.

B. Appropriate file and folder structures will be maintained on the server such that one folder will be available for all electronic data associated with each plot.

C. Copy the pair of photographs taken at each plot from the camera to the appropriate folder on the server.

D. Open and review each of the photos to ensure that both a photoplot and photopoint image are present for each plot. Also check to ensure that the plot number on the photo identification label in the picture matches the plot number on the folder into which the photos were copied.

E. After the photos have been copied to the server, rename each photo on the sever according to the following convention:

- **i.** Acronym of the project (in this case “ltv”).
- **ii.** Date in mmddyy (6 numbers and no symbols).
- **iii.** Plot number preceded by the letter “p.”
- **iv.** Initials of recorder.
- **v.** The letter “p” again, to denote that it is a photo file, followed by a “1” or “2.”

  The number “1” indicates that the photo is of the photoplot, and the number “2” indicates that the photo is from the photopoint.
- **iv.** Example:

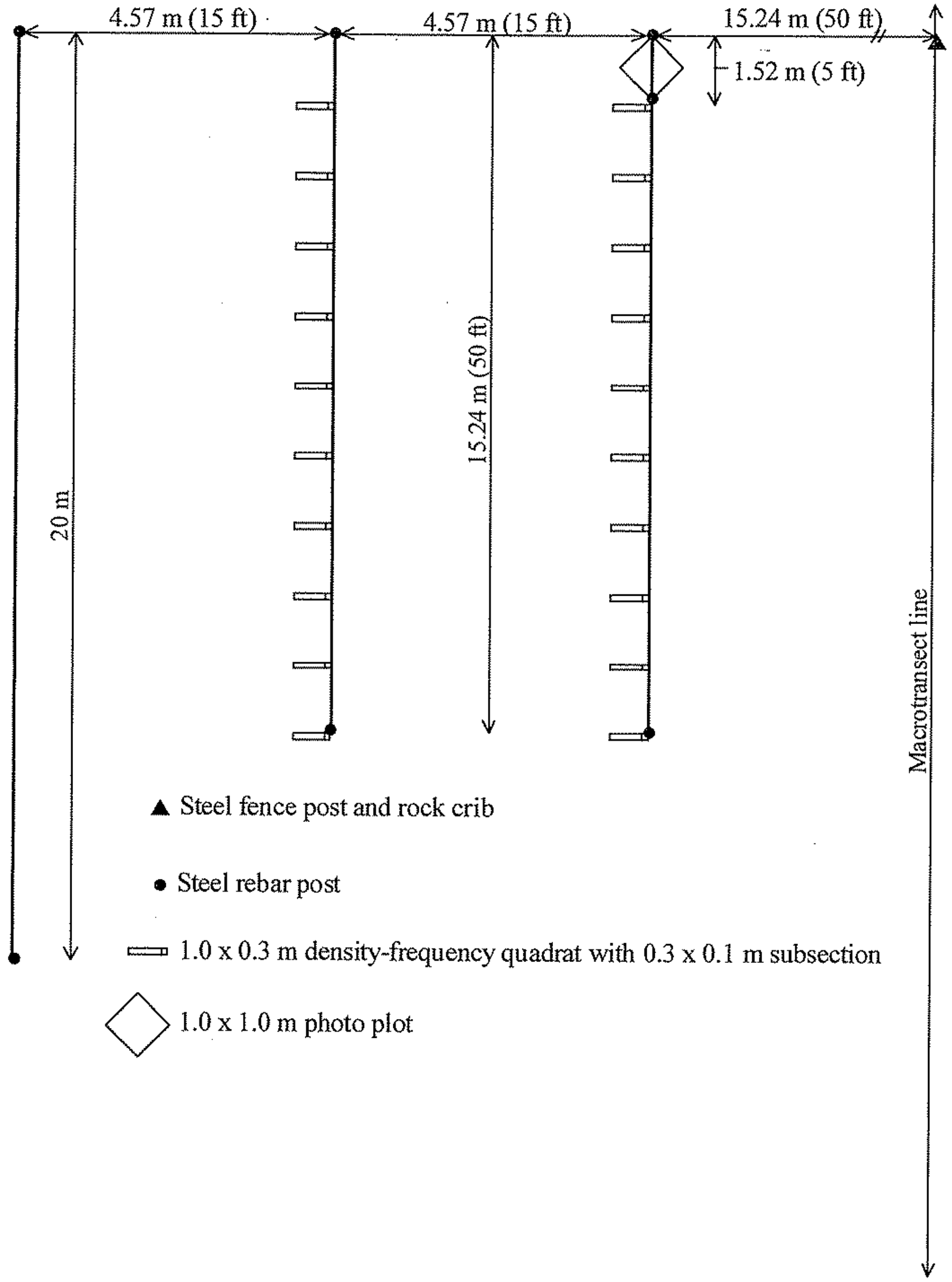
  ltv062806p1afp2

  indicates that the photo is from the Long-Term Vegetation Transects on June 28, 2006. Plot 1 was photographed by Amy Forman and the photo was taken from the photopoint perspective.

- **F.** Copy the electronic data files from the hand held unit to the appropriate folders on the server.
- **G.** Open and review each file to ensure that the datasheets are complete. If more that one hand held unit was used at each plot, resulting in multiple data files, combine the data files so that one complete data file is available for each plot. Maintain the original data files as they were upon completion of data collection in the field and name the new, complete data file according to the file naming convention described above. Omit the letter indicating which handheld unit was used for all files generated during the download process.
- **H.** Place the hardcopy photo identification label and associated plot drawing in the folder located next to the desktop being used for data downloads.
- **I.** Mark the plot checklist to indicate that data transfer has been completed for the plots photos, electronic data files, and photo identification label.
- **J.** Deliver completed plot checklists to the data manager.

Supplemental Materials

I. Plot Drawing



II. Plot Checklist

Long Term Vegetation Transects Plot Checklist

Plot Number _______ Date ____________ Observers ___________________

Data Collection (Initial as Completed)

____ Photos Taken
____ Photo Data Sheet (Electronic Data)
____ Plot Drawing (Paper Data)
____ Point Interception (Electronic Data)
____ Line Interception (Electronic Data)
____ Density/Frequency (Electronic Data)

Data Transfer (Initial as Completed)

____ Photos
____ LTV Electronic Data File
____ Photo Plot ID Label and Drawing

Unknown Species Log

Location in Plot ____
Description ____
Code in Electronic Data Sheet ____
Final ID ____

Location in Plot ____
Description ____
Code in Electronic Data Sheet ____
Final ID ____

Location in Plot ____
Description ____
Code in Electronic Data Sheet ____
Final ID ____

III. Photo identification label with photoplot sketch space on back.

Long-Term Vegetation Transect

Date: ____________________

Plot No: ________________

TOP

Appendix B

Summary Statistics Tables

ANOVA Results Tables

Table B1a. Estimates of mean cover for native perennial functional groups from the line-interception data on the "core" Long-Term Vegetation Transect plots at the Idaho National Laboratory from 1950 to 2006. Minimum significant difference indicates the value at which means of pairwise comparisons between two sample years within each functional group becomes significant.

Total		**Shrub**		**Grass**	
Year	**Mean**	**Year**	**Mean**	**Year**	**Mean**
1950	16.91	1950	16.41	1950	0.50
1957	17.89	1957	16.88	1957	1.01
1965	25.39	1965	23.88	1965	1.51
1975	30.56	1975	23.89	1975	6.68
1978	26.39	1978	23.10	1978	3.30
1983	20.50	1983	17.45	1983	3.05
1985	23.22	1985	21.66	1985	1.57
1990	22.60	1990	18.61	1990	3.99
1995	24.86	1995	21.91	1995	2.95
2001	19.86	2001	17.39	2001	2.47
2006	22.16	2006	17.67	2006	4.49
Minimum Significant Difference	**5.53**		**6.03**		**1.93**

Table B1b. Results tables for one-way repeated measures ANOVAs comparing mean cover for native perennial functional groups from the line-interception data on the "core" Long-Term Vegetation Transect plots at the Idaho National Laboratory from 1950 to 2006.

Total, One-way Repeated Measures ANOVA Results

Source of Variation	DF	SS	MS	F	P
Plot	42	27442.76	653.40		
Year	10	6580.53	658.05	11.18	<0.001

Shrub, One-way Repeated Measures ANOVA Results

Source of Variation	DF	SS	MS	F	P
Plot	42	32711.10	778.84		
Year	10	3898.52	389.85	6.25	<0.001

Grass, One-way Repeated Measures ANOVA Results

Source of Variation	DF	SS	MS	F	P
Plot	42	1216.72	28.97		
Year	10	1359.02	135.90	21.72	<0.001

Table B2a. Estimates of mean cover for *Artemisia tridentata* (ARTR) and *Chrysothamnus viscidiflorus* (CHVI) from the line-interception data on the "core" Long-Term Vegetation Transect plots at the Idaho National Laboratory from 1950 to 2006. Minimum significant difference indicates the value at which means of pairwise comparisons between two sample years within each species becomes significant. The significance column indicates whether the mean cover difference between each species was significant for a given sample period.

Year	ARTR	CHVI	Significant
1950	16.57	0.99	Yes
1957	15.90	1.15	Yes
1965	22.90	2.37	Yes
1975	21.68	3.48	Yes
1978	18.40	3.70	Yes
1983	13.48	2.98	Yes
1985	16.24	5.76	Yes
1990	11.79	4.69	Yes
1995	13.63	7.61	Yes
2001	8.88	6.38	No
2006	8.33	7.43	No
Minimum Significant Difference	**4.51**	**5.06**	

Table B2b. Results table for two-way repeated measures ANOVA comparing mean cover for *Artemisia tridentata* (ARTR) and *Chrysothamnus viscidiflorus* (CHVI) from the line-interception data on the "core" Long-Term Vegetation Transect plots at the Idaho National Laboratory from 1950 to 2006.

Two-way Repeated Measures ANOVA Results					
Source of Variation	DF	SS	MS	F	P
Plot	32	12748.76	398.40	0.86	0.66
Species	1	22063.18	22063.18	45.79	<0.001
Species x Plot	32	15419.35	481.86		
Year	10	2333.61	233.36	8.99	<0.001
Year x Plot	320	8307.84	25.96		
Species x Year	10	6703.90	670.39	14.97	<0.001

Table B3a. Estimates of mean cover for *Artemisia tridentata* (ARTR) and *Chrysothamnus viscidiflorus* (CHVI) from the line-interception data on the "core" Long-Term Vegetation Transect plots at the Idaho National Laboratory from 1950 to 2006. Plots that burned or contained *Agropyron desertorum* were removed from 1995 and subsequent sample years of analysis. Minimum significant difference indicates the value at which means of pairwise comparisons between two sample years within each species becomes significant. The significance column indicates whether the mean cover difference between each species was significant for a given sample period.

Year	ARTR	CHVI	Significant
1950	15.44	1.10	Yes
1957	14.81	1.14	Yes
1965	21.84	2.71	Yes
1975	20.61	3.93	Yes
1978	17.50	4.09	Yes
1983	12.60	3.11	Yes
1985	15.48	5.74	Yes
1990	10.88	4.99	Yes
1995	11.94	8.24	No
2001	10.18	6.26	No
2006	9.42	5.80	No
Minimum Significant Difference	**4.57**	**5.13**	

Table B3b. Results table for two-way repeated measures ANOVA comparing mean cover for *Artemisia tridentata* (ARTR) and *Chrysothamnus viscidiflorus* (CHVI) from the line-interception data on the "core" Long-Term Vegetation Transect plots at the Idaho National Laboratory from 1950 to 2006. Plots that burned or contained *Agropyron desertorum* were removed from 1995 and subsequent sample years of analysis.

Two-way Repeated Measures ANOVA Results					
Source of Variation	DF	SS	MS	F	P
Plot	25	8705.59	348.22	0.64	0.86
Species	1	15252.35	15252.35	27.75	<0.001
Species x Plot	25	13738.76	549.55		
Year	10	1705.02	170.50	7.45	<0.001
Year x Plot	250	5722.31	22.89		
Species x Year	10	3969.69	396.97	12.78	<0.001

Table B4a. Estimates of mean cover for native perennial bunch grasses and native perennial rhizomatous grasses from the line-interception data on the "core" Long-Term Vegetation Transect plots at the Idaho National Laboratory from 1950 to 2006. Minimum significant difference indicates the value at which means of pairwise comparisons between two sample years within each functional group becomes significant. The significance column indicates whether the mean cover difference between each functional group was significant for a given sample period.

Year	Bunch	Rhizomatous	Significant
1950	0.27	0.07	No
1957	0.60	0.20	No
1965	0.78	0.37	No
1975	4.11	1.46	Yes
1978	1.92	1.41	No
1983	1.54	1.51	No
1985	0.90	0.47	No
1990	2.64	1.44	Yes
1995	2.47	0.47	Yes
2001	2.07	0.58	Yes
2006	3.95	0.70	Yes
Minimum Significant Difference	**1.27**	**1.31**	

Table B4b. Results table for two-way repeated measures ANOVA comparing mean cover for native perennial bunch grasses and native perennial rhizomatous grasses from the line-interception data on the "core" Long-Term Vegetation Transect plots at the Idaho National Laboratory from 1950 to 2006.

Two-way Repeated Measures ANOVA Results					
Source of Variation	DF	SS	MS	F	P
Plot	32	432.00	13.50	1.03	0.47
Growth Form	1	237.00	237.00	18.13	<0.001
Growth Form x Plot	32	418.42	13.08		
Year	10	460.45	46.04	17.64	<0.001
Year x Plot	320	835.25	2.61		
Growth Form x Year	10	193.19	19.32	7.55	<0.001

Table B5a. Estimates of mean cover for native perennial grasses and introduced perennial grasses from the line-interception data on the "core" Long-Term Vegetation Transect plots at the Idaho National Laboratory from 1950 to 2006. Minimum significant difference indicates the value at which means of pairwise comparisons between two sample years within each functional group becomes significant. The significance column indicates whether the mean cover difference between each functional group was significant for a given sample period.

Year	Native	Introduced	Significant
1957	1.01	0.00	No
1965	1.51	0.02	Yes
1975	6.68	0.00	Yes
1985	1.57	0.03	Yes
1995	2.95	0.31	Yes
2001	2.47	0.55	Yes
2006	4.49	0.77	Yes
Minimum Significant Difference	**1.38**	**N/A**	

Table B5b. Results table for two-way repeated measures ANOVA comparing mean cover for native perennial grasses and introduced perennial grasses from the line-interception data on the "core" Long-Term Vegetation Transect plots at the Idaho National Laboratory from 1950 to 2006.

Two-way Repeated Measures ANOVA Results					
Source of Variation	DF	SS	MS	F	P
Plot	42	445.51	10.61		
Nativity	1	1108.70	1108.70	74.30	<0.001
Nativity x Plot	42	626.74	14.92		
Year	6	570.97	95.16	26.98	<0.001
Year x Plot	252	888.75	3.53		
Nativity x Year	6	497.36	82.89	18.07	<0.001

Table B6a. Estimates of mean cover for introduced perennial grasses, native perennial grasses, and shrubs from 1957 to 2006 for the three of the "core" Long-Term Vegetation Transect plots in which *Agropyron desertorum* has become established. Minimum significant difference indicates the value at which means of pairwise comparisons between two sample years within each functional group becomes significant. Letters indicate significant differences among functional group in a given sample year.

Year	**Introduced Grasses**	**Native Grasses**	**Native Shrubs**
1957	0.00	0.00	21.70
	a	**a**	**b**
1965	0.00	0.27	28.24
	a	**a**	**b**
1975	0.00	7.33	21.91
	a	**a**	**b**
1985	0.42	1.67	25.44
	a	**a**	**b**
1995	4.38	0.74	20.33
	a	**a**	**b**
2001	7.81	0.16	13.86
	a	**a**	**a**
2006	11.06	0.08	9.41
	a	**a**	**a**
Minimum Significant Difference	**N/A**	**N/A**	**14.39**

Table B6b. Results table for two-way repeated measures ANOVA comparing mean cover for introduced perennial grasses, native perennial grasses, and shrubs from the line-interception data on the "core" Long-Term Vegetation Transect plots at the Idaho National Laboratory from 1957 to 2006.

Two-way Repeated Measures ANOVA Results					
Source of Variation	DF	SS	MS	F	P
Plot	2	332.83	166.42		
Functional Group	2	4427.81	2213.91	15.678	0.013
Functional Group x Plot	4	564.83	141.21		
Year	6	77.80	12.97	0.666	0.679
Year x Plot	12	233.74	19.48		
Functional Group x Year	12	1178.64	98.22	3.51	0.004

Table B7a. Estimates of mean density and frequency for *Bromus tectorum* from the density/frequency data on the all of the Long-Term Vegetation Transect plots for which data were available in each sample year at the Idaho National Laboratory from 1950 to 2006. Minimum significant difference indicates the value at which means of pairwise comparisons between two sample years within either density or frequency becomes significant. *Frequency data were not available for 1995.

Density		**Frequency**	
Year	**Mean**	**Year**	**Mean**
1950	44.08	1950	7.63
1957	21.85	1957	4.78
1965	33.01	1965	6.88
1975	27.07	1975	13.65
1985	9.04	1985	7.14
1995	42.14	1995	*
2001	88.73	2001	26.08
2006	56.99	2006	19.33
Minimum Significant Difference	**66.88**		**11.70**

Table B7b. Results tables for one-way ANOVAs comparing mean density among sample periods and mean frequency among sample periods for *Bromus tectorum*. Data are from all of the Long-Term Vegetation Transect plots for which data were available in each sample year at the Idaho National Laboratory from 1950 to 2006.

Density, One-way ANOVA Results					
Source of Variation	DF	SS	MS	F	P
Year	7	370689.30	529.56	2.61	0.01

Frequency, One-way ANOVA Results					
Source of Variation	DF	SS	MS	F	P
Year	6	33161.03	5526.84	10.01	<0.001

Table B8a. Estimates of mean density and frequency for introduced annual forbs from the density/frequency data on the all of the Long-Term Vegetation Transect plots for which data were available in each sample year at the Idaho National Laboratory from 1950 to 2006. Minimum significant difference indicates the value at which means of pairwise comparisons between two sample years within either density or frequency becomes significant. *Frequency data were not available for 1995.

Density		Frequency	
Year	**Mean**	**Year**	**Mean**
1950	14.15	1950	3.40
1957	3.90	1957	5.61
1965	6.68	1965	3.23
1975	1.68	1975	2.25
1985	1.44	1985	1.63
1995	9.91	1995	*
2001	43.92	2001	15.114
2006	120.22	2006	22.53
Minimum Significant Difference	**76.30**		**7.41**

Table B8b. Results tables for one-way ANOVAs comparing mean density among sample periods and mean frequency among sample periods for introduced annual forbs. Data are from all of the Long-Term Vegetation Transect plots for which data were available in each sample year at the Idaho National Laboratory from 1950 to 2006.

Density, One-way ANOVA Results					
Source of Variation	DF	SS	MS	F	P
Year	7	1036790.10	1481.13	10.16	<0.001

Frequency, One-way ANOVA Results					
Source of Variation	DF	SS	MS	F	P
Year	6	34029.87	5671.65	19.38	<0.001

Table B9a. Estimates of mean density and frequency for native annual forbs from the density/frequency data on the all of the Long-Term Vegetation Transect plots for which data were available in each sample year at the Idaho National Laboratory from 1950 to 2006. Minimum significant difference indicates the value at which means of pairwise comparisons between two sample years within either density or frequency becomes significant. *Frequency data were not available for 1995.

Density		**Frequency**	
Year	Mean	Year	Mean
1950	3.70	1950	7.24
1957	9.79	1957	12.56
1965	8.02	1965	10.59
1975	33.31	1975	44.83
1985	13.72	1985	11.01
1995	71.72	1995	*
2001	15.72	2001	19.261
2006	30.58	2006	25.449
Minimum Significant Difference	**16.86**		**8.25**

Table B9b. Results tables for one-way ANOVAs comparing mean density among sample periods and mean frequency among sample periods for native annual forbs. Data are from all of the Long-Term Vegetation Transect plots for which data were available in each sample year at the Idaho National Laboratory from 1950 to 2006.

Density, One-way ANOVA Results					
Source of Variation	DF	SS	MS	F	P
Year	7	301319.70	430.46	28.72	<0.001

Frequency, One-way ANOVA Results					
Source of Variation	DF	SS	MS	F	P
Year	6	89854.12	14975.69	39.07	<0.001