

Rocky Mountain Network - Full Study Plan for Biological Inventories: Leading to an Integrated Monitoring Program

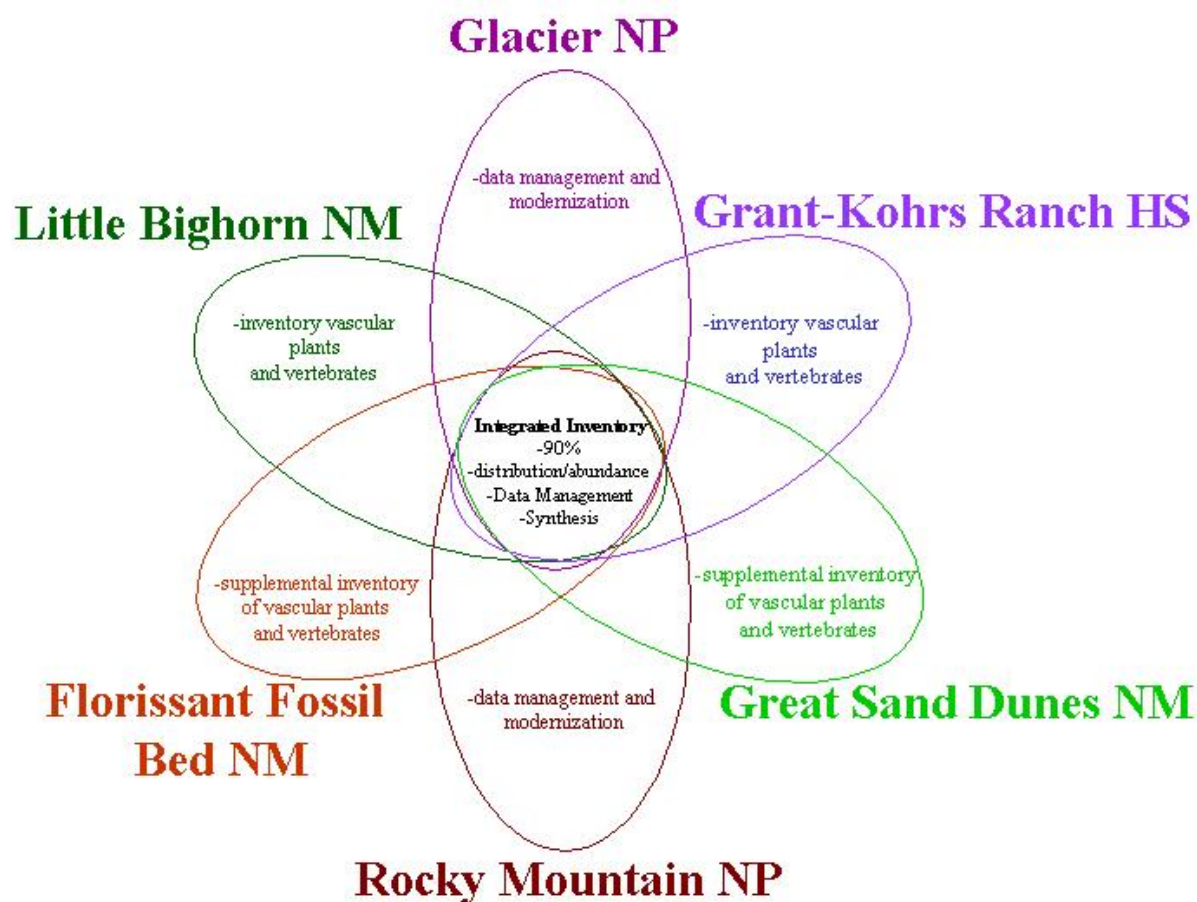


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Executive Summary

We propose a four-year project to conduct biological inventories of vertebrates and vascular plants in the Rocky Mountain Network including Rocky Mountain NP, Glacier NP, Florissant Fossil Beds NM, Grant-Kohrs Ranch NHS, Great Sand Dunes NM, and Little Bighorn Battlefield NM. Four goals guide the Rocky Mountain Network inventory initiative: (1) Inventory 90% of vascular plant and vertebrate species; (2) Collect distribution and abundance data for species of concern; (3) Establish baseline information and associated database to support future monitoring efforts; and (4) Establish an unbiased and coordinated inventory program. This program integrates the expertise and resources of park personnel and many taxa-specific experts, with existing scientific information and peer-reviewed inventory techniques to support a scientifically sound inventory. The plan will catalogue the present condition of these species while functioning as a baseline for future monitoring efforts to facilitate scientifically sound management decisions. By adhering to basic principals of biological inventory, this program responds directly to a need for a comprehensive, standardized, and systematic inventory and monitoring program throughout the National Park Service (NPS) system.

We will: (1) Continue to gather previously collected data and converting existing information to useful formats - Dataset Catalog, GIS Databrowser; (2) Improve documentation of evidence for park species lists – NPSpecies; (3) Conduct coordinated field inventories where necessary; (4) Use modeling and other data synthesis techniques to make inferences about specific species within each park, and to make comparisons across parks that will provide regional Network conclusions; and (5) Provide data synthesis on the status of biological inventories that will facilitate the transition to the monitoring of natural resources in the Rocky Mountain Network.

We identify five integrated projects identified as the top priorities by park staffs and resource management plans. The first project continues work on vascular plants, mammals, and birds, specifically targeting the park units with greatest information needs. The second project improves the information base on amphibians, fish, and bats. The third and fourth projects consolidate and improve natural resource data in Glacier National Park and Rocky Mountain National Park, respectively, with assistance to the smaller park units in the north and south. The fifth project synthesizes network-scale data on all biological groups, and integrates information for resource management.

What sets this proposal apart from many others? First, data management and integration are the major components in each project and over the entire program. Second, the methods, and the theory supporting the methods are well founded, peer-reviewed, and state-of-the-art. Third, the projects are integrated with the newest spatial models and synthesis tools available. The strengths of the project are: (1) close coordination and partnerships of NPS staff, the network Advisory Council, and university scientists; (2) demonstrated partnerships with NPS-knowledgeable Principle Investigators that are nationally and internationally known and respected; (3) issues of accuracy, precision, completeness, and scale are identified and resolved for each biological group with a firm understanding of biology, ecology, statistics, and uncertainty; (4) emphasis on data documentation for each park and the network so that the data stand the test of time; and (5) cost-efficiencies by integrating field crews, data management, and synthesis across projects.

I. INTRODUCTION

I.A. Summary: Goals

This study plan describes a coordinated and prioritized inventory of targeted vascular plant and vertebrate animal species for the Rocky Mountain Network. This program integrates the expertise and resources of park personnel and many taxa-specific experts, with existing scientific information and peer-reviewed inventory techniques to support a scientifically sound inventory. The plan will catalogue the present condition of these species while functioning as a baseline for future monitoring efforts to facilitate scientifically sound management decisions. By adhering to basic principals of biological inventory, this program responds to a need for a comprehensive, standardized, and systematic inventory and monitoring program throughout the National Park Service (NPS) system.

Four goals guide the Rocky Mountain Network inventory initiative:

- **Inventory 90% of vascular plant and vertebrate species.** Documentation of species occurrence and location, either by collecting new data or modernizing existing data will facilitate appropriate management decisions and monitoring efforts.
- **Collect distribution and abundance data for species of concern.** Species of concern will be documented in greater quantitative and spatial detail, as they are likely to be subjected to pressure of stressors.
- **Establish baseline information and associated database to support future monitoring efforts.** The data collected and organized in the inventory effort will be quantitative and unbiased. Abundance or cover data as well as predictive distribution maps will describe the current status of resources so future monitoring efforts will accurately describe any resource changes over time.
- **Establish an unbiased and coordinated inventory program.** By focusing on rare and threatened habitats, the program will assess the status and trends of species and habitats within each park unit, and at regional scales across the Rocky Mountains. The Rocky Mountain Network will serve as model for other Networks and thus encourage comparability at national scales.

I.B. The Rocky Mountain Network

The Rocky Mountain Network is one of thirty-two such National Park Networks established to maximize efficiency and comparability of inventory and monitoring efforts within the NPS units of the Rocky Mountain region. Six NPS units comprise the Rocky Mountain Network: Rocky Mountain National Park, Glacier National Park, Florissant Fossil Beds National Monument, Grant-Kohrs Ranch National Historic Site, Great Sand Dunes National Monument, and Little Bighorn Battlefield National Monument. These diverse NPS units were selected to represent the Rocky Mountain region's diverse natural and cultural heritage. Despite different legislative mandates, goals, objectives, staffing, and funding, these and other NPS units are plagued, to a greater or lesser extent, by the same suite of threats: loss of native species and degradation of natural habitats; altered disturbance regimes; invasive species; pollution; urban/boundary development; and inadequate scientific data with which to make informed management decisions. Although each NPS unit supports a unique combination of natural resources, common threats influence a theme of habitats and species of special concern throughout the network: rare species, alien species invasion, and unique habitats such as wetland and riparian areas.

I.B.1. Structure and Organization of the Rocky Mountain Network

The Rocky Mountain Network has established a framework to insure that the inventory moves forward in a scientifically sound and timely manner. The organization of the Network has several components: the regional coordinator of the National Park Service Inventory and Monitoring Program, the Rocky Mountain Network steering committee, and the science advisory team. Figure 1 provides a visual representation of the following text.

The National Park Service regional coordinator passes on information regarding program inventory funding, timelines, and provides suggestions on documents that guide the Network. The regional coordinator also provides contact information for other networks and facilitates cooperation across networks.

The steering committee is comprised of a member from each National Park Service unit that is part of the Rocky Mountain Network. The steering committee oversees the inventory of the Rocky Mountain Network. The steering committee will work as a team via conference calls and email communication to make decisions that guide elements of the inventory such as the creation of the full inventory study plan, cooperators, and timelines. The steering committee is also responsible for reviewing reports that describe the progress of the inventory progress and insuring that the information and suggestions contained in these reports guides management in an adaptive manner in the respective National Park Service units.

The science advisory team is responsible for identifying the needs of the respective park units based on data collected and requests from managers. By accounting for these needs, and the goals outlined by the National Park Service Inventory and Monitoring Program, the science advisory team is responsible for outlining scientifically credible plans for meeting the needs of the inventory. The team also collaborates with cooperators and hires, project leaders, biological technicians, and data managers to make some of the other projects happen. In the case of some projects, specific parks hiring employees internally needs will meet inventory and data management. The science advisory team is responsible for drafting reports of work in progress that they are responsible for at scheduled intervals, and synthesis of the overall inventory effort at

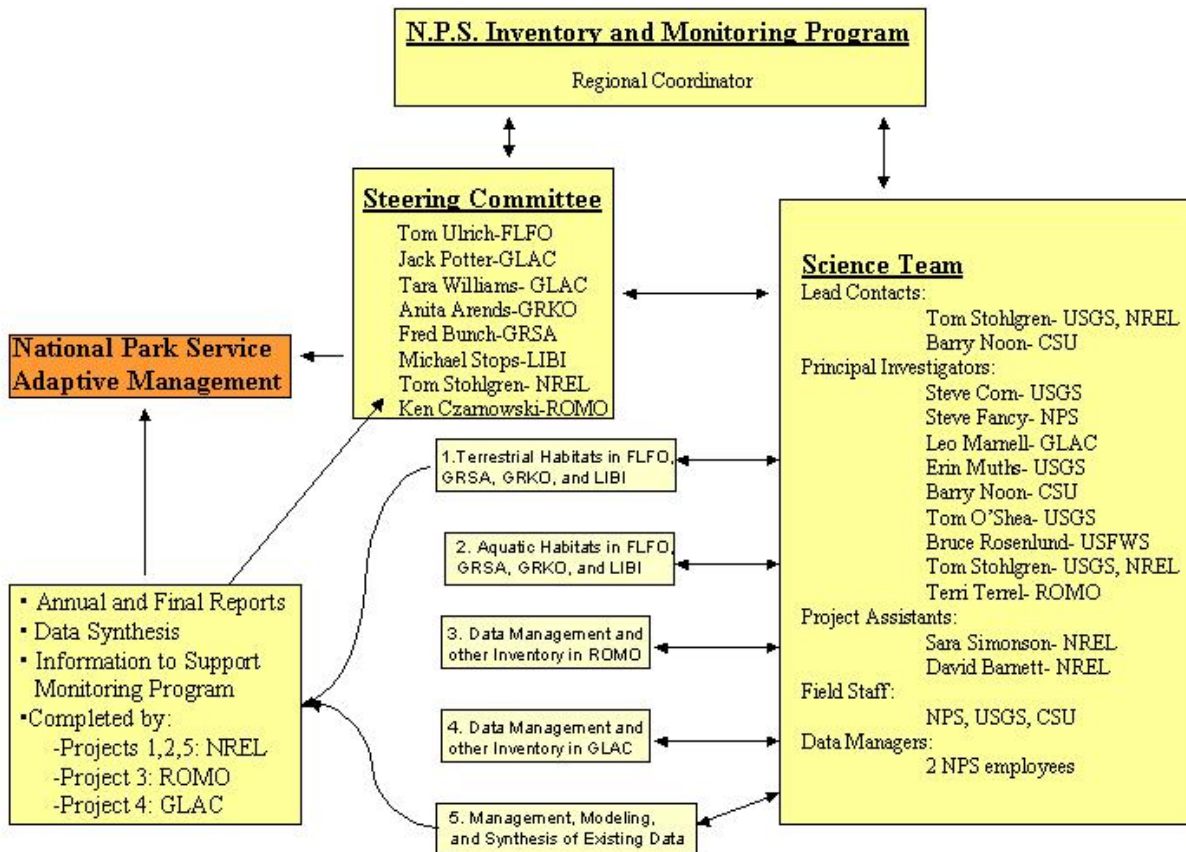


Figure 1. Organization and structure of the Rocky Mountain Network inventory program.

the end of the project.

Each project will have a regular reporting schedule. These reports, as well as the final report will be submitted to the steering committee for review to ensure that information gleaned from various investigations is transferred to park unit managers. The goals of the inventory have been developed with intentions of supplying managers with information that will facilitate management of resources. The methods to accomplish this are outlined in great detail in this document. The structure described here provides a framework to accomplish these goals.

I.B.1. Approach for completion of inventories in the Rocky Mountain Network

We first detail the specific mandates and policies to which this proposal directly responds. We then describe how the proposed network of NPS units will work together to conduct the projects outlined in this study plan to complete an inventory of their vertebrate and vascular plant species. The major steps will include:

1. Continuing to gather previously collected data and converting existing information to useful formats - Dataset Catalog, GIS Databrowser.
2. Improving documentation of evidence for park species lists – NPSpecies.
3. Conducting coordinated field inventories where necessary.
4. Using modeling and other data synthesis techniques to make inferences about specific species within each park, and to make comparisons across parks that will provide regional Network conclusions.
5. Providing data synthesis on the status of biological inventories that will facilitate the transition to the monitoring of natural resources in the Rocky Mountain Network.

I.C. Biological Inventories in National Parks

I.C.1. Responding to the NPS Mission, NPS Policies, and Recent Legislation

The mission of the National Park Service is "... to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (NPS Organic Act, 1916). To ensure the successful achievement of this mission, the NPS Management Policies (Chapter 4:4, 1988) mandate that "The National Park Service will assemble baseline inventory data describing the natural resources under its stewardship and will monitor those resources at regular intervals to detect or predict changes. The resulting information will be analyzed to detect changes that may require intervention and to provide reference points for comparison with other, more altered environments."

Furthermore, the importance of inventorying and monitoring natural resources has been reinforced by recent legislation (National Parks Omnibus Management Act of 1998): "The Secretary shall undertake a program of inventory and monitoring National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of NPS resources. The monitoring program shall be developed in cooperation with other Federal monitoring and information collection efforts to ensure a cost-effective approach."

Additionally, FY2000 is the first year of the Natural Resource Challenge (an NPS initiative to revitalize and expand the natural resource program within the park service and improve park management through greater reliance on scientific knowledge), and the upcoming Natural Resource Reference Manual (currently in draft) will provide additional direction for future Inventory and Monitoring (I&M) Programs.

The I&M Program is a high priority within the NPS, and I&M programs have become

highly valued among other agencies as well. The following statement is from "From the Hand that Feeds Us " (FY2000 Congressional Appropriations Language):

"The Committee applauds the Service for recognizing that the preservation of the diverse natural elements and the great scenic beauty of America's national parks and other units should be as high a priority in the Service as providing visitor services. A major part of protecting those resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."

Thus, a comprehensive, standardized, and systematic I&M program is sorely needed throughout the NPS system. This proposal directly responds to these needs and details the approach the Rocky Mountain Network plans to follow to carry out the inventory part of the I&M process.

I.C.2. Attributes of Effective Inventory Programs

An inventory of natural resources provides an estimate or complete enumeration of occurrence, existence, status and distribution of resources (Peterson et al. 1995, NPS-75 1992). Adequate stewardship of land requires ecosystem changes be documented and observed. To understand changes on the landscape that result from management activities or natural and other processes, it is necessary to inventory biotic elements of the system (NPS-75 1992) that can later be monitored over time.

I.C.2.a. Inventory Purpose and Objectives

Geissler (Geissler, 2000 [online] <http://www.mpl-pwrc.usgs.gov/fgim/istatmain.htm>.) provides examples of the purposes and objectives of National Park inventories. Possible inventory purposes include:

- Document the occurrence, location, or condition of specific park resources (e.g., species, habitats, plant or animal communities)
- Identify the occurrence of rare, threatened or endangered species.
- Assess the full range of resources (species, communities, habitats, or ecological processes) that are candidate measures for subsequent monitoring.
- Identify stressors or threats to sustaining the biological resources of the park over time.
- Provide information for ecological modeling in order to extrapolate estimates of resource occurrence or condition to unsampled areas within the park.

Inventory objectives vary in terms of resolution and amount of information provided. Possible park objectives include:

- Derive a complete or partial species list.
- Create a map showing the major plant communities.
- Create a map of known and predicted location for each species within the park.
- Document the location of rare or threatened species or communities.

Because the objectives of the inventory dictate the sample design, it is important to be clear about the possible types of inventory data, their information content, and the amount of effort necessary to acquire the data.

I.C.2.b. *Types of Inventory Data*

Presence. Documenting the occurrence of a species within the boundaries of the park. This is potentially the least intensive of possible inventory methods because sampling stops once the target species has been detected. However, to have high degree of certainty that a species is present (or absent) can be much more difficult if that species is rare, difficult to detect, or highly mobile.

Species Richness. Documenting the total, or some percentage of the total, number of species in the park. The current Park Service inventory effort has the goal to detect 90% of the true number of vertebrate and vascular plant species present at the time of survey. This task can be formidable if the number of species is large and there are many rare or cryptic species. Unfortunately, based on previous surveys of plant and animal communities, our expectation is that many species will be rare (Preston 1948), and therefore estimating a high percentage of the 'true' species richness will require extensive sampling. In addition to extensive sampling, there must be some way to establish a stopping rule for continued sampling when the true number of species is unknown. That is, when can we be reasonably certain that we have tallied 90% of the true number of species? We will discuss various approaches to this problem in a separate section of our proposal.

Frequency of Occurrence. An estimate of the number of survey sites occupied by a species or habitat type. Such data can provide an index of population size and, by sampling habitat covariates at occupied sites, lead to a statistical, habitat relationship model. Changes in the number of occupied sites over time can provide a crude estimate of trend and be useful for long-term monitoring.

Distribution. A spatially explicit characterization of frequency of occurrence data. To estimate a species' distribution requires extensive sampling throughout the sampling frame. Probability of occurrence in non-sampled areas can be inferred from a habitat relationship model for the species. Changes in the spatial pattern of occupied sites can be useful for long-term monitoring.

Relative Abundance. An index assumed to be correlated with the parameter of interest in some way. For example, an index of relative abundance is an incomplete count assumed to be proportional to true abundance. Use of a relative abundance index across space or time requires a critical assumption: the index is monotonically related to the variable it indexes (Thompson et al. 1998). To estimate the functional relationship between an index and the parameter requires that both be simultaneously estimated on some subsample of plots and the relationship estimated via regression analysis. Without knowledge of the functional relationship between the index and the parameter of interest, the index is of little utility. Only where the index and the parameter are linearly related is interpretation of changes, or differences, in the index easily interpreted.

Abundance. The total number of plants or animals within a defined area at a specified point in

time. In order to interpret count data from field plots as estimates of abundance, one must be able to account for incomplete detectability. This is necessary because the number of organisms counted (C) is equal to the product of the number of organisms present (N) and the fraction detected (p), $C = Np$. To estimate abundance requires sampling to acquire the count data as well as a study design that provides an estimate of p ,

$$\hat{N} = \frac{C}{p}.$$

Because of the importance and difficulty of estimating p , and the frequency with which this assumption is ignored by field biologists, we devote a separate section to a discussion of abundance estimation.

I.C.2.c. *Effective Inventory Procedure*

A great deal of information regarding the state of natural resources has been collected in national park units. Increased understanding of threats to biological resources in national parks and other natural areas has emphasized the need for I&M programs at broad scales (Peterson et al. 1995). Several general guidelines have been put forth to carry out such an effort (NPS-75 1992, Peterson et al. 1995), but little comprehensive information exists on how to conduct a thorough inventory program at a regional scale. The following sixteen points describe an inventory process that produces data relevant to specific park units while allowing for analysis of patterns at a regional scale:

1. Develop flexible goals and refined objectives.

Setting and adapting realistic goals and objectives of a long-term study is essential to success. This challenging initial step will direct future actions and guide prioritization of tasks (Silsbee and Peterson 1991). The goals and objectives listed in the introduction of this document guide this outlined inventory, but the Rocky Mountain Network maintains that the work to be done within the bounds of these guiding objectives must be flexible. The inventory must take place in an iterative format that allows for reaction and adjustments as the status of resources in each of the parks becomes more defined and clear.

2. Secure long-term funding and commitment.

A principal purpose of an inventory is to provide a baseline of information from which a subset may be used for monitoring and future comparative investigation. The inventory itself must be an ongoing process in order to detect the arrival of new species such as invasive exotics, and to collect inventory data on specific species that may become of interest for monitoring in the future. Long-term studies are difficult to carry out and maintain due to insufficient time and funding, organizational challenges, and too little baseline information (NPS-75 1992). This new initiative has the long-term funding and commitment, in the form of networks, to complete a successful and informative inventory and monitoring program.

Large-scale field inventories are expensive and require a considerable commitment by managers, scientists, and research organizations (Strayer et al. 1986, Franklin et al. 1990, Stout 1993). With graduate research programs and National Science Foundation grants that last

typically only 2 to 5 years (Pickett 1989), it is little wonder Tilman (1989) found only 1.7% of continuous ecological studies lasted at least 5 field seasons. In order to detect subtle changes that occur across a landscape, an inventory and monitoring plan must often continue for a many years (Likens et al. 1985, Franklin and DeBell 1988). The National Park Service inventory and monitoring initiative must maintain the highest standards of quality and products to ensure future funding from legislative bodies and to attract supplemental funding that will ensure long-term success and usefulness of this inventory and monitoring program.

3. Identify highest priority inventory needs.

Because few inventory budgets are extensive enough to meet the needs and desires of managers involved, priorities need to be established. Existing species lists need to be evaluated and assessed for completeness. Gaps in species lists need to be integrated with top priority species and habitats as identified by managers and previous research. Top priority stressors should also be considered as they may point to previously unidentified species and habitats that may be or become a concern. These priority species and habitats should be evaluated for abundance and distribution in preparation for monitoring to detect trends over time. It may be that species of less immediate importance could receive significant inventory effort if they can be collected incidentally or with little extra effort during the collection of data on species of special concern. It may also be that these species receive less funding and time and may simply be documented with presence/absence data within a geographic region.

4. Stratify habitats to meet multiple objectives.

Cost efficiency, the amount of information gained for the money spent, can be increased by designating sampling effort to areas that contribute a greater proportion of regional diversity and contain more species of special concern (Stohlgren et al. 1999a). Common habitat types on the landscape may require just a few sample sites before an abundance of redundant information is collected. Rare habitat types on the landscape should receive a greater proportion of sample sites as they often contribute a disproportionately high level of diversity; top priority species of concern should be the focus of most sample sites. Investigators need to be flexible: they should be prepared to add new habitats such as burned sites, flooded areas, or blowdowns to a stratification as an inventory progresses. An effort should be made to be as consistent as possible across inventories in other regions so comparisons can be created.

5. Adequately address information management.

A good rule of thumb is that about 20% to 25% of the budget be devoted to data and information management. Whether a centralized or distributed architecture is selected, several tasks must be fulfilled including: quality control/quality assurance for field data, metadata catalog, and statistical analyses (Shampine 1993). One of the strengths of the Long-Term Ecological Research (LTER) program is its hiring of data managers, use of consistent hardware and software, early development of network-wide data standards, and attention to data synthesis (Stafford 1993).

About 25% of the resources should be devoted to data and information management in each park unit, but fed periodically into a centralized geographic information system data archive. The information management program should be divided into four major components: (1) program and project tracking; (2) strict adherence to metadata standards; (3) database

management; (4) quality assurance and quality control throughout the research program.

Metadata (information about program funded datasets) should be collected following the Federal Geographic Data Committee's "Content Standards for Spatial Metadata." In short, information gathered includes: dataset name, responsible organization, contact person and address, project codes, data form and format, key words and geographic coverage, scale, time span of data, accessibility, and additional comments about the data sets.

Data gathered for specific hypotheses are the responsibility of individual investigators. Hardware and software used, and the particular format used etc., are less important than contributing details to the metadata. However, investigators must keep detailed information on dataset structure, units of measurement, and whether or not the data have been quality checked. And, to set the stage for data integration, all spatially explicit data are incorporated into the GIS databrowser developed for this inventory and monitoring project.

Quality assurance and quality control from data collection to publication of results are everyone's responsibility, including field and data entry staff, statisticians, and principal investigators.

6. Improve information management of past data.

Previously collected data is often in old electronic formats or hard paper copies that make access difficult so that the information is seldom utilized or referenced. However, this 'mature' data can often be of use for filling in holes in current understanding of resources and processes on the landscape (NPS-75 1992). Updating this information into formats that can be integrated and compared with newer data sets and data collected in an inventory can be extremely useful and eliminate the need to waste valuable funding on recollecting existing data. Even if out of date methods or biased site selection were employed, some of the information may still be extractable for use with modern data sets (i.e. in a presence/absence framework). However, it should be noted that some data sets may not be worth the time and money to update.

7. Iteratively approach sampling design.

Many techniques are used in landscape-scale ecology with little standardization (Stohlgren 1994, Stohlgren et al. 1994). Long-term research programs may also lock into a sample design too early, reducing flexibility and commonality among evolving programs. Although there are components of many existing programs that may meet general needs, there is no consensus on sampling designs for long-term landscape-scale studies for natural resources, although there are components of many existing programs that may meet general needs. Strayer et al. (1986) stress the importance of a simple, accommodating design, and suggest "experimentation" in the sampling design phase. They mention the need to develop new methods (i.e., the experimental nature of long-term studies), and emphasized early attention to sample archiving, data management, and statistical considerations. We would add that a sampling design must also be flexible enough to meet flexible goals and refined objectives, yet standardized to meet local, regional, national, and global information needs.

For landscape-scale vegetation studies, for example, decisions must be made about plot shape and size, the parameters selected to study, and the frequency, precision, and accuracy of measurements -- all of which affect the value of the long-term data set. It is necessary to test various techniques to quantify specific resources before the merits of each can be known. In all

cases, it is worthwhile to consider other options before defaulting to use existing field methods. For example, recent tests of techniques to assess vascular plant species richness proved that older field methods are less accurate than newly devised techniques (Stohlgren et al. 1998a). Radically changing a sampling protocol midway in long-term studies can be disastrous unless new methods are calibrated to the old methods (Stout 1993).

8. Obtain peer-review and statistical review of research proposals and publications.

An important but underrated phase of the research process is the peer-review of the experimental design. Hurlbert (1984) thought that about 70% of ecological studies suffered design or statistical problems. Many of these problems, particularly pseudoreplication, are best alleviated early in the project. Often in science, review of manuscripts for publication receives more attention than the review of protocols and sampling designs. Rigorous plans for data analysis must be developed prior to data collection (Stout 1993), understanding that some features of the sampling design may adapt and evolve. That is, determining adequate sample sizes is an iterative process, recalculating variance and temporal and spatial replication needs as the study progresses.

9. Reduce bias in selection of plot locations.

Since ecosystems are complex and vast, ecologists cannot measure everything everywhere. Yet, an important feature of landscape-scale inventory is the explicit intent to extrapolate information from plots to landscapes and from landscapes to regions. Palmer (1993) warned that several sources of bias must be avoided in the selection of permanent plots: the use of current species rarity, abundance, or homogeneity as selection criteria can cause the appearance of a trend when in fact none exists. Hinds (1984) implied that most long-term study findings are a direct result of subjective study site selection. Krebs (1989) suggested many ecologists do not sample according to the principles of probability sampling. He cites many ecological examples of accessibility sampling, haphazard sampling, and judgmental sampling. The selection of long-term study sites near roads or trails is an example of accessibility sampling. Where sampling is restricted by accessibility, investigators are uncertain of the representativeness of the sample in space. Likewise, haphazard sampling (selection of arbitrary samples) may not be representative in space or time. For many long-term biodiversity monitoring plots (Dallmeier 1992) and forest dynamics studies (Hawk et al. 1978, Riegel et al. 1988), investigators have selected "typical" sample units (or "reference stands"). Only data produced from unbiased study plots can be evaluated by the theorems of probability theory. Unbiased plot selection using random sampling, stratified random sampling, or systematic sampling provides ecologists with an important tool to extrapolate information from plots to landscapes and from landscapes to regions.

10. Ensure adequate spatial replication.

Hinds (1984) stated "the major statistical difficulty is specifying appropriate replication standards in a world that is full of unique places." In most cases, there are rarely enough replicates in ecological studies for statistical extrapolation or inference (Kareiva and Anderson 1988). Sample size determination in long-term landscape-scale studies requires an

understanding of sources of variability at different relevant spatial scales, and use of a statistical model that best controls those sources of variability. Typically, appropriate sample sizes are determined after evaluating between-plot variance from initial field tests (Krebs 1989). Besides systematic error (bias in measuring devices or methods employed), long-term landscape-scale measurements may have considerable random error, inherent spatial and temporal variability: the "signal to noise ratio" may be very small. Since disturbances of some kind or another frequently occur on most landscapes, studies designed to quantify disturbance effects must anticipate a range of disturbances and site-specific responses.

Spatial variability is addressed often by selecting smaller, more homogenous areas to study (e.g., the "reference stand" approach). However, homogenous areas may be the most stable and persistent on the landscape. Heterogeneous areas and ecotones (Holland et al. 1991, Hansen and di Castri 1993) may be more important areas in which to detect locally rare, or important species or to monitor change. For example, if a study objective is to assess changes in exotic species distributions, the limits of a species' distribution might be important to survey and monitor. If an objective is to survey and monitor changes in a species' productivity or demography, then sites might be selected throughout a species' range.

11. Ensure adequate temporal replication.

Adequate temporal replication is essential for the monitoring phase that follows the inventory phase. Adequate temporal replication is also important for an inventory to assure maximum recognition of species within a given habitat or park unit. With a fixed budget, a trade-off exists between spatial and temporal replication. That is, you can collect data frequently at few sites or less frequently at many sites. Determining the appropriate frequency and periodicity of sample collections depends on the species of interest and the degree of detail of the inventory (Stohlgren et al. 1995a). Regional experts should be consulted to determine the optimal period for sampling specific taxa, combined with the aims of a particular study. For example, the breeding season may be the best time to observe an abundance of bird species. But breeding season may vary according to individual species, latitude, rainfall pattern, temperature, elevation and even year (Ralph et al. 1993). Furthermore, if migrants that use a park unit on a migratory route are of interest, then surveys would need to be conducted during their temporary occurrences (Ralph et al. 1993).

12. Build on existing data.

Ecological research requires the integration of a variety of approaches (Tilman 1989). Synthesis with other studies is difficult simply because it can be difficult to obtain and process older data that were not subject to rigorous quality control procedures. Still, a synthesis of results from retrospective and experimental studies with long-term, landscape-scale studies can provide important insights of the causes, magnitude, and direction of change (Fritts 1976, Davis 1986).

Fortunately, a great deal of inventory information already exists on vascular plants and vertebrate species in the Rocky Mountain Network. Adequate funding must be used to update and process previously collected data, while additional funding is used to fill the holes or gaps in current data bases. Some effort must be dedicated to checking the completeness of data sets with mathematical models or the use of independent sampling. Also, some regions must be revisited

in order to create maps of distribution and obtain abundance data on habitats or species of special concern.

13. Use spatial modeling early and throughout.

To obtain distribution and abundance data, inventories must use random or stratified random sampling designs that allow for extrapolation and spatial modeling. Spatial modeling should take place in conjunction with the design phase and field sampling phase in an iterative manner. The results of a spatial model provide feedback on the process of understanding the distribution and abundance or cover of a species by assisting in the identification of gaps that may still exist in the data, identifying the need for and location of further stratification, and assessing variation and sources of error in the data.

14. Periodically review program evaluation.

The integrity of any program is increased by periodic program review. Maintaining an adaptive approach is important, while initiating a core set of long-term measurements. Program objectives and tasks must be re-evaluated often, and hypotheses confirmed or new ones created as the study evolves. This is an important feedback loop to measure success and to maintain an open dialogue among scientists, land managers, and program coordinators.

15. Integrate and synthesize with larger and smaller scale research, inventory, and monitoring programs.

The value of long-term data sets from many sites can be enhanced greatly by incorporating that data into other larger- and smaller-scale, and longer- and shorter-term data sets (Levin 1992). The greatest impediment to integration and synthesis is getting investigators to share data, a situation that is averted by agreements early in the research program.

16. Develop an extensive outreach program.

Information is powerful only when it is transferred and used. Outreach programs include publications for scientific and lay audiences; interpretive programs for visitors, schools, service groups and others; and regular communication with local, regional, national, and international communities and policy makers. An effective outreach program informs and educates, develops partnerships, and delivers needed products to program customers.

I.C.3. The Link to an Effective and Informative Monitoring Program

Inventory and Monitoring are frequently thought to be a unified process. However, critical differences in the objectives and goals necessitate two distinct, yet closely associated initiatives. Monitoring detects change in species, habitats, and processes by quantifying trends and conditions of a few, carefully chosen species over time (Noon et al. 1999). An in-depth monitoring focus on a subset of the inventoried species that are indicative of change often requires different sampling design and methodologies. 'Natural' changes, such as successional shifts, and both deliberate and unintentional manipulations may drive change in abundance or distribution of these species on the landscape. Habitat loss, establishment of exotic species, and the disruption of natural processes characterize just a few of the inadvertent, human-induced alterations. Intentional manipulations or management practices may also be evaluated with monitoring. This requires an iterative process whereby the impact of a manipulation or other

management action is evaluated and informs continued management. These management activities are often motivated by an effort to mimic natural change, or come in response to detected disturbance.

As the human-induced mechanisms seem to be more relevant and useful to management, a well-designed monitoring plan must be able to separate results of different drivers of change (Noon et al. 1999). For example, managers must be able to isolate changes in species composition caused by habitat loss from those caused by natural disturbance regimes; different processes inspire different management actions. As populations and processes are naturally variable, thresholds that trigger management must be established. A threshold indicates that a specific indicator has exceeded expected and natural bounds of variation, and may require management intervention. The inventory process outlined in this proposal creates a foundation for monitoring. The initial investigation identifies a crucial subset of ‘indicators,’ determines where, when and how to measure them, and establishes thresholds that trigger active management.

Effective I&M programs must be relevant to current management issues as well as anticipate future issues based on current and potential threats to park resources. Such I&M programs must be scientifically credible, produce data of known quality that are accessible to managers and researchers in a timely manner, and be linked explicitly to management decision-making processes (S. Fancy, personal communication).

I.C.4. The Iterative Inventory

To obtain the largest amount of quality data for the least cost, the Network maintains the importance of iterative flexibility in both planning and implementing the inventory. This approach will allow organizers to maximize the possibility of working with various cooperators, methodological approaches, and to focus inventory efforts towards needed and valuable data.

Scientifically effective and credible methods that meet the needs of the Rocky Mountain Network have been identified and are outlined below. The Principal Investigators and protocols for each project within the inventory program have been identified. Projects to be initiated early in the program have been outlined in more detail, while those planned for future years require further definition.

However, in the interest of obtaining the highest quality data while maximizing cost-efficiency, the Rocky Mountain Network maintains the need for flexibility. After the initiation of the inventory program, other cooperators or channels may surface to carry out the inventory projects in a more efficient manner. Given the long list of desirable inventory projects that will not be carried out due to insufficient funding, any way that the Network can undertake more of these projects by increasing the cost efficiency of other projects should be considered. Changes to projects that will occur within the inventory program will be outlined in detail and submitted to the NPS inventory and monitoring office for review and approval.

The details of data collection must be flexible as well. The amount of effort and time spent in each park on each taxon must be approached in an iterative manner. Data collection must be alternated with analysis and evaluation of data that will inform managers and investigators if and where further data needs to be collected. The evaluation of data directs subsequent collection of data, which is then analyzed and evaluated for spatial and inventory completeness with the possibility of indicating that more data collection is necessary. Data and information obtained is evaluated against the goals established for the inventory. For example,

Great Sand Dunes National Monument vegetation data is estimated to be 90% complete. Further vegetation work will be done to assess the cover and distribution of species of special concern. This data and existing species lists must be combined with modeling tools and species area curves to assess completeness and to indicate where gaps exist. A decision criteria based on predetermined inventory goals will determine if work should be continued or if time and energy should be focused in other areas. The size, intensity, and logistics of a study depend on the information gleaned from these iterative investigations.

I.C.5. A Model for Comparable Inventory and Monitoring

Methods for inventory and subsequent monitoring need to be accurate, repeatable, and appropriate to detect the state and trend of natural resources. The Rocky Mountain Network strives to collect data that provides an assessment of resources and trends within each park unit and at Network, regional, and national scales when merged with other data.

A lack of comparable methods has prohibited the emergence of such a program in the past (Stohlgren et al. 1995a). Accurate and repeatable methods require the use of appropriate methods for the given situation; therefore, the parameters of a study must be adjusted to suit the site to be sampled. The variability of habitats and species assemblages existing in the Rocky Mountain Network alone explains the difficulty of utilizing comparable methods that facilitate regional perspectives. Two issues complicate comparability: the use of accurate and reliable methods, and the lack of common metrics.

Many commonly used methods do not account for variability inherent on the landscape and thus do not provide an accurate representation of resources. For example, simple point count bird techniques assess species richness without accounting for variations in observer and detectability, and tend to misrepresent species, or not account for many rare species on the landscape (Fancy and Sauer 2000). Methods like these have the potential to provide an inaccurate picture of actual biological trends. Methodological weakness at one park can only exacerbate when repeated at many parks, complicating regional comparisons.

The use of common metrics allows for comparability at the regional scale, and even within park units. For example, obtaining cover and richness of plant species in 1-m² plots along with species richness data at multiple scales provides a powerful metric of comparison when applied across a variety of habitats (Stohlgren et al 1997a, Stohlgren et al. 1998c, Stohlgren et al 1999 a,b). Collection of data at multiple larger scales leverages the use of species area curves. The slopes of these curves tell a great deal about species assemblages, and can be compared regardless of successive plot sizes (Stohlgren et al. 1997b, Stohlgren et al. 1997a).

The Rocky Mountain Network inventory will take advantage of the Network approach by ensuring that inventories of particular taxa incorporate common metrics. It is important to note that this does not necessitate identical standardization, but allows for flexibility, and frequently allows for use and augmentation of methods already in place.

This inventory has been designed to allow for flexibility. A variety of methods allows for appropriate sampling efforts given variability to be encountered across the Network. Maintaining coordination in study design and metrics assures comparability. For example, the USDA Forest Service has developed a vegetation sampling design for the Forest Health Monitoring program (Stohlgren et al. 2000b) that collects data comparable to the Modified-Whittaker sampling method (Stohlgren et al. 1995b), even though the plot design and sampling strategies are different. Both methods collect data on species richness and cover in 1-m² quadrats, and both collect data at multiple scales. Because both methods assess diversity and cover at large scales within stratified habitats, they tend to capture more rare and patchily distributed species (i.e. invasive species), and provide a more accurate assessment of the status and trends of species of concern.

The Network approach signals the future of significant inventory and monitoring planning for park units of the Rocky Mountain Network. An integrated approach may provide opportunities for efficiency, sharing resources and knowledge, and for attracting future funding. For example, the inventory could demonstrate that both Little Bighorn National Battlefield National Monument and Grant-Kohrs Ranch Historic Site may both be subjected to invasion of the weed St John's Wort. Time and money could be saved by cooperating efforts to combat the early invasion. Such incidence may even provide justification for further funding to monitor potential invasions in proximate parks such as Glacier National Park.

I.C.6. The Rocky Mountain Network Focus on Species of Concern

The Rocky Mountain Network inventory will establish a baseline of resources. A large percentage of the inventory effort will simply document the presence of species within a park unit. Some distribution data will also be gathered in this process, as documentation will be spatially referenced. Species presence data provide managers with a detailed understanding of the resources held in trust and may reveal species that were previously unknown to the park. The inventory will dedicate greater time and effort in documenting the abundance and a detailed picture of distribution of species of concern. The National Park Service Inventory and Monitoring Program defines a species of special concern as any threatened and endangered species, nonnative species, and those species identified as being of special interest and importance by park unit managers (**Gregson web page citation**).

Species of concern will be monitored in the future. Being of special interest, a change in number or location of the species is important to the management and integrity of a park. In order to detect and understand changes over time, unbiased and quantitative data must be collected at periodic intervals. Distribution and abundance data will be collected on habitats and species of special concern that will facilitate the monitoring effort and provide a more detailed analysis of the current status of the species of concern as part of the inventory effort.

II. BACKGROUND

II.A. Status of Biological Inventory in Rocky Mountain Parks and Monuments

The six NPS units in the Rocky Mountain Network include two mountainous NPS units (Rocky Mountain National Park and Glacier National Park), two predominantly historical / cultural NPS units (Grant-Kohrs Ranch National Historic Site and Little Bighorn Battlefield National Monument), and two geologically unique sites (Florissant Fossil Beds National Monument and Great Sand Dunes National Monument). These NPS units represent a rich variety of natural and cultural resources embedded within diverse natural and human-influenced landscapes. Despite valiant efforts by each of these units, no standardized, systematic, and comparable I&M program has been established to effectively inventory and monitor the remarkable natural and cultural resources these six NPS units aim to protect. The paucity of scientifically based biological inventories conducted at these six NPS units illustrates the need for a sound I&M program in the Rocky Mountain region (Table 1, Appendix C). More detailed information about the history, resources, and inventory efforts of each of the six Network park units follow in a park-by-park format.

Table 1: *Estimated status of park species lists*

Status: Goal 1	Amphibians and Reptiles	Birds	Fish	Mammals	Vascular Plants
GLAC	Species list 90% - Need data management	Species list 90% - Need data management	Species list 90% - Need data management	Species list 90% - Need data management	Species list >90% - Need data management
ROMO	Species list 90% - Need data management	Species list 90% Need data management	Species list 90% - Need data management	Species list 90% - Need data management	Species list 90% - Need data management
GRSA	Species list 65-70% - Need basic inventory	Species list 65-70% - Need basic inventory	Species list 90% - Need data management	Species list incomplete- Need basic inventory	Species list < 90% - Need more inventory
FLFO	No species list - Need basic inventory	Species list incomplete - Need basic inventory	No species list - Need basic inventory*	Anecdotal Species list- Need basic inventory	Species list incomplete - Need basic inventory
GRKO	No species list - Need basic inventory	Species list incomplete- Need basic inventory	No species list - Need basic inventory	Species list incomplete - Need basic inventory	Species list incomplete - Need basic inventory
LIBI	No species list - Need basic inventory	Species list incomplete - Need basic inventory	No species list - Need basic inventory	No species list - Need basic inventory	Species list incomplete - Need more inventory

II.A.1. Florissant Fossil Beds National Monument (FLFO)

Thirty-five million years ago, massive volcanic eruptions buried a lush green valley. This catastrophic event preserved parts of an ecosystem that is drastically different than the Colorado of this region we know today. The monument houses some of the world's best, most detailed insect and plant fossils such as huge petrified redwoods and other large fern and understory plant species.

Florissant Fossil Beds National Monument sits on 2,428 ha of montane habitat just west of Pikes Peak in central Colorado. Rolling forested hills dominated by ponderosa pine and Douglas fir give way to montane meadows as they are cut by several small perennial and annual streams. Fifty small earthen dams created by early residents frequently block these streams creating minor wetlands. Several natural wetlands and small bodies of natural water also populate the landscape. Other abundant natural resources within the park include various wildlife species associated with the monument's vast Ponderosa pine stands and diverse vascular plant communities.

Homesteaders settled the region in the 1860's with little regard for the abundant fossils that created difficult ranching conditions. Ranchers had little use for the volcanic tuff and fossils that littered the ground they wished their cattle to graze. Potato farmers also tilled the soil that the monument now sits on. Fields of seeded smooth brome grass persist as a legacy to these agricultural efforts. Records indicate that as early as 1910 members of local communities began to express interest in protecting the fossils as visitors would frequently remove pieces for private collections.

In 1969, a group of scientists and concerned citizens known as the Defenders of Florissant submitted legislation for the creation of the National Monument. After a public hearings and court battles with land developers, the park proponents succeeded as Florissant Fossil Beds National Monument was signed into law by President Nixon later that same year. The monument is devoted to the protection and preservation of the fossils of the Florissant Valley.

The natural resource inventories completed for the national monument are in need of attention; no inventories have been conducted on fish, amphibians, or reptiles, and only anecdotal species lists exist for most biotic groups. An elk population and movement study was completed by Scott Roush (1997). Floral studies have received the most attention. The Colorado Native Plant society completed random walks identifying species in major habitats. Alex Birchfield, monument resource specialist has established 900 Daubenmire plots in an effort to monitor the effects of removing the earthen dams on vegetation. Specific mapping work has been done to document the distribution of exotic weed species, mostly in riparian areas, but no quantitative data has been collected in conjunction with these efforts.

Monitoring and management concerns at the Monument include invasive plant species, altered fire regimes, surrounding private land development, and impacts from previous agricultural land use.

The staff of Florissant Fossil Beds identified as a high-priority need, a systematic inventory that will incorporate all taxonomic groups in a general community based sampling effort.

II.A.2. Glacier National Park (GLAC)

Glacier National Park is renowned for its unique geological formations and numerous glaciers. The park encompasses over a million acres of pristine habitat for plants, birds, mammals, fish, reptiles and amphibians. Glacier National Park represents an intact ecosystem including gray wolves and grizzly bears. Over 1,200 species of vascular plants are found there, 41 of which are classified as rare in the state of Montana, and 130 exotic species.

Glacier National Park has a long history of scientifically based inventory, monitoring and study of natural resources. The Park has a highly respected fisheries program headed by Leo Marnell. Steve Corn of the USGS/BRD has an established amphibian survey and monitoring program that is closely tied to amphibian research in Rocky Mountain National Park by Erin Muths and the national amphibian monitoring programs. Steve Corn is also about to expand the project as the principal investigator on the new amphibian initiative funded by the Department of the Interior ARMI project. Glacier National Park has an extensive plant species list created by many years of various plant inventories. Partners in Flight has completed a great deal of avian inventory and monitoring of bird species. The Park has done a great deal of work studying mammals. These include studies on charismatic megafauna, such as the dynamics of resident

wolf and grizzly bear populations, as well as studies carried out by Kim Keating and others on small mammals. The results of these research projects lead park managers to believe that inventories are 90% complete for all taxa of interest to this initiative.

The managers at Glacier National Park are confronted by a suite of factors that threaten natural resources: burgeoning recreation, development on and within the park boundary, altered fire regimes, invasive plant species, rare plant species conservation, air and water pollution, and rapid climate change. Increased visitation and travel on the Going-To-The-Sun Road also presents additional threats to resource conditions in the park.

Funding will be focused on upgrading previously collected data into modern databases to effectively contribute to resource management and to facilitate trend analysis in later monitoring phases of the I&M program.

Although the park's first priority is to transform old data into a useful, modern format, they also recognize future research concerns. Some of the historic data is incomplete or insufficient to direct future monitoring. Therefore, the resource management staff at Glacier National Park identified and prioritized their needs for natural resource data.

High Priority Projects:

1. Distribution of forest carnivores – Continue winter track surveys to determine the distribution of lynx, wolverine, marten, and fisher utilizing accepted methodology.
2. Distribution of selected noxious weeds - Expand inventories to cover more areas and include several new species of concern.
3. Distribution of bat species in selected habitats - Expand inventories to determine species and habitat utilization, particularly in developed areas.
4. Status, trend, and distribution of fish in selected lakes, including genetic analysis - particularly bull trout and westslope cutthroat.

Medium Priority Projects:

1. Coordinate with Colorado Bird Observatory and partner organizations and agencies to participate in Montana statewide songbird surveys.
2. Conduct additional plant surveys in bogs, fens and wetlands.

Lower Priority Projects:

1. Distribution of forest and cliff-nesting raptors – particularly golden eagles and prairie falcons.
2. Distribution of owls – species, nesting and use areas, particularly near developed areas.

II.A.3. Grant-Kohrs Ranch National Historic Site (GRKO)

Grant-Kohrs Ranch National Historic Site is located in the Northern Rockies of west-central Montana. The ranch sits on 607 ha of upland rangeland, 182 of which have been converted to irrigated pasture for hay production. The historic site manages 120 cattle and 90 historic buildings that serve as a source of income, and preserve the cultural landscape of the western cattleman era.

With the decline of the bison on the grasslands of the West, the ‘open range’ was left open for the cattle industry. In 1857, John Grant established the ranch that now is the center of today’s historic site. Grant eventually sold the ranch which came to be run by two half brothers by the name of Conrad Kohrs and John Bielenberg. The cattle from the ranch first served the masses of people moving to California and other places on the west coast and then continued success was fueled by high demand brought on by the Montana gold rush that started in the 1860’s. The ranch headquarters of today were the headquarters of the massive cattle operation that at the height of its prime encompassed ten million acres. The Grant-Kohrs Ranch National Historic Site aims to preserve, protect, and embody the historic cattle ranch and natural western landscape that these two brothers worked with great success for many years.

Despite a 1993 General Management Plan (GMP) and Development Concept Plan (DCP), and a basic Resource Management Plan (RMP), only incomplete species lists exist for birds, plants and mammals. Furthermore, no inventories have been conducted on reptiles, amphibians, or fish. The park unit’s bird list was prepared by Powell County High School and its mammalian and plant species lists were prepared by Peter Rice and Gary Ray in 1984 while conducting heavy metal research in riparian areas onsite. Several other studies have been conducted, mostly focusing on the aquatic environments in response to upstream activities. Natural resource management reports that some currently classified reports may provide incidental documentation of species occurrence. However, they are not substantiated nor do they contain data on abundance or distribution.

The ranch is concerned with invasive exotic plant species and mine tailing contamination on the Clark Fork River running through the park. A Natural Resource Damage Assessment is currently being prepared in efforts to evaluate environmental damage and create a restoration / cleanup plan for the river.

A systematic I&M program will provide much needed information on natural resource conditions to this historic cultural landscape and will complement their Natural Resource Damage Assessment. The natural resource managers have requested that community based sampling of all taxa of interest to this inventory initiative be conducted.

II.A.4. Great Sand Dunes National Monument (GRSA)

Located in the arid San Luis Valley of southern Colorado, the Monument contains the tallest sand dunes, up to 213 meters, in the United States. Studies show that the dunes migrate across the land but do not change much in height. These fragile dunes are formed from sand blown across the valley floor and deposited at the foot of the Sangre de Cristo Mountains. This national monument contains native desert scrub vegetation, cold desert vegetation, Pinyon-juniper and Ponderosa pine woodlands, and impacted riparian zones. Mammals that inhabit or visit the Monument include coyotes, bears, mountain lions, mule deer, and a host of small mammals such as kangaroo rats. The Great Sand Dunes are also known for being host to an impressive array of insect diversity.

There is currently a bill to make the region a National Park. This would be accompanied by the purchase and inclusion of the Baca ranch that borders the Monument. This expansion would approximately triple the area of the Monument and include the entire watershed above the dunes, encompassing tall alpine peaks of the Sangre de Cristo mountains, and considerable land below the dunes as well. The effort would preserve the entire local system. Passage of this bill would also put to rest the threat of water extraction for sale to Colorado's booming Front Range communities.

Some information suggests early peoples known as the Clovis and Folsom cultures inhabited the Valley about 10,800 years ago. Native Americans known as the Utes followed, occupying the region from the late 16th to early 20th century. Many ponderosa pines in the monument bear markings left behind by the Utes. The first documentation of the dunes was made by the explorer Zebulon Pike in 1807. Exploration gave way to farming, ranching and mining in the San Luis Valley. The remains of an early irrigation ditch can be found within the monument. The Great Sand Dunes National Monument was established in 1932 to protect this unique sand dune ecosystem.

Great Sand Dunes National Monument has been the subject of quite extensive scientific investigation. The threat of ground water pumping from beneath the Dunes forced quite a bit of physical investigation to examine the potential impacts the sale would have on the dunes. There has been a variety of vegetation work throughout the history of the monument leading management to estimate the vegetation species list to be 90%. There is a set of 118 permanent monitoring plots that utilizes the releve method to assess species richness and cover. However, the plots were placed on a systematic grid, and the authors suggest that further work is needed to obtain a comprehensive picture of vegetation trends. There has been several other studies completed but no other studies adhere to principals of unbiased investigation essential to monitoring.

John Alves of the Colorado Division of Wildlife and others have done substantial work on the various fish species that occupy the monument. The species list is complete for the requirements of this inventory. Anecdotal species information exists for reptiles, birds and mammals. All three species lists are estimated to be about 70% complete. Some studies have been done on specific species such as a variety of small mammals, and others that looked into reptile residents in the monument. Little data has been collected to document the presence of amphibians in the Great Sand Dunes National Monument.

Management issues for the monument include prevention of ground water withdrawal from the San Luis Valley groundwater basin (such removal would have serious consequences to the natural dune system), management of vegetation stabilizing the natural sand deposits located near the dunes, control of invasive plant species effects on native desert scrub and riparian zone vegetation, fire suppression, and visitor impacts.

Natural resource management at Great Sand Dunes National Monument have requested that all taxa of interest in this inventory receive general community based sampling, with less emphasis on fish which have been extensively studied given the presence of several state listed endangered species.

II.A.5. Little Bighorn Battlefield National Monument (LIBI)

Little Bighorn Battlefield National Monument lies along the banks of the Little Bighorn River in a northern high plains environment. The monument is vegetated by northern mixed

grass prairie and sagebrush shrub-steppe vegetation. Grazing has been excluded from the monument since 1891, creating an unusually pristine example of southeastern Montana grasslands. Recent fires have provided the opportunity to examine post-fire responses of this unique ecosystem.

The following text describes the events that took place and the significance of the monument as phrased in the resource management plan:

The Battle of the Little Bighorn fought on June 25-26, 1876 symbolized a high water mark in a 400-year struggle between Euro-Americans and Native Americans. The defeat of 12 companies of the Seventh United States Cavalry by Lakota, Cheyenne and the Arapaho warriors has achieved a symbolic dimension from film, theater, art, and other media. Little Bighorn Battlefield National Monument is a special place allowing profound personal reflection on the historic event and the American consciousness.

The site commemorates one of America's most famous battles, the Battle of the Little Bighorn when two culturally divergent forces clashed in a life and death struggle to on one hand, perpetuate national expansion, and on the other, to preserve a nomadic way of life. The nationally significant battle was unquestionably the most dramatic and glorified battle on the Great Plains. A large coalition of Sioux, Northern Cheyenne, and Arapaho gathered because of their rejection of the reservation system and annihilated Lt. Col. George Armstrong Custer's Companies. The battle catapulted Custer's standing as an American hero, and became a rallying point for the military's subjugation of Native Americans in the West. The battle has become an icon in American culture (Resource Management Plan, 1999).

Little Bighorn Battlefield National Monument has no staff with natural resource expertise. Yellowstone National Park has sent vegetation teams to conduct treatments of several exotic plant species. Jane Bock at the University of Colorado directed a multi-year inventory of the upland grassland to evaluate effects of fire on the vegetation. The Natural Resource Ecology Laboratory at Colorado State University recently conducted a brief investigation of vegetation concentrating on habitat types not surveyed intensively in the Bock investigation. Mari Eggers at the Little Bighorn Community College has conducted other anecdotal surveys. Informal surveys have been conducted for most biotic groups, but complete, quantified inventories do not exist.

Management concerns include invasive exotic plant species and the effects of altered fire regimes on native vegetation. The superintendent is also concerned with the impact of visitation on vegetation. They have recently closed several trails to visitor travel due to erosion and to allow for vegetation recovery.

With the data collected by the Natural Resource Ecology Laboratory, which will provide data on plant species distribution and cover, in combination with the extensive work done by Jane Bock in the grasslands, Little Bighorn should require just a minimal amount of vegetation work to complete the species list and obtain adequate data on distribution and cover of species of special concern. All other taxa will require general community based sampling efforts.

II.A.6. Rocky Mountain National Park (ROMO)

Rocky Mountain National Park's 107,534 hectares encompass an impressive variety of montane forests and meadows, subalpine forests, and alpine rock and tundra. The Park contains more than 110 peaks over 3,000 m, 60 of which top 3,500 m with Long's Peak being the tallest at 4344.9 m. More than 259 square kilometers of the park lie above treeline, populated by arctic-like vegetation commonly found in Glacier National Park and other alpine ecosystems throughout the North American continent. Many of the park's 150 lakes occupy these high alpine zones, perched on rocky shelves. Rainfall, snowmelt, and springs run off of either side of the continental divide, feeding notable rivers such as the Colorado, Cache La Poudre, and Big Thompson. These rivers increase in flow as they pass through the lower elevations of the park. They first pass through vast forests of subalpine fir, Engleman spruce, and lodgepole pine. At lower elevations, these forests give way to montane habitats characterized by ponderosa pine, Douglas fir, and wet and dry meadows. Interspersed throughout, stands of aspen, riparian corridors, and moist wetlands can be found. These regions host a vast array of fauna from a variety of taxonomic groups. Home to over 1,200 plant species, the park provides habitat for 60 known mammals, numerous bird species, 8 fish species, and the rare boreal toad, among others.

Evidence of arrowheads, scrapers, and teepee rings suggest that the Ute and later Arapaho tribes used the region as a seasonal hunting ground. French fur traders and American settlers followed, but Europeans, namely the Estes family, did not settle the area until 1859. In 1867 the homestead buildings were converted to guest cabins when the winters proved to be too harsh for cattle. Visitation to the area has increased ever since.

The region went through a period of homesteading, endured mining booms and consequently was subjected to a great deal of hunting and game trapping through the later part of the 19th century and the beginning of the 20th century. A dedicated naturalist by the name of Enos Mills first proposed that the park be protected in 1909. After extensive campaigning by Mills and others, including the Colorado Mountain Club, Woodrow Wilson signed legislation that established the Nation's tenth National Park in 1915.

Since that time visitation to the destination has grown to more than 3 million visitors a year, most visiting during the summer and fall months. Popular attractions include abundant wildlife viewing, most notably of elk and bighorn sheep. Autumn aspen leaves, which coincide with elk rut season, also attract many visitors. Recreation also attracts a great many people drawn to the park's 571 kilometers of hiking trails. The summit of Long's Peak, the park's highest point, is attempted by approximately 15,000 mountain enthusiasts each year.

Rocky Mountain National Park has an extensive history of documentation and scientific investigation of natural resources. Most recently, Geneva Chong of the USGS/BRD has been adding spatially explicit plant data to the already extensive vegetation species lists and studies, much of which were organized by various park and independent investigations. Bruce Rosenlund of the USFWS has been studying the fish populations of the park for the past twenty years, most recently focusing on invasive species and the genetics of natural populations. For many years, Francis Singer, USGS/BRD has been working closely with park staff and the Colorado Division of Wildlife to understand elk distribution and abundance, and elk impact on vegetation and ecosystem processes. Tasha Kotliar of the USGS/BRD and others are extensively documenting and studying the dynamics of avian communities. Erin Muths, also of the USGS/BRD, has an amphibian project in place that is about to be expanded with new funding from the ARMI. This small list just begins to touch on a few of the investigations, current and past, that collectively provide a comprehensive picture of the current status of resources in Rocky Mountain National Park. Park managers estimate that these efforts have completed inventory to the 90% level for these taxonomic groups of interest (Table 1.).

Natural resource management concerns in the park are diverse and quite extensive. They include elk effects on vegetation (specifically aspen and willow decline on the east side of the park), loss of critical habitat, altered fire disturbance regimes (due to past fire suppression), invasive exotic plant and animal species, air and water pollution, boundary development issues (e.g., altered vistas), and management of the effects of increased visitation (e.g., overcrowded parking lots and increased traffic on Trail Ridge Road). These ecosystem stressors, coupled with the findings of many natural resource studies, have helped managers identify and prioritize native and exotic species of special concern. Lists of species and habitats of special concern for each Park unit appear in Appendix 1.

Although Rocky Mountain National Park has a wealth of natural resource data, much of this data is in formats that are not useful to managers or to the needs of a monitoring program. The chief focus of this inventory effort for Rocky Mountain National Park will be to update previously collected information to modern formats by incorporating it into databases that will become the standard for the Rocky Mountain Network -- Microsoft Access and the ArcView supported GIS Databrowser. A critical aspect of this undertaking will be to assess the quality and value of historic data to assure that we use only relevant, accurate, or useful information. Modernization of data will enable management decisions, create a database management system for all future data, and facilitate easy assessment of trends during the monitoring phase.

Managers at Rocky Mountain National Park have also identified top priority inventory and management objectives that could be undertaken by this inventory effort:

1. Map the distribution and abundance of mountain lion. The mountain lion is considered a keystone species, drawing increasing concern as human-wildlife interactions that jeopardize public safety have become more frequent. The park would like to establish records of population abundance, trends, or distribution that would greatly increase effective management of this important species.

2. Develop methods to understand trends in beaver populations and impacts on vegetation. By combining historical records with new assessments of distribution and abundance, the park might be able to assess trends in beaver populations and the impacts that this assumed decline may have on other species associated with the riparian and aquatic habitats maintained by beaver.
3. Understand the distribution and abundance of mountain goats. Goats are an exotic species in the park. By spending a great deal of time in the alpine tundra they may have a significant impact on the native vegetation in the fragile alpine environment.
4. Assess moose distribution and abundance.
5. Assess the distribution and abundance of lynx.
6. Assess the black bear distribution and abundance.
7. Assess wolverine distribution and abundance.
8. Understand the distribution and genetics of the sculpin and cutthroat trout in aquatic environments in the Park.

II.B. Common Concerns and Threats

The Park units within the Rocky Mountain Network, as different as they are, have not even begun to collect data with a unified approach, but simple comparison of species of concern, the habitats that these species occupy, and identified habitats of concern reveals the similarities that exists across the Network. Certain themes can be seen throughout the suite of species of concern in each park and associated threats facing each of the six member NPS park units of the Rocky Mountain Network. Many of the shared concerns are at the species level- the same species are of issue in different parks.

The number of species of concern identified by each park unit seems proportional to the size and history of data collection in each park, the bigger parks have more information and more recognized species of concern (Fig. 2). Given the disparity of information at the various park units, discerning the cause for this remains difficult. It may be that data-rich parks have a comprehensive understanding of species and therefore a better understanding of species that deserve concern status. It may simply be that larger parks cover greater landmass and are therefore more likely to include a species in jeopardy. An understanding that systems are open and interact beyond park borders might suggest that the smaller parks would have more concerns as they cope with proportionately greater stressors from regions outside park management. This inventory will level data and provide the answers to such questions.

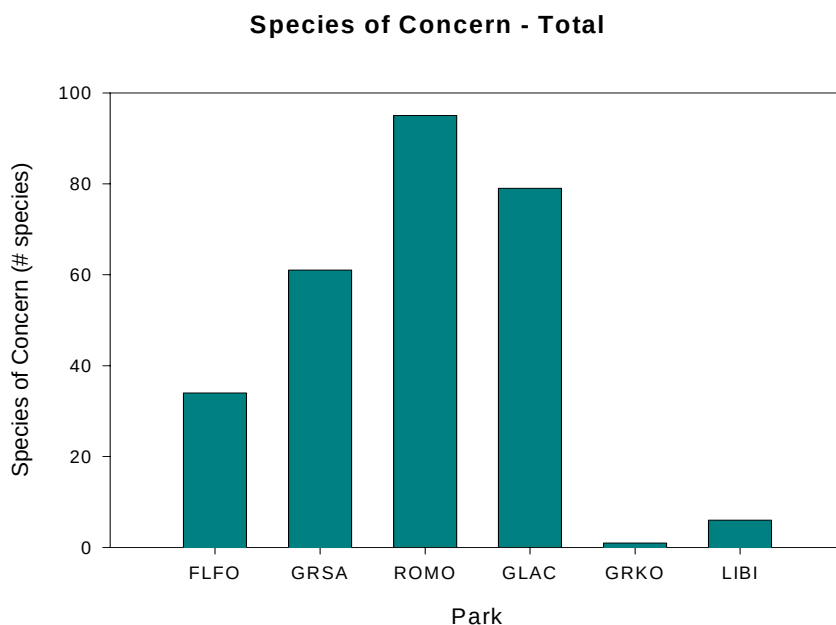


Figure 2. The number of species of concern in the Rocky Mountain Network by park.

Assessment of the number of species of concern by taxa (Fig. 3), shows that plants are the most common taxa of special concern in every park except for Great Sand Dunes National Monument where plants had the second most species of special concern. This is not to indicate that plants should be the main focus of the inventory, but it is worthy to note. This may simply be caused by the fact that there is a greater abundance and variety of plant species than many other taxa, and that there tends to be many more invasive plant species than in other taxa.

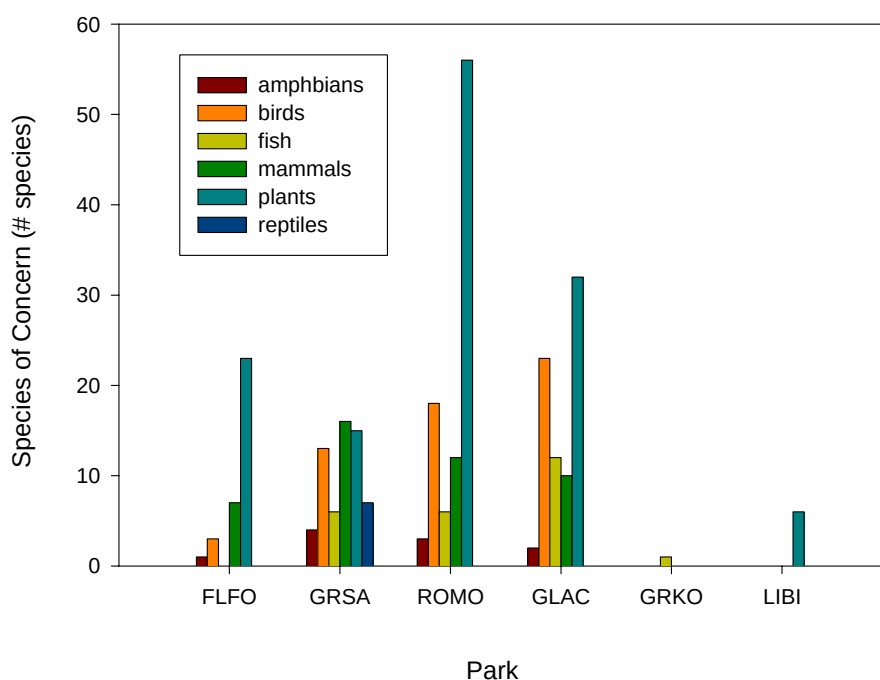


Figure 3. The number of species of concern in the Rocky Mountain Network NPS units, species categorized by taxonomy.

Separating species, regardless of taxonomic categorization, into the habitats they commonly occupy offers a look at habitats that might be of particular concern (Fig. 4). Some common categories were lumped for this analysis to keep the number of potential habitats to a manageable number.

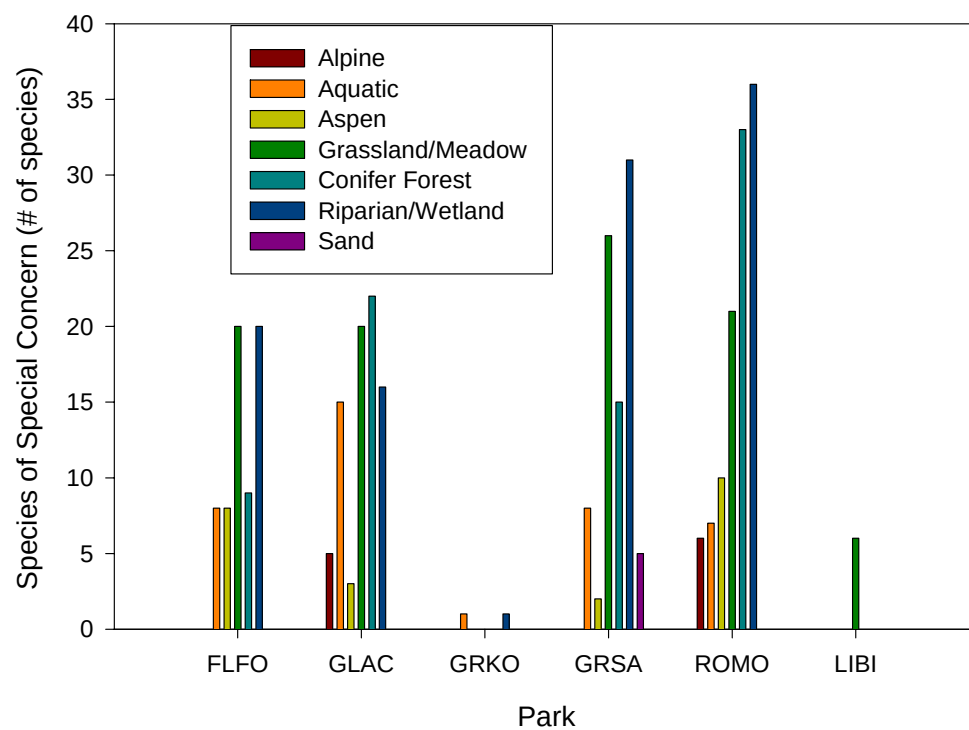


Figure 4. Habitats of Concern within each Rocky Mountain Network NPS unit. Rankings are derived from habitats associated with species of concern and may not reflect specific habitats of concern as identified by managers.

Riparian/wetland, grassland/meadow, and conifer forest top the lists across the different parks. The occurrence of an abundance of species of concern in the coniferous forests and grasslands and meadow habitat types is quite expected given the commonality of these habitat types in parks throughout the Rocky Mountain Network. The combination of riparian and wetland habitats contained the most species of special concern in two of the park units, Rocky Mountain National Park and Great Sand Dunes National Monument, and shared the distinction with grassland and meadow classification at Florissant Fossil Beds National Monument. This result is of interest because by cover it occupies a very small proportion of the landscape while containing and supporting a disproportionate number of species of special concern. Although not containing quite so many species, other areas such as the aspen and aquatic habitat types also contain a significant proportion of species of special concern. Aspen is commonly thought to occupy approximately 2% of the Rocky Mountain landscape (Baker 1925, Krebill 1972), yet Rocky Mountain National Park identified ten species of concern that exist in the aspen habitat type. These results suggest that not only do the parks in the Rocky Mountain Network have similarities in habitats of concern, but also the small habitats may deserve a sampling effort that is disproportionate to size of land area that they cover.

As previously noted, exotic species are of particular interest for the inventory, as data should be collected for these species that allows for future monitoring. Analysis of the exotic species of special concern by park unit reveals information that mirrors the complete species of special concern list- presumably the same speculative reasons apply. The bigger, data-rich parks have more documented exotic species of special concern (Fig. 5). Plants were consistently the taxon with the most number of recognized exotic species of concern (Fig. 6). Somewhat different from the general species of concern list, the grassland and meadow habitat type consistently contained the most exotic species of concern (Fig. 7).

The presence of some trends of species of concern in certain habitats suggests that the Network may be able to implement a habitat-focused inventory. This approach would document many of the species of concern in a cost efficient manner. Managers at each park within the Rocky Mountain Network also identified specific habitats of concern. The list turns up some very specific uncommon habitat types that are more often than not very limited in extent. For these reasons the lists are quite variable (Table 2). However, the riparian and wetland habitat types top the list at three of the six park units, and are in the top three habitats of concern in two others. Thus there is consistency with the lists from the species of concern and even more consistency in that non-riparian or wetland habitats of concern are often disproportionately small habitat types such as the Cedar devils club at Glacier National Park.

For a species or habitat to be considered of concern there has to be some process or change acting upon the species or habitat. Because it has already been demonstrated that many species of concern occupy similar habitats of concern, and because ecological processes often involve groups of species, the causes have been evaluated with respect to habitats of concern. Given the consistency in habitats of concern across park units, it follows that there is continuity among the stressors to habitats of special concern across the park units. Many stressors have been identified, but three stressors commonly act upon important habitat types in the Rocky Mountain Network: 1) the invasion of exotic species, 2) habitat loss, and 3) alteration to natural disturbance regimes.

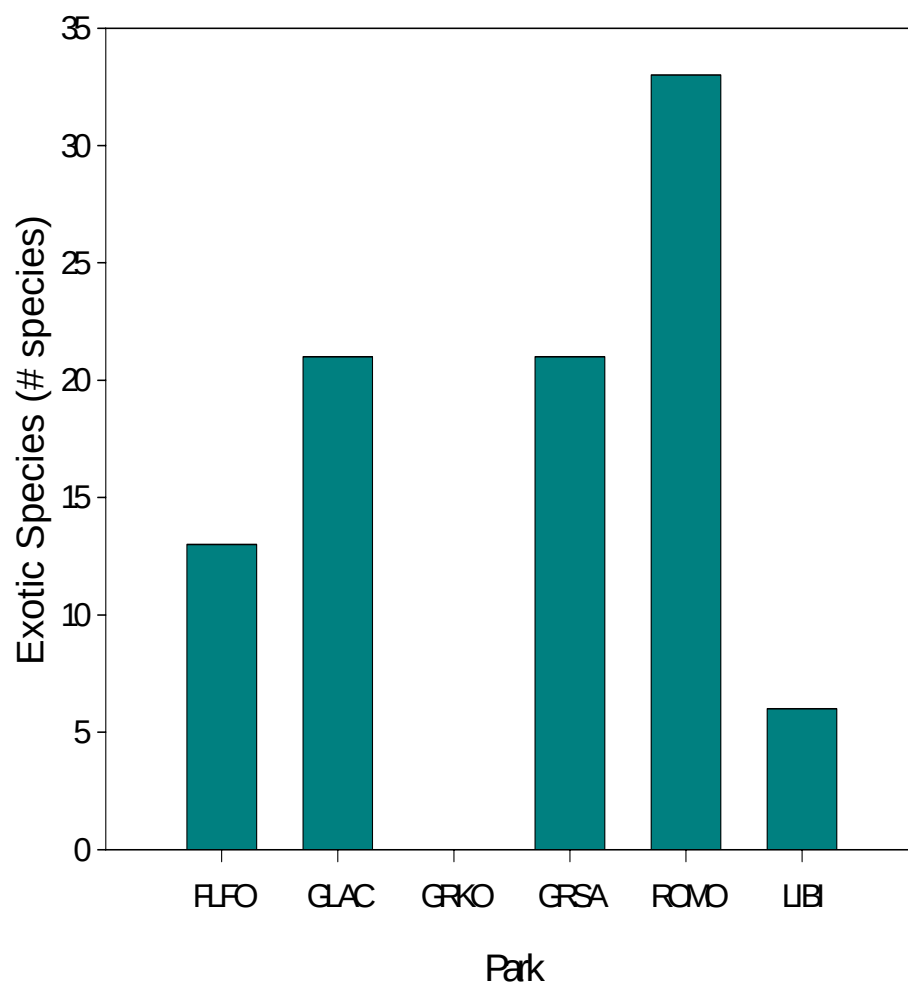


Figure 5. The number of exotic species of concern by Rocky Mountain Network NPS unit.

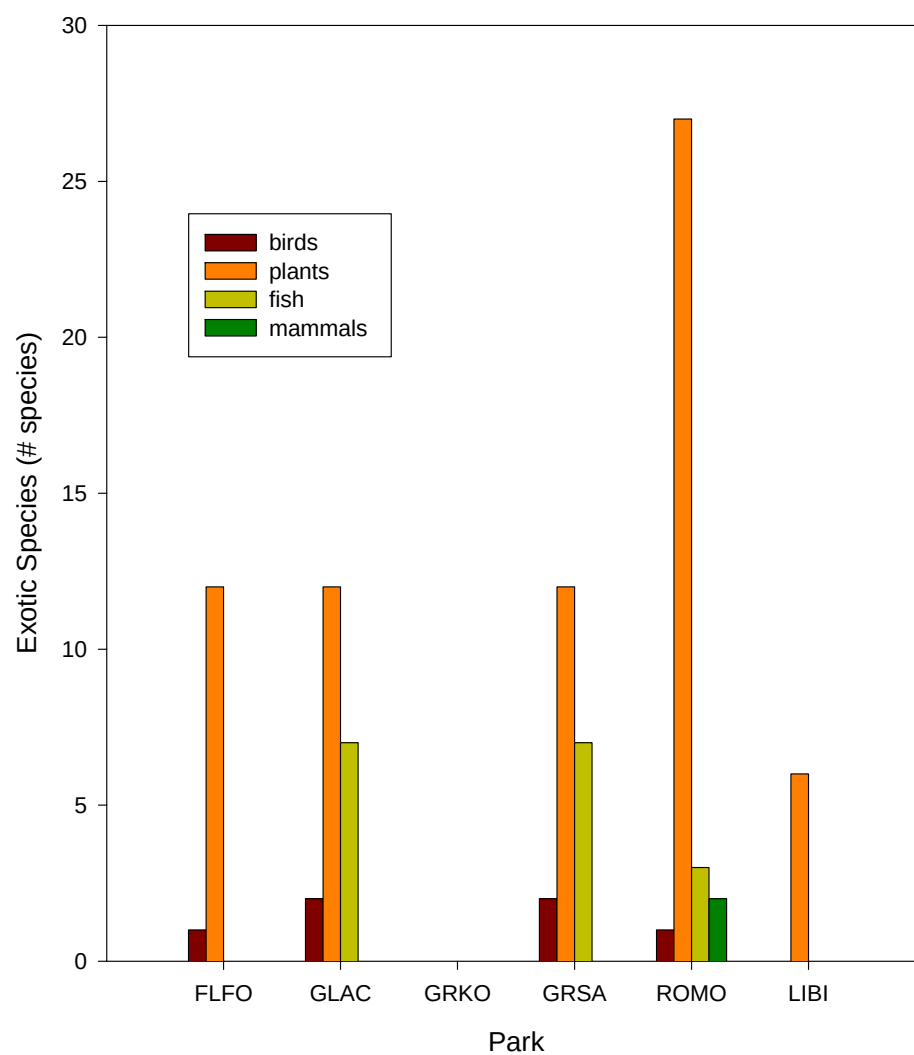


Figure 6. The number of exotic species of concern by taxa.

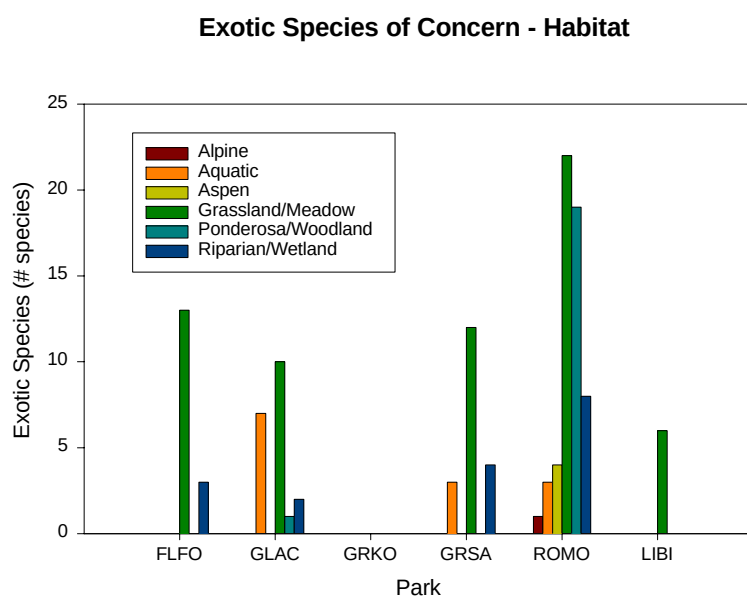


Figure 7. The number of exotic species of concern by habitat type.

Table 2. Common habitats of concern and associated stressors in the Rocky Mountain Network.

Vegetation Type	GRKO	GRSA	LIBI – no data exists	ROMO	FLFO	GLAC
Riparian / Floodplain	1, 2, 3, 4, 5	5, 14	Of concern		5, 9, 10, 11	
Lowland Wetlands		5, 14	Of concern		5, 9, 10,	
Willow				1, 5, 9, 12, 14, 15		
Grasslands	2, 4, 5	5, 14			1, 5, 8	1, 5
Tame pastures and hayfields	5					
Sagebrush and Mixed Foothill Shrubland				1, 5, 12, 14, 15,		
Sand Sheet / Dunes		5, 13, 14				
Recently Burned Areas			Of concern			
Aspen		1		1, 5, 14, 15	1	1,
Cedar Devils Club						12, 14
Old Growth Cedar/Hemlock						14
Pinyon – Juniper		1				

Ponderosa Pine		1		1, 5, 12, 14, 15	1	1
Mature Western Larch						16
Old Growth Spruce						14
Whitebark and Limber Pine						1, 17
Montane Riparian Forest				1, 5, 9, 12, 14, 15		
Montane Wetland				1, 5, 9, 12, 14, 15		
Montane Grassland				1, 5, 12, 14, 15		
Krummholz				12		
Subalpine Meadow						13
Alpine Meadow/Wetland				12, 15		13

- 1 Fire Suppression
- 2 Past Overgrazing
- 3 Stream Erosion
- 4 Metals Contamination
- 5 Exotic Species
- 6 Alteration of Native Species
- 7 Habitat/species Composition
- 8 Previous Land Use
- 9 Beaver Exclusion
- 10 Altered Flood Intervals and
Geomorphologic Processes
- 11 Earthen Dams
- 12 Rare Habitat Type
- 13 Recreation/Visitor Impacts
- 14 Development/ Adjacent Land Use
- 15 Climate Change
- 16 Habitat Loss
- 17 Disease

The identification of common stressors and habitats of concern has implications for the design of this inventory program. Because the Network intends to collect and predict distribution and abundance or cover data on species of concern, this inventory will adopt a habitat focused approach. This approach will direct the study design. These rare and disproportionately small habitats of concern will receive a disproportionate sampling effort. This approach maximizes cost efficiency because a great deal of sampling effort takes place where there are many species of concern and where there is change is likely to occur given the common stressors. Furthermore, when sampling many taxa, the focus is on a habitat rather than a specific species. The most efficient way to sample both birds and plants for example involves cataloging every species encountered, not just a single species of concern. Such inventory efforts are recommended when sampling in a habitat of concern as stressors will likely influence all of the species in a given area. A species that is not presently of concern may be vulnerable because of its association.

II.C. Park Priorities and Goals for Biological Inventories

Not only are the NPS units that comprise the Rocky Mountain Network different in size and diverse in natural and cultural resources, the extent of knowledge and understanding of natural resources is dramatically diverse. The discussion above and the figures and tables demonstrate these discrepancies. However, despite these differences, the NPS units of the Rocky Mountain Network share common needs and goals. The NPS units face similar challenges as many of the same forces stress their natural resources. To understand the state of these resources similar methods and data management techniques can be utilized and shared.

As we look towards the goal of 90% complete inventories for each of NPS unit, a variety of approaches will be implemented in reflection of different inventory status. Table 1 specifically describes the estimated status of inventory by taxa for each NPS unit. Grant-Kohrs Ranch National Historic Site and Little Bighorn National Monument have little to no understanding of their natural resources. Florissant Fossil Beds National Monument and Great Sand Dunes National Monument both have a bit more inventory work done, but the inventories are still far from 90% complete. These four smaller NPS units require highly comparable data collected with some level of standardized sampling across all taxa.

Where justified, species of concern, or species that occupy habitat of concern will be inventoried for distribution and abundance. Some of these inventories may be carried out with less intensity due to financial and logistical constraints. It should be noted that species or habitats of concern may not be prioritized with confidence or accuracy due to a lack of data. In such cases, inventories will be designed with an understanding of stressors and threats to the landscape and commonly sensitive habitat types such as riparian zones. A central goal of such inventories will be to identify species and habits of concern.

Glacier National Park and Rocky Mountain National Park, the larger NPS units in the Network have inventories that are 90% complete for many of the taxa. Some field inventories may be needed for these NPS units to fill gaps in information and to garner more informative data such as distribution and abundance of species and habitats of concern. A great deal of the effort in Glacier and Rocky Mountain National Parks will update and convert previously collected data into modern and accessible databases. Standardized formats will render these data more useful to management of these NPS units and facilitate comparison and cohesion with other units within the Network and across other Networks.

III. METHODS

III.A. General Approach

Methods were selected to meet the specific goals and objectives of the inventory program. Methods used in the Rocky Mountain Network inventory will record information at a variety of scales, including large scales and account for the variability of organisms, habitats and processes in space and time.

Given funding constraints, only a small portion of the landscape can be sampled. This makes the ability to accurately infer results to the larger unsampled areas an imperative. While the multi-scale methods facilitate this inference, the design of the sampling method- the when, where, and intensity of sampling, must be carefully considered and planned well in advance.

To maximize cost efficiency and effectiveness, sampling will focus on the habitats and species of concern. A concerted effort will be made to collect data on the distribution and abundance of these species, while other species may be documented with less detailed distribution data. Many of the species of concern from various taxa occupy a few habitat types, often the habitats of concern. This co-occurrence allows a habitat approach, the inventory and monitoring of specific habitats, as a means to optimize detection of individual species. For example, birds and native and exotic plant species of concern often share specific habitats (e.g., wetlands, riparian areas).

To efficiently meet the goals of the inventory, while keeping with the attributes of an effective I&M program, the quality of the assessment is important. An inventory must be both precise (consistent over time) and accurate (correct in defining the state of the resource unit measured). We consider the inventory, specifically concerning species of concern, a first step in the monitoring process. Our methods are designed to accurately evaluate the status of a resource so a trend in the condition of that resource may be detected. If the methods are neither accurate nor precise, then variability of the method might suggest a trend that actually does not exist, or the method may not detect a trend that is occurring. Our goal is to insure high-quality inventories establish an effective baseline, recognize resources of concern, and establish thresholds for the monitoring effort.

Finally, flexibility has been incorporated into the monitoring plan in the interest of leveraging the cooperative nature of the Network and the available funds. The taxa that will be inventoried, the methods, and the priorities for each park unit have been identified, but the actual logistics of the program must be allowed to evolve. Many opportunities exist for cooperation of sampling efforts within the park, with associated agencies, and with other contractors. Opportunities for further cooperation will continue to emerge. For example, several taxa may be sampled with a single team of diverse experts. And, as the sampling effort progresses, the flexibility of an iterative approach will allow shifts in focus as that may be necessitated as data is processed and analyzed throughout the effort. The goal is to produce the highest quality inventory possible given the resources available.

III.B. Sampling Issues

The ability to document the presence or absence of species within a sample frame (i.e., a

national park) is affected by many factors. These include the spatial and temporal definition of the target population, the spatial distribution of species across the landscape, variation in species' abundance, and the size and shape of sample plots (Thompson et al. 1998). At least two aspects of sampling must be considered when the goal is to estimate the presence/absence of the majority (e.g., 90%) of species of vertebrates and vascular plants. The first is the sampling frame – that is, what total area do you wish to make inference to, and how should sample plots be selected? The second is at the scale of the individual sample plot where sampling must address issues of differential detectability of species.

III.B.1. Issues Concerning the Sampling Frame

The first task is to define the sample frame—that is, the population that you wish to make inference to. If it is the entire park, then all areas of the park must have some likelihood of being included in the sample. Because both space and time affect the expected number of species, both these dimension need to be considered when defining the sample frame. Based on the well-known species-area relationship, we expected a strong relationship between the number of species and the size of the sample frame. But, in addition, we need to recognize that the sample frame is not static, particularly if the inventory effort is extended over a long time period. Species will move in and out of the frame as the survey is being conducted. Thus, in some sense, the parameter of interest (90% of the true number of species in the park) is a moving target.

Within the sample frame, species will differ in their spatial distribution. A species randomly distributed across the landscape is more likely to be included in a small sample than one that is clumped in its distribution. Because resources and habitats are often spatially discrete and disjunct, most species show clumped distributions. This suggests that a simple random sample of the frame, unless it is extensive, will fail to detect many species.

Species also differ in their relative abundance, with most species being represented by few individuals (see Preston 1948). If a species is rare, then we would expect it to occur in only a few of our sample plots. For example, imagine a national park overlaid by a grid with each grid cell defining a possible sample plot (grid cells are small relative to the size of the park). If a species is rare, then it occurs in only a few plots. Assume that *species A* occurs, on average, in only 1 out of every 100 plots. Then, the probability that a given plot does not contain *species A* is 0.99. If n plots are sampled, the probability of failing to detect *species A* is $(0.99)^n$. If we want to be 95% confident that we will detect *species A* when it is present in the frame, we set $(0.99)^n = 0.05$. Solving for n , the number of plots we need to sample for 95% confidence, gives $n \approx 298$. When rarity is combined with the clumped distribution of most species, maintaining a high likelihood of detecting most species can require prohibitively large samples.

The above discussion suggests that it is unlikely that a simple random selection of plots within the frame will be optimal for our objectives. To increase the likelihood of including a given species in the sample suggests some sort of a priori stratification of the frame. One possibility is to stratify on the basis of species' habitat affiliations, with those strata with more expected species receiving greater sampling intensity. To do this, however, requires prior life history information for the species in question which may, or may not, be available. There is also the possibility of stratifying the sample frame by some attribute associated with the spatial clustering of species. However, this method provides no simple solution because different species will be associated with different environmental attributes. The unfortunate conclusion is

that no single type of stratification can address the variability in life histories and ecology of multi-species inventories. Any sample design for multi-species inventory will represent some sort of compromise.

III.B.2. Issues Concerning Differential Detection of Species

Given that a plot has been selected for sampling, the task then becomes one of sampling so as to have a high confidence of detecting all species present within the boundaries of the plot.

There are at least three key issues relevant to multi-species counts at the plot scale. First, not all species will be equally detectable. Therefore, to have a fixed confidence of detection of all species, sampling must be sufficiently intense to detect the most cryptic species. Second, not all species in a plot are equally abundant. The likelihood of detecting a species is a function of its abundance on the plot—all else being equal, a more abundant species will have a greater likelihood of being detected. Third is the uncertainty that accompanies a conclusion of ‘absence’ when sampling effort is finite. That is, it is possible to incorrectly conclude that a species is absent from a plot, even though it was present, simply because survey effort was insufficient.

Because of concerns arising from differential detectability of species, the inventory design must address questions such as the survey time per plot and number of visits to each plot.

Obviously, rare, cryptic species are more likely to be detected if individual surveys are long and surveys are repeated many times. However, for any realistic inventory program, pragmatic constraints result in limiting survey time and number of visits per plot.

The number of surveys necessary to confirm the presence or absence of a species on a given plot is a function of the abundance and detectability of the species on the plot (Thompson et al. 1998). Let p_i equal the probability of detecting species i on the plot given that it is present.

Then, $(1-p_i)$ is the probability of failing to detect species i when it is present. If there are N_i individuals of species i on the plot, and we assume detections to be independent events, then the overall probability of failing to detect species i when it is present is $(1-p_i)^{N_i}$. Assuming p_i to be relatively constant for a given species, one simple-minded way of increasing the likelihood of detection is to increase N_i by increasing the size of the plot. However, given a fixed budget, increases in plot size usually result in a decrease in replication and the spatial extent of the sample.

If we want to determine the number of plots (n) we need to sample to be 95% confident of detecting the species on at least one plot within the entire sample frame, then we could set

$$((1-p_i)^{N_i})^n = 0.05$$

and solve for n . There are two obvious problems with this approach that prevent its use. These are that detectability (p_i) and abundance (N_i) are typically unknown for most species (if they were known there would be little need to conduct the inventory).

Two sources of bias arise in presence/absence surveys. First, is to conclude that a species is absent when it is truly present on a plot. This false negative (‘0’) is referred to as an omission error. Second, is to conclude a species is present when it is truly absent (e.g., occurring via a misidentification of the species or a species cue). This false positive (‘1’) is referred to as a commission error. By far, the most common in multi-species inventory are errors of omission. These can only be addressed, in part, by sampling so as to increase each p_i as much as possible. In multi-species surveys this will often translate into using a variety of different sampling

methods each targeted to best detect a different species or taxonomic group.

III.B.3. Summary

Community-based inventories present problems in both the overall design for plot allocation and plot selection and for how best to sample within a given plot. As concluded by Thompson et al (1998), there is no way to achieve an optimal frame design, plot selection scheme, and plot size and shape when attempting to survey many different species each with their own abundance, spatial arrangement, and detectability. An iterative approach is needed.

III.C. An Iterative Sample Design

The primary goal of the Park Service biological inventory program is to estimate 90 percent of the true number of species of vertebrates and vascular plants present in a given park. To that primary goal, we also propose a sampling design that will provide broad-scale information on the spatial distribution of these taxa based on species occurrence or absence. A final goal is to estimate the abundance and fine-scale distribution of species of concern in a park unit. This goal requires a specific sampling design that will be discussed separately.

III.C.1. Sample Design: Occurrence and Distribution of Target Taxa

An extensive sample frame will be established in each Park Service unit by overlaying their park with a grid to establish sample units. The grid-cell size will vary by park size but should be sufficiently fine so as to contain at least 100 sample units. After establishment of the grid, we propose an *a priori* stratification of the grid with each cell assign to one stratum. Selection of cells within a stratum will be based on a systematic or random selection of sites. The primary principle for park stratification is that sample units drawn at random from within a stratum are much more similar in species composition than two samples selected at random from different strata. This process involves the following steps:

1. Establish the grid: Select a grid cell size and grid orientation. Cell size should be sufficiently large to support the largest study area necessary to document, with high likelihood, the presence or absence of a species within a cell. The center of each cell defines the sampling point. The actual sampling takes place in a random distance and direction from this central point.

In some cases it will be logistically impossible to get to some of the sample points. Double sampling techniques can be used to assess the similarity and bias associated with sampling primarily “accessible” sites (Krebs 1999).

2. Determine the number of strata to recognize: Determining the number of strata should be based on the number of discrete land types for which separate estimates of species richness and distribution are desired.

We suggest that primary strata boundaries be based on plant community types classified by dominant vegetation. Our reasons for defining strata boundaries according to vegetation communities include:

- i. By definition such strata should be associated with variation in vascular plant species composition, one of the primary inventory goals;

- ii. Because a given animal species' habitat is, in part, determined by plant species composition and structure, changes in vegetation community type are often accompanied by variation in the associated animal communities;
 - iii. Such strata should prove useful to any subsequent monitoring program which will focus strongly on documenting changes in plant community structure and composition and, from such changes, may predictions to anticipated changes in animal species;
 - iv. Changes in plant communities are usually associated with changes in edaphic, topographic, and climatic variables that are relatively stable over long time periods (thus strata boundaries will remain stable).
3. Assign grid cells to strata and create a strata map of the park: This map will allow the computation of strata sizes (measured in terms of the number of grid cells) and give some insights to the initial allocation of survey samples. For example, an initial allocation would distribute sample locations proportional to strata size.
4. Develop a process for the allocation of the survey samples: The allocation of the sample across strata is affected by (i) the total number of grid cells in each stratum; (ii) the variability among sample units within each stratum; and (iii) the cost of obtaining a sample from each stratum. In general, more samples should be assigned to larger strata, to strata that are more variable in species richness among sample plots, and to strata that are less costly to sample. To compute an allocation that minimizes costs for a fixed level of precision, or maximizes the precision of the estimate for a fixed cost, prior information on size (N_i), variance (σ_i), and cost (c_i) for each stratum is required. Given this information, the optimal allocation of sampling intensity to stratum i (n_i) based on a total sample of size n is computed as (Schaeffer et al. 1996):

$$n_i = n \left(\frac{N_i \sigma_i / \sqrt{c_i}}{\sum_i N_i \sigma_i / \sqrt{c_i}} \right)$$

In addition to the traditional criteria that determine an optimal sample allocation in a stratified design, we propose that information on the expected species richness within a stratum also be used to determine sample allocation. A consequence is that rare, but biologically rich, vegetation community types will be more likely to appear in the sample. Using this information, as well as information on stratum size, variance, and sampling costs, brings prior biological knowledge and should increase the efficiency of the sample design.

5. Select sample locations within each stratum: We propose that some probability based method be used to select sample cells within each stratum. Depending upon efficiencies of sampling, grid cells can be selected from a simple random sample or from a systematic sample with a random start point. The center point of each grid cell anchors the sampling location.
6. Apply the appropriate set of sampling methods to the selected sample locations: We assume that the center of each selected grid cell determines the start point for specific sampling methods. Different sampling methods will need to be applied to each cell in order to exhaustively sample all possible terrestrial vertebrates. For example, each selected cell within a given stratum may contain
 - a grid of live trap station to sample small mammals
 - a set of quadrats to sample reptiles and amphibians via time-constrained or area-constrained searches
 - a set of scent-stations to sample mid-sized carnivores using tracks or camera traps
 - a set of baited-track stations to sample large mammals
 - one or more points to sample birds via variable distance point counts.
7. Determine what variable(s) is (are) to be estimated from each sample location: The goal of the biological inventory is to estimate species richness to within 90% of its true value. This goal can be accomplished by recording simple presence/absence data for each sample location, or by estimation of abundance of each detected species. As discussed elsewhere in our proposal, estimation of abundance requires a much more intense sampling design because of the need to estimate the probability of detection for each species present on the sample unit. Below we discuss methods for estimating species richness based on either abundance or presence/absence data.

This initial focus of the sample design is on the estimation of species richness in a broad-scale spatial context. To achieve this goal, we propose that a detailed map of each park be overlain with an extensive grid to define sample units (quadrats). Sample units will then be stratified by major vegetation community type, and within each stratum a random sample of quadrats will be selected. For each quadrat sampled, we will record a list of the species detected. Thus, the primary data for estimating species richness can be described in a two-dimensional matrix with rows listing the species detected across all quadrats sampled and columns representing the individual quadrats. The elements of this matrix are simply “0’s” and “1’s” representing absence and presence, respectively. This spatially referenced occurrence data provides distribution information at the scale of the applied grid. The methods employed for estimating species richness from these data adjust for “missed” species and provide unbiased estimates of true species richness (Nichols et al. 1998).

III.C.2. Sample Design: Abundance and Fine-Scale Distribution of Species of Concern

The design outlined above is spatially extensive, but with relatively low sampling intensity at the scale of the individual quadrat. In contrast, estimation of the abundance of a

given species of concern will require a much more intensive, and therefore less extensive, sample design. Abundance is much more difficult to estimate, thus time and funding limit extent.

As previously discussed, abundance and fine-resolution distribution data will be collected on species of concern as they are likely to be the species relevant to future monitoring efforts. The limitations associated with the collection of abundance data justify the habitat of concern approach to collecting abundance data. The extent of the abundance collection points will be limited to strata that represent strata of concern. Abundance data cannot and need not be collected at the same extent as the design associated with the inventory goal of detecting 90 percent of the species present in a park unit.

The sample grid described above will provide the basic framework for the location of points to be intensively sampled. Several of the above steps will be modified:

- Step 1. The resolution of grid cells assigned to habitats of concern will be increased by subdividing the grid cells.
- Step 2. The strata will be reassigned at the finer scale to account for habitats of concern that might otherwise be detected by the large-scale grid system as these habitats are often rare or limited in extent on the landscape. This step will also facilitate the spatial modeling that will produce fine-grain distribution maps based on sample efforts at this scale.

With these modifications, effort will be increased in habitats of concern; relatively more locations will be selected, and for many taxa, more intense methodology will be implemented to account for abundance. This data will also be incorporated into spatial models that will build predictive distribution models.

III.C.3. The Adaptive Sampling Design

Both of the above sampling designs will be adapted and modified in an iterative manner as data is collected. It is important that the inventory not be locked into a specific sample design. The principals of the design will remain consistent, but attributes such as the size of the grid cells and needs to be explored and adjusted according to specific species and other variables as the inventory progresses. This adaptive flexibility is an integral part of the inventory and will assure that high quality, scientifically credible data will be collected in an efficient manner.

III.D. Estimating Animal Abundance

The plot-based techniques that form the core of most sampling methods in ecology are intended primarily for estimating the presence/absence or abundance of plant species or relatively immobile animal species. Plants have several redeeming qualities that make them easier to sample: they are often abundant, readily visible, and immobile. Sampling animals is much more difficult because, for the most part, they are less abundant, less visible, and more

mobile. Plot techniques can be utilized for immobile animals like barnacles, starfish, or even salamanders, but the process is less satisfactory than for plants. In general, because of problems with **1) rarity, 2) detectability, and 3) mobility**, estimating abundance for animal populations is much more difficult than for plants.

Why is a reliable estimate of an animal's abundance important? The primary reason is because of the strong relationship between the abundance of an organism and the likelihood of its continued persistence. Given this relationship, abundance is one of the most important concerns of managers, and it is often the single measurement by which management success is measured. When a species is characterized as rare, threatened, or endangered, we recognize that its abundance is low and the population is in danger of extinction. When we recognize a species as a pest, as with rats on remote seabird nesting islands, we recognize that the population is too high and in need of reduction. The goal is to manage so that most populations persist at desirable levels, neither too rare nor too abundant.

III.D.1. Some Terms and Definitions

Population: A *biological population* is a group of potentially interbreeding individuals that occupy a particular area at a particular time, whereas a *species* is defined as a reproductively isolated aggregate of interbreeding populations (Mayr 1970). For convenience, a *research population* may be identified which is smaller than a biological population.

Abundance is the number of individuals within a population. **Population size** is synonymous with abundance. The true value is always an integer, and it is determined by a complete and thorough **census** of the entire population. However, abundance is usually unknown and must be estimated through sampling, and in this case the value is known as a **population estimate**, which could be a non-integer number.

Relative abundance is an index of population size. It differs from absolute abundance in that population size is not known exactly, but the value of the index is assumed to be monotonically related to true population size. Relative abundance is often measured with a **population index** that is presumed to be correlated with true population size, although true population size is often unknown. To be confident that an index reliably relates to the true, but unknown, abundance, requires a prior calibration study.

The simplest measure of relative abundance is **presence/absence** of the focal organism within the sample unit. For example, it doesn't matter if a forest stand has 1 or 5 spotted owls, if the area has ≥ 1 spotted owl it is occupied by a threatened species and subject to certain levels of protection. When we obtain presence/absence data on multiple plots, we have data on **frequency of occurrence**. It is important to recognize the possible ambiguity that surrounds the conclusion of presence or absence. Was the organisms assumed absent from the plot because it was there but not detected, is normally present but was missing from the plot when the sample was taken, or was truly (and normally) absent from the plot? Also, presence may be misleading if an animal was recorded on a plot but was simply moving through the plot when detected.

Density, or population density, is the number of organisms per unit area; e.g., 0.71 salamanders/m², or 27.1 mallards/km². As for abundance, we can also describe **relative density**, which is a rank scale measurement of density relative to other populations or habitats.

Calculations of abundance require an estimate of the fraction of the population detected as well as the survey (count) data. Density estimates require abundance estimates plus an

estimate of the effective area sampled. The latter can be difficult to compute for mobile organisms.

III.D.2. Population Processes

Estimates of presence/absence, relative abundance, spatial distribution, or abundance are reflections of underlying population processes. To properly manage any natural population, we need more than just abundance data, we need information on the causes of population changes. Such data are unnecessary for basic inventory purposes, but are often required for long-term ecological monitoring. All changes in population size can be attributed to 4 fundamental population processes:

1. **natality** (B; additions due to reproduction)
2. **mortality** (D; losses due to death)
3. **immigration** (I; additions due to interpopulation transfer)
4. **emigration** (E; losses due to interpopulation transfer)

Population size at time $t+1$ (N_{t+1}) can be expressed as a function of these processes according to the following equation,

$$N_{t+1} = N_t + B - D + I - E$$

If we want to understand population dynamics, we need to measure all four of these population processes, in addition to changes in abundance.

For purposes of designing studies to estimate animal abundance is important to distinguish between open and closed populations. An **open population** is one that is subject to any or all of the processes of B, I, D, or E. A **closed population** is subject to none of these processes. The only way to be comfortable with an assumption of population closure is to estimate abundance over a very brief time period so that these four processes are unimportant. A population may be only partially closed: it is **demographically closed** if birth and death processes are negligible during the survey period, and it is **geographically closed** if emigration and immigration are trivial during the sample period.

A flowchart in the text *Ecological Methodology* (Krebs 1989:18) provides a decision pathway for selecting an appropriate method to estimate abundance of an animal population. The first and most important question to ask is “Do I really need an estimate of absolute abundance?” If the answer is no, then an easier and cheaper option is to use **population indices**.

A population index will be useful if it is positively and linearly correlated with population abundance; such an index is referred to as a **constant-proportion index**:

$$E[C] = pN$$

Where, $E[C]$ is the expected value of the index C , p = the proportionality constant relating the index value to abundance, and N = true abundance. If p is estimated empirically, then we no longer have an index, because we can use p and C to estimate N directly (this would be a population estimate). A technique is an uncalibrated index when we fail to estimate p and assume that it remains constant for different values of N . If p does not remain constant among

different years, habitat types, or population sizes, then C may be poorly correlated with N , and the index will be of little value. Of particular importance to long-term monitoring is that fact that if p varies by year, reliable estimates of population trend are not possible.

Many of the techniques that wildlife managers use for estimating abundance are best thought of as indices. Allen and Sargeant (1975) used rural mail-carrier sightings of red fox in North Dakota as an index of fox populations. Fecal pellet counts have been widely used as indices of abundance in rabbits and deer. Track-plate surveys have been used as indices of abundance (presence/absence) of secretive forest carnivores like fishers and martens. Inland, breeding season surveys of Marbled Murrelets are best thought of as indices because the true nesting population is unknown. The Christmas Bird Count and Project Feeder Watch provide annual winter indices of population trends in North American birds, but they do not provide data on true population size. Many of the techniques currently available for monitoring breeding birds (e.g., the Breeding Bird Survey) and amphibian populations represent indices only.

There have been surprisingly few studies designed to validate the claim that indices are linearly correlated with population size, in part because indices have usually only been used where estimates of population size are impossible or impractical to obtain (i.e., an estimate of p is infeasible or impossible). The study by Rotella and Ratti (1986) is an example exception to this rule.

When count data are combined with an estimate of detectability, direct estimation of population size (N) is possible using some form of the general model:

$$E[N] = C/(\alpha p),$$

where $E[N]$ is the expected value of N , C is the number of organisms actually counted, α is the sampling fraction (proportion of the study area that was surveyed), and p is the detection rate of organisms within areas that were surveyed. Unlike indices, where we assumed that p was constant and proceeded to ignore it, population estimates require that we estimate the value of p in order to estimate population size.

If $p=1$ (all individuals can be detected in surveys) and $\alpha=1$ (all areas are surveyed), then the above equation simplifies to:

$$N = C,$$

and the count C is equal to a census of the entire population (N).

If $p=1$ (all individuals can be detected in surveys), then the above equation simplifies to:

$$E[N] = C/\alpha.$$

And, we can estimate population size using standard quadrat surveys. This might be appropriate for surveying relatively immobile organisms like salamanders, but will not usually apply to mobile and secretive organisms like birds and mammals.

If $p \neq 1$, there are several choices available to estimate p :

1. mark-recapture or mark-resighting techniques (which can also allow an estimate of natality and mortality rates)
2. removal methods (useful only with exploited populations)
3. variable-distance, line-transect methods (includes point-count surveys)
4. quadrat sampling (i.e. aerial surveys) with additional surveys on a subset of sample

units to measure detectability (i.e. ground surveys).

III.E. Mammals

Based upon methods for field inventory, most Rocky Mountain mammals fall into four main categories: small mammals (live traps and conspicuous den surveys), bats (ultrasonic detectors, mist nets and telemetry), mid-sized carnivores (tracking stations and hair snares), and large mammals (pellet and sign surveys, aerial counts, etc.). Established terrestrial and aquatic sample locations will be used for mammal surveys whenever possible for efficiency and to assure replication in the different habitats of concern. This standardized design will be supplemented by focal sampling for species of special concern and coordination with related ongoing programs.

III.E.1. Mid-sized carnivores

Mid-sized forest carnivores, principally lynx, fisher, American marten, and wolverine will be surveyed at Glacier and Rocky Mountain National Parks using standardized USFS methods (Ruggerio et al. 1999, Zielinski and Kucera 1995). A combination of methods provides the best opportunity to document the occurrence of these elusive animals. Snow surveys are often favored for high detection rates, but survey logistics are problematic (limited timing due to impermanence of tracking medium and substantial experience required for reliable field identification) (Halfpenny et al 1995). Tracking stations using smoked tracking plates and/or photography at bait stations have proven a useful medium for detecting secretive species such as marten and fisher in areas of dense forest (Zielinski 1995).

A system of hair snares and DNA testing established for grizzly bear monitoring in the Glacier area has already proven successful in detecting lynx (K. Kendall personal communication). Ongoing efforts may also reveal the occurrence of other forest carnivores. The DNA analysis allows for the identification of individuals, thus the study incorporates the essence of a mark-recapture study and allows for estimates of relative abundance.

III.E.2. Small Mammals

Track plate and passive track surveys as listed above for mid-sized carnivores will also facilitate the occurrence of small mammals. Pellet counts will also be used to determine occurrence at the sample sites.

Sherman traps, placed on a grid at each sample site, will be used to document small mammal species. Mark-recapture trapping must be used to determine abundance by obtaining an estimate of uncaptured individuals (Jones et al. 1996). Where there is biological justification for the inclusion of additional unique habitats, sub-strata can be defined and sampled. Conspicuous den surveys (for beaver, gopher, squirrels, etc.; Wemmer et al 1996) will supplement the standardized trapping design at each location. Photographs will be used whenever possible for documentation, and supplemented by necessary voucher collections.

III.E.3. Megafauna

Although large mammal species are relatively well-documented in most National Parks (e.g. elk, deer, mountain lion, black bear, etc.), an information gap has been identified at GRSA. Large mammals are reported to frequent sand dunes for cover in the complex topography as well as advantages for hunting. These animals will be documented by searching for tracks (sand

is often a suitable tracking medium (Wemmer et al. 1996) and pellets/scat at the established plot locations. Targeted species will also be documented by photographs if encountered during surveys focused on other taxa.

III.E.4. Bats

A comprehensive bat inventory involves both indirect (ultrasonic bat detection, roost observation), and direct (mist netting, telemetry) survey methods (Kunz et al 1996, Jones et al. 1996). A combined survey approach during the summer season is the most efficient way to maximize detection as well as provide information to address concerns of managers (Tom O'Shea, personal communication). Bat detectors are useful in preliminary assessment and identification of important roosts, but ultrasonic interpretation requires expertise and the reliability of resulting species identifications is controversial (Kunz et al. 1996). Although bats are readily captured at feeding areas over water, roosting and breeding habitats are often of greater management concern (Jones et al. 1996). Mid-summer fieldwork is necessary to document breeding occurrences through the capture of lactating females, and critical breeding and roosting habitats are best determined through telemetry (Tom O'Shea, personal communication).

Bat inventory depends on expert field technicians as there are human health issues, complex handling procedures, and many species that are difficult to distinguish (Jones et al. 1996). Furthermore, the necessity of voucher specimens decreases with knowledge and experience (Tom O'Shea, personal communication). Personnel costs are significant as night surveys are performed in teams for safety and the handling of bats requires rabies immunization and frequent boosters.

III.E.5. Data Analysis

Due to the difficulty in collecting data on animal abundance, much of the data associated with mammals in the Rocky Mountain Inventory will be occurrence data. The number of individuals of each species associated with each taxa will be tabulated for each location. The presence absence data will allow for some distribution based on occurrence and this will be further facilitated by the use of the GIS Databrowser.

III.E.4.a. *Data Analysis*

Data will be analyzed by the cooperator who conducts the field data. The data will be spatially located and compared to the other aquatic information collected at the same sample points to look for multi-taxa regions of diversity. The data will be incorporated into Access and therefore be compatible with the various National Park Service databases.

III.F. Birds

As with any survey, the objectives of the inventory dictate the methods to be used. Many approaches are used to sample birds, and no single method adequately samples all species. Methods tend to sample groups of species that share common habitats or life history traits. The Rocky Mountain Network will use distance sampling methods that allow for detectability adjustments while providing abundance estimates that are comparable among species, habitats and sites. Some species-specific inventories will also be used to catalogue species for which the variable plots are not appropriate such as raptors and shore birds.

III.F.1. Distance Sampling

It is possible to simply document the presence of a bird species in a park by having qualified ornithologists generate a checklist of species found at various locations and times in a NPS unit. In keeping with the goal of generating data that is comparable to other places within a park, throughout the Network, and over time, simple checklists will be avoided for this inventory. The standard Point Count method is commonly used to determine distribution and to get a qualitative measure of relative abundance of species. The Point Count method is currently used in the Breeding Bird Survey, National Wildlife Refuge monitoring programs, National Forest monitoring (Fancy and Sauer 2000), and have been frequently been used in NPS units within the Rocky Mountain Network. Point counts do provide a great deal of information and are easy to implement. Because they reflect the number of birds actually at a site and the proportion that can be detected, they do not offer a reliable measure of differences in bird population size over time or among locations.

To account for differences in detectability, many bird inventory and monitoring programs have incorporated distance methods (e.g., the Landbird Program). Distance sampling is basically the same as point counts, but the observer estimates the bird to observer distance. The distance accounts for differences in detectability and therefore provides a better estimation of abundance and facilitates comparison over time and across regions. Because distance sampling is similar to point count methods, it generates data that is comparable to data collected in past inventory and research efforts.

Point counts are generally recognized as appropriate and superior to other methods such as transects when 1) habitats are difficult to traverse on foot, so that walking investigators are unable to look for birds, 2) habitats occur in small patches, so that transect lines would intersect multiple habitat types, 3) birds are disturbed by moving investigators, and require a cooling off period before they start singing again, or 4) investigators would like to associate bird detections with specific habitat features, which are more easily measured using point-centered methods. However, point counts detect fewer birds than transects when conditions are favorable for walking through the habitat. One concern with point counts is the "donut effect"--detections are usually limited close to the observer because birds flee from the investigator, and detections are also limited at farther distances due to declining detectability.

III.F.2. Field Methods

The following methods are taken from a National Forest Service handbook on avian monitoring (Ralph et al. 1993). Points to be used should be at least 250 m apart along a transect that initiates from the selected starting point within the stratified region. The observer should arrive at a point causing minimal disturbance to birds as possible and counts should be started immediately upon arrival at a given point. All species either seen or heard and the number of individuals should be recorded in order of encounter along with the estimated observer-to-bird distance for a ten-minute period. If a bird departs when the censuser arrives at a point, then that individual should be included according to the take-off point. Birds that fly overhead should be listed separately from those observed in surrounding vegetation. If a flock of birds is encountered during the ten-minute census period the flock may be approached and followed after

the period to determine composition and abundance. Individuals issuing an unknown song or call may also be tracked down after the ten-minute period to confirm identification visually.

For each point sampled along a transect, the following ancillary data should be collected: the point reference number, name of the point, date, time, the location of the point (utm), slope, and aspect. In some cases the point should be marked to assure that future monitoring efforts take place at the same location.

III.F.4. Shore Birds

Hérons, egrets, gulls, and alcids are counted at their nesting colonies, where their colonial habit makes them easier to count. Obviously, this technique misses out on non-breeding individuals.

III.F.5. Raptors

Raptors occur at low densities, and often in inaccessible habitats. Continental population monitoring efforts often focus on migrational counts, counting individuals as they move through natural congregation points, often along large bodies of water (Hawk Ridge along Lake Superior, Whitefish Point along Lake Michigan, Hawk Cliff in Pennsylvania).

III.F.6. Data Analysis

The data will be recorded into Microsoft Access databases to allow easy manipulation and spatial analysis with the use of the GIS Databrowser. As mentioned above, by accounting for the observer to bird distance, detection differences can be accounted for, this will be done with the appropriate modeling (Fancy and Sauer 2000). The number and abundance of species will be tabulated at each sample location and by each transect to account for differences in scale.

III.G. Amphibians and Reptiles

III.G.1. Specific Inventory Concerns

All amphibian species (and several reptile species at GRSA) are considered to be of special concern due to pathogen and disease related declines (Corn, Livo and Muths; Missoula Workshop). Bullfrog invasion is also a concern in several areas.

III.G.2. Pathogen Issues

All aquatic survey teams will need to follow strict equipment isolation and disinfection protocol to prevent spread of disease and pathogens across parks as well as drainages. This is especially critical with a coordinated team approach and established sample sites.

III.G.3. ARMI

ARMI is a large-scale, long-term amphibian inventory and monitoring program on Department of the Interior lands. The ARMI project is in progress in both Rocky Mountain and Glacier National Parks under the guidance of Erin Muths (USGS) and Steven Corn (USGS/University of Montana) respectively. The Rocky Mountain Network has established a

cooperative relationship with ARMI that will expand the effort to include amphibian inventory efforts in the remaining parks in the Rocky Mountain Network.

III.G.4. Habitats or Strata of Importance

Most species in our area occur in ponds and riparian areas, which will be priority strata for aquatic sample site selection. The unique interdune ponds at GRSA are a rare but important strata for amphibian sampling. Stream surveys for fish may detect the tailed frog in streams at GLAC.

III.G.5. Field Methods

ARMI is developing a tailored program of standardized basic survey techniques that will be used for the survey of aquatic habitats in the Rocky Mountain Parks (e.g., Bury and Corn 1991, Heyer et al 1994, Fellers and Freel 1995). Visual encounter surveys (VES) are a widely used time-constrained survey of a defined habitat feature such as pond and shoreline vegetation (Crump and Scott 1994, Feller and Freel 1995). Visual encounter surveys involve low time, low cost, and low personnel, and the results are quantitative and repeatable. However, VES do not estimate abundance or density--they provide only an index of relative abundance. A VES involves searching for amphibians in a predetermined search area for a predetermined amount of time--it is often referred to as a time-constrained search method. The standard units of measurement are people-hours: a one-hour search can be accomplished by 1 person searching a plot for 1 hour, 2 people combining to search a plot for 30 minutes each, 3 people searching for 20 minutes each, etc. Several different search patterns are also possible.

Assumptions of the VES include the following:

1. Every individual of every species has the same chance of being seen.
2. Every species is equally observable during each sampling session.
3. Individuals are recorded once during each survey (i.e., they don't move).
4. Results do not vary among observers.

Assumptions 1 and 2 specify that the fraction of the true number of organisms detected (p) is constant for all individuals of all species. A bit of thought about these 2 assumptions leads to the conclusion that they are almost certainly false. Some individuals have well-concealed hiding places, whereas others are located in easily observable locations. Likewise, some species utilize different types of hiding places and are more difficult to observe (arboreal salamanders are often found underneath bark of standing trees and are very difficult to find). Assumption 3 is easy to verify for small salamanders and lizards that remain hidden under logs. For mobile species, assumption 3 can be satisfied by capturing and holding animals until the survey is completed. Assumption 4 is difficult to test, but is almost certainly false. Some investigators will have a greater knack for finding amphibians, whereas others won't want to get their fingers dirty. Training can help here--but a minimum level of competence should be established.

Teams will use medium intensity searches, which balance the benefits of disturbing substrates (e.g. overturning rocks) while minimizing habitat destruction. VES will be repeated through the season at random-stratified aquatic sample locations to provide occurrence, species

composition and distribution information.

Abundance estimates and models require methods that address differential detectability such as capture/recapture and distance sampling. Relative data on abundance is highly dependent on species detectability, observers and seasonality. For this reason it is better to look at turnover in populations across the landscape instead of relative abundance for monitoring (Steve Corn, personal communication). To lead into turnover monitoring, survey teams will record information on all life history stages: eggs, larvae, juveniles and adults (Fellers and Freel 1995).

Although all the parks would benefit from a comprehensive survey of reptiles in terrestrial habitats, detection rates for such surveys are often low. Reptiles are hard to inventory and even harder to monitor, so VES teams will also aim to document reptiles. GRSA is unique among the network parks in reporting several reptile species of special concern. A qualified herpetologist (such as Lauren Livo) will augment the GRSA aquatic strata VES with reptile surveys at established terrestrial sample locations. Opportunistic documentation of reptiles will be encouraged with a booklet of potential reptile species. This cooperative observational approach may be quite productive - for example in Yellowstone NP, most existing reptile records have been submitted by botanists!

III.G.6. Data Analysis

The inventory data will be collected and analyzed by members of the ARMI initiative in accordance with standardized practices. It should be noted that the VES does not provide estimates of relative abundance but measures of occurrence and species turnover. In addition, metadata will be recorded, and the data will be entered into the National Park Service databases: NPSpecies, the Data Set Catalogue, and the GIS Databrowser.

III.H. Fish

Patchy distributions, varying abundances, and highly mobile across sites characterizes dynamics of fish populations. These traits necessitate extensive and large-scale inventory and monitoring of fish within a park unit. Assessment across large areas allows an observer to tease out patterns and trends in monitoring phase from the variability that inherently exists across space, or sample sites such as pools and riffle units of a stream (Lohr and Fausch 1997, Fausch and Bestgen 1999).

Sampling at large scales simply means an extensive effort, or multiple investigations within watersheds within a park. Sampling at many sites is conducive to analysis at many scales. Conclusions about assemblages of species in any system will depend on the scale and time at which they are measured (Wiens 1989), a species may seem to be in decline at the scale of a single pool, while no trend may be found at the watershed scale. Investigations of fish populations can account for perspectives at multiple scales by manipulating the resolution of analysis (Lohr and Fausch 1997). The scale that is most important to management and monitoring can remain flexible, but such an analysis can provide insight to trends at different scales and how key processes interacting across spatial scales may relate to habitat and life history to influence a variety of fish population abundances and fluctuations.

III.H.1. Field Methods

The exact site to be selected for sampling will be a part of the larger site selection process

for all the park units. In the case of streams, the optimal length of sections to study to ensure that the sample is representative of the stream will depend on the size and complexity of the stream (Fausch and Bestgen 1999). If distribution data is required for a specific species of interest or special concern, it may be necessary to sample at different seasons as some species of fish may migrate within a stream and thus contribute spatial and temporal variability. It may also be necessary to sample sites considered to be of poor habitat as they may be utilized by species at various life history stages to escape intraspecific competition, all potential habitats must be sampled in order to acquire accurate distribution data (Labbe and Fausch in press).

As no fish sampling technique escapes bias, a variety of techniques must be employed in order to obtain a robust estimate of composition and relative abundance (Lohr and Fausch 1997). Furthermore, the exploratory nature of an inventory effort mandates the need for implementation of a variety of sampling techniques that will detect a variety of species (Tilmant pers comm.). The specific methods used at each site selected will depend on habitat at the sample site and what is expected to be found in such a habitat (Tilmant pers comm.). Lake inventories require techniques that differ from those used in streams, and stream techniques vary depending on the volume of flow in the channel.

Electrofishing will be used at many stream sites chiefly to detect salmonid species. The method allows for careful identification and measurement of all individuals at each site, and allows for the return of all individuals to the stream unharmed (Fausch and Bestgen 1999, Michels pers comm.). Electrofishing may not be appropriate for all sample site locations. Large rivers make control of the habitat and conductivity difficult, rendering the method ineffective. Furthermore, the charge has the capacity to be too strong for minnow species (Labbe and Fausch in press, Tilmant pers comm.).

Where electrofishing is inappropriate due to location or in an effort to detect minnow species, other trap and net methods will be used. Seine nets will be used to make down stream hauls in pools for 1.5 hr at each pool. Stream riffles will be sampled by disturbing stream substrate upstream from a stationary sein net and by making stream hauls with a sein net (Lohr and Fausch 1997).

In pools and riffles that are too deep for block nets and effective seining both seins and passive gear will be used to obtain a robust sample (Lohr and Fausch 1997, Tilmant pers comm.). Baited trap nets and gill nets will be left in place overnight. Trap nets specifically designed for minnow species will be left out overnight as well. Lohr and Fausch (1997) also found that regardless of depth, the use of passive gear often added an additional 1-2 additional species to the number encountered by using sein nets alone.

Lake habitats will be sampled either with experimental gill nets (Michels pers comm.), baited traps, or hand seining (Tilmant pers comm.) depending on the site to be sampled at a given lake. The experimental gill nets and trap nets will be left in place overnight and pulled in the morning. Experimental gill nets result in mortality (Tilmant pers comm.) to the individuals sampled and will be used with care in habitats expected to support sensitive species.

III.H.2. Data Analysis

The data will be analyzed by the cooperator that collects the data, and will therefore vary. It will be important to look at data, specifically the species documented, at local pool scales, the scale of stretches of streams, watersheds, and whole parks.

III.I. Vascular Plants

Note: It should be noted that because plants are generally not mobile organisms, the issues that apply to sampling abundance of mobile vertebrates as described above do not apply to plants. The methodology presented below provides an accurate and tested method for determining vascular plant species richness and abundance.

The Rocky Mountain Network's vascular plant sampling design accounts for spatial heterogeneity by collecting information at multiple scales (including large scales), recognizing rare habitats, and being compatible with mathematical and spatial models. The Modified-Whittaker (Stohlgren et al. 1995b) plot design meets these criteria and is an accurate and cost-efficient method for inventory of vegetation across landscapes.

Simple botanic searching techniques frequently miss many of the plant species in a given area (Stohlgren 1994, Stohlgren et al. 1998a). The lack of systematic methodology often employed exacerbates problems caused by various taxonomic expertise and search efficiency: there is no way to determine what areas have been sampled and no way to estimate the completeness of the survey. Similarly, commonly used methods such as the Parker (1951) and Daubenmire (1959) transects tend to underestimate species richness as they cover a small sample area and have a high degree of spatial autocorrelation. Multiple plots in four different prairie vegetation types found that the Parker and Daubenmire method detected 31-65% fewer species than the Modified-Whittaker (Stohlgren 1998a). These results suggest that the Parker and Daubenmire transects are not adequate for detecting plant species that are patchy in distribution such as locally rare or exotic plant species. Nor will transect methods be adequate for this inventory, especially given the goal of documenting 90% occurrence. The variance also suggests that the methods may not even consistently underestimate species richness and are therefore worthless for monitoring purposes. The Modified-Whittaker takes more time to complete, but the benefits of a multi-scale method, and the information gained make the investment cost efficient (Stohlgren et al. 1998a).

The cost of inventorying any taxa increases as the inventory nears 60-70% completion (Stohlgren 1999a). Our approach accounts for the spatial heterogeneity or variability of landscapes and will reduce costs. At local scales, the large plot size of the Modified Whittaker (20 m x 50 m) tends to detect patchy species distributions frequently missed by other methods. At larger, landscape scales the vegetation types will be stratified with a resolution small enough to detect small and rare vegetation types that tend to contribute a disproportionate amount of species richness. We will randomly place more plots in these rare habitats to increase the completeness of the inventory in a cost efficient manner.

The invasion of non-native species was a common concern among Park units. Previous investigation in many vegetation types across the West demonstrated that exotic species tend to invade habitat types high in native plant diversity (Stohlgren et al. 1998c, 1999a, 2000a, 2000c).

These diverse habitat types are the same rare and diverse habitats that will be intensively sampled. The large-scale nature of the Modified-Whittaker has also been found to effectively detect exotic species in the more common vegetation types such as rangelands and forests (Stohlgren et al. 1997a, 1997c, 1999a, 1999b, 1999c). Furthermore, the ability of the sampling design to detect species with great accuracy and precision and therefore detect change over time will facilitate early detection across the landscape. Plots void of exotics but near outbreaks will represent sites for future early warning and possibly a management threshold marker.

III.I.1. Habitats or Strata of Importance

Through analysis of current data and by request of park unit managers, habitats and vegetation species of concern have been documented in each NPS unit. Vegetation types of concern will receive a more intense level of sampling. Not by coincidence, many habitats of concern tend to be the same vegetation types that are rare on the landscape and will receive a greater sampling effort based on their disproportionate contribution to species diversity. These habitats include riparian areas, wetlands, aspen and other relatively rare habitat types.

III.I.2. Field Methods

At each randomly selected point, a Modified-Whittaker nested vegetation sampling plot will be established within the vegetation type and across the major environmental gradient (Stohlgren et al. 1995). The Modified-Whittaker plot is 20 x 50 m, with ten 0.5 x 2 m (1- m²) subplots arranged systematically inside and adjacent to the plot perimeter, two 2 x 5 m (10- m²) subplots in opposite corners, and a 5 x 20 m (100-m²) subplot in the center of the plot. Percent cover by species and average height by species will be recorded in the 1-m² subplots. Cumulative species (additional species found in the subplot or plot) are recorded successively in the ten 1-m² subplots, the two 10-m² subplots, the 100-m² plot, and the remaining unsampled areas of the 20 x 50 m plot. The 1000-m² plots are searched completely for species not encountered in the 1, 10, and 100-m² subplots. Species richness for a vegetation type is determined by combining species lists from the replicate plots and removing duplicate entries. For small vegetation communities, the dimensions of the Modified-Whittaker plots and subplots can be shrunk proportionately.

At each location ancillary data such as slope, aspect, evidence of disturbance, and surrounding vegetation type should be noted. Global positioning systems will be used to document the location (UTM) of the plots and to facilitate the incorporation of data directly into the spatially referenced database and databrowser.

It should be noted that the method utilized does not have to be the Modified-Whittaker, but the sampling protocol must sample vegetation at multiple scales and at least one larger scale. As long as data is collected at multiple scales, the data is comparable across sites and across time. For example, the Forest Service Forest Health Monitoring program has modified its original sampling method to incorporate multiple scales. This allows for greater comparison across time at one location, across the Forest Service land and to other vegetation inventories that use multi-scale designs such as the Modified-Whittaker.

III.I.3. Data Analysis

The methods for data analysis of plant data collected through the use of Modified-Whittaker vegetation plots have been tested and applied to several management scenarios (Stohlgren et al. 1997a, 1997c, 1999a, 1999b, 1999c). Data is easily imported into MSAccess databases where it is easily manipulated and compatible with National Park Service Inventory databases. The ability to draw species-area curves by combining plots within and across habitat types (accounting for species overlap using Jaccards coefficient) provides not only a good picture of species diversity locally, but also on a regional scale. These curves allow for accurate prediction of the number of species in a given area. The number of species found at the various scales can be compared as desired, and the cover of species found at 1-m² can be compared. The

structure of the method allows for a variety of information, what is analyzed will reflect the inventory and future monitoring needs of the various park units sampled.

III.J. Methods for Data Management and Synthesis

Meticulously careful and accurate handling, analysis and presentation of data is essential to the success of the Rocky Mountain Network inventory process. A variety of approaches will be taken to handle the needs of different data. There is an abundance of data that needs to be modernized. A great deal of data needs to be evaluated for completeness both in species list and abundance. New data will be collected. A host of tools has been developed to ensure that the data is organized into databases that are standardized across the nation. Most importantly, all data must be evaluated in an iterative manner. Data will either be collected or organized, then evaluated using both spatial and quantitative modeling tools that will direct further inventory. Information gleaned from this second phase will then again be evaluated, and so on. The iterative process will ensure accuracy and cost efficiency that will enable the Network to collect the most high quality data for the least cost.

III.J.1. Data Management Tools

III.J.1.a. *Existing Data Management Activities*

The National Park Service has created several tools to manage the data and information concerning natural resources that exist within the parks under NPS jurisdiction (See Appendix C for Current Database Status). NRBib is a nationally standardized Microsoft Access based bibliography (Microsoft 1997) that documents all reports and publications created within or about any NPS unit. The Data Set Catalogue is another Access database set up to document any article of information about resources. The list of acceptable entries might include maps, voucher specimens, memos, or aerial photographs. The database lists the location of the article, when it was collected, condition and accuracy. NPSpecies, also Access based, is a list of all species known to exist in each park. The database includes the reference, voucher and observation documentation, level of certainty, and date of recognition.

In a previous NPS wide effort, all reports were included in NRBib in the year of 1995. A significant portion of the initiation of the Rocky Mountain Network inventory effort has been dedicated to updating the data at each of the park units into these databases. This effort will continue throughout the inventory process.

III.J.1.b. *Updating Previously Collected Data*

A great deal of existing data needs to be converted to useable formats. Every Park unit in the Rocky Mountain Network has some information on natural resources. Glacier National Park and Rocky Mountain National Park, the larger, data rich Parks have inventories that are at 90%. However, much of this data exists in inaccessible formats or not conducive to influencing current management decisions. Data that is useful needs to be converted to modern formats that allow easy manipulation and integration with other datasets.

Additionally, the National Park Service has developed a tool that will ameliorate the condition of antiquated data. The GIS Data Browser provides a data management tool that organizes and displays data in a user-friendly GIS framework. The Data Browser is also Access based, so voluminous amounts of data can be stored while incorporating intricate detail. The

GIS Data Browser allows data to be stored behind the scenes of an easy to use GIS environment that allows for manipulation by managers with minimal specialized training. Individuals familiar with GIS technology can utilize the Data Browser while accessing normal capabilities of a GIS environment. The GIS Data Browser is an effective way to manage, manipulate, synthesize, and present data. While much of the information about this inaccessible data has already been entered into the other NPS data management tools, incorporating it into the GIS Data Browser will be a big job that will also make the data useful to managers.

III.J.1.c. *Handling New Data*

The ability of the Rocky Mountain Network to effectively and accurately manage newly collected data will be an essential part of the success of the inventory. The data will be evaluated and updated into databases early and often. The data management tools that have been developed for NPS inventory purposes will be utilized, and will help to ensure that the data collected will be stored in an effective manner.

Accurate and careful data management begins in the field. In many cases field teams will enter data directly into hand held computers that will be backed up nightly onto lap top computers to protect against loss of data. Software has been developed that will transfer data directly from the laptop computers into a centralized Access database that will serve as a clearinghouse for data and link directly to the GIS Data Browser. The collection of data in electronic formats reduces potential for error, increases cost efficiency as data entry is eliminated, and allows for immediate and frequent analysis of data that will be the core of the Rocky Mountain Network iterative inventory.

In other cases, data will be collected on to paper data sheets and then transferred into Access databases early and often to protect against data loss and to ensure that the process of actually using the data does not become a low priority. Contracted scientists will be encouraged to collect data in manners that they feel most comfortable.

III.J.2. Assessing Inventory Completeness

To obtain reliable estimates of species richness based on survey data it must be assumed that all species are detected or that detectability of the different species is the same or at least does not vary among samples (Boulinier et al. 1998). We define detectability of a species as the probability of detecting at least one individual of a given species in a particular sample unit, given that individuals of the species are present during the sampling session (Boulinier et al. 1998). Note that a species' detection probability depends on both its population size and the behavioral attributes of individuals relative to the sampling methods employed (Nichols et al. 1998).

Unfortunately, the assumption of equal detectability among species, or the assumption that the likelihood of detection, given presence, equals 1 is almost never true. As a consequence, we need a method that accounts for species that are present but not detected. A number of different methods have been proposed (reviewed in Bunge and Fitzpatrick 1993) all based on estimating the "missing" species based on the observed patterns of species occurrences across samples. Based on previous empirical and simulation studies, we propose statistical methods derived from capture-recapture models for the Park Service inventory goal of estimating 90% of true species richness (Burnham and Overton 1979, Nichols and Conroy 1996, Boulinier et al.

1998, Nichols et al. 1998).

III.J.2.a. *Sampling Design*

Capture-recapture methods for estimating species richness are often based on quadrat sampling. This design is compatible with the design we have proposed for the survey of national parks. Specifically, we propose that each park be partitioned into a large number of equal-sized quadrats by overlaying a grid over a vegetation map of the park. A random sample of quadrats is then selected within each vegetation stratum and the investigator identifies and enumerates species found in each selected quadrat using a variety of taxa-specific sampling methods. The estimation method is more precise when an equal sampling effort and identical sampling methods are applied to each quadrat. However, variation in sampling effort or methods can be accommodated in more complex estimation models (see below).

At the completion of the sampling process the data within each stratum, and for the park in total, can be summarized in a two dimensional matrix. Each row of this matrix represent an individual species and the total number rows is equal to the total number of different species detected. The columns of the matrix represent the sampled quadrats. Entries in the matrix are either a “1” to indicate presence of the species or “0” to represent absence of the species from that quadrat.

III.J.2.b. *Estimating Species Richness*

The species capture matrix is analogous to a capture history matrix for individuals within a single-species capture-recapture study (Burnham and Overton 1979). Based on the distribution of detections across the quadrats, these data are used to estimate the likelihood of detecting a species given its presence on a quadrat. By adjusting the observed number of species detected by the likelihood of detection, it is possible to estimate the total number of species including those not observed in the sample (Boulinier et al. 1998).

The estimation models we propose to use are based on capture-recapture models developed for estimating population size from closed populations (see Otis et al. 1978). In single-species capture-recapture models a closed population is one that is closed to immigration, emigration, birth, or death during the period of study. By analogy, using these models to estimate species richness assumes that the community of plants or animals sampled is closed to colonization or local extinction during the sampling period. Given the relatively short duration of the sampling process relative to the dynamics of colonization and extinction processes, this assumption seems tenable.

Closed population capture-recapture models address three sources of variation in detection probabilities (Otis et al. 1978). These include variation in detection from one quadrat to another, variation among species, and variation between the first quadrat sampled and subsequent ones arising from investigator learning (Boulinier et al. 1998). In a broad-scale comparative study of bird survey data, Boulinier et al. (1998) found that the primary source of variation occurred because of differential detectability of species and that other sources of heterogeneity were usually negligible. When the primary source of variation is heterogeneity in species detectabilities, then the jackknife estimator proposed by Burnham and Overton (1979) can be used to estimate species richness from the species occurrence matrix. The data required for estimation with the jackknife estimator are the frequencies, f_h or number of species detected

on exactly $h = 1, 2, \dots, K$ of the sampled quadrats where K is the total number of quadrats sampled (Burnham and Overton 1979, Nichols et al. 1998). The general form of the jackknife estimator for species richness is

Where R is the number of species observed in the sample, and the ah_k are constants corresponding to jackknife estimators of order k (Nichols et al. 1998). The jackknife estimator based on the above equation is available in the COMDYN software available free from U.S. Fish and Wildlife Service (Hines et al. 1999).

The above equation represents the point estimator of species richness. Because estimates of unknown community parameters are subject to both estimation and sampling error, we must also compute an estimate of the variance. Variance estimates are computed in program COMDYN using a bootstrapping algorithm (see Nichols et al. 1998). The point and variance estimates allow computation of a 95% confidence interval estimate of total species richness.

III.J.2.c. *Retrospective Analyses of Species Occurrence Data*

Based on the methods outlined above, some park service units may have existing data sets that can be used to estimate species richness. However, existing data sets are seldom based on data collected from standardized survey protocols. Often these data will have been collected in an ad hoc manner and subject to multiple sources of heterogeneity including species, observer, habitat, and time effects. In this case, a more general class of capture-recapture models can be fit to the species occurrence data using program CAPTURE (Burnham and Rexstad 1991). In general, additional sources of heterogeneity will lead to less precise estimates of species richness. However, we encourage the analysis of existing data sets with these methods. Often the results of these analyses will suggest that less is known (seldom more) about the species composition of the park than originally believed and be a stimulus for more standardized sampling.

III.J.2.d. *Establishing a Stopping Rule for Sampling*

The park service inventory design has a goal of estimating 90% of the true number of species in a given park. However, without prior knowledge of the true number of species, how is it possible to know when the 90% goal has been attained? This conundrum requires some a priori estimate of the possible number of species of vertebrates and vascular plants that could potentially occur in a given park. However, there is no rigorous way to arrive at this estimate.

Fortunately, the methods described above for estimating species richness will provide an interval estimate of the total number of species expected to occur in the park. As a result, this method of sampling and estimation avoids the arbitrary goal of 90% completion. However, it is still useful to compare the interval estimate from program COMDYN (or CAPTURE) with some prior expectation of species richness. If the confidence interval is very broad (i.e., high uncertainty in the estimate) or falls short of the expected number of species, then additional sampling is probably warranted.

III.J.3. Spatial Modeling of Natural Resources

Ultimately, the inventory effort aims to support management decisions. Managers must have knowledge of where species exist on the landscape. Managers must know the location of threatened and important species, stressed habitats, and habitats that might be susceptible to

invasions by exotic species. For both native and exotic species, managers must have an idea of how many species and how many individuals exist in specific regions; such knowledge might identify the location of exotic species source populations. Finally, an understanding of how distributions change over time provides truly useful monitoring information such as the spread of exotic species or localized extirpation of threatened native species. Predictive models developed from multi-scale, spatially explicit data will be developed using stepwise multiple regression and spatial analysis (kriging and co-kriging) to provide distribution information that can be essential to effective management. An example of the type of predictive distribution models that can be developed shows the probable distribution of weed species in Rocky Mountain National Park (Fig. 8).

Predictive distribution and abundance models will guide the iterative inventory process. The procedure can be broken down in a stepwise manner:

1. The acquisition of data. This could either be utilization of previously collected data or data gathered from a primary investigation.
2. This data is used to model the distribution and abundance of the taxa or species in question using specific spatial statistics and geostatistical procedures. The model generates coverages with associated error bars that assess the relative accuracy of the prediction. In this way the model directs the need for further spatial investigation and inventory. Regions associated with greater uncertainty may require more data collection.
3. Subsequent data collection efforts serve to check the accuracy of the model predictions and to collect data in regions of high uncertainty as predicted by the model.

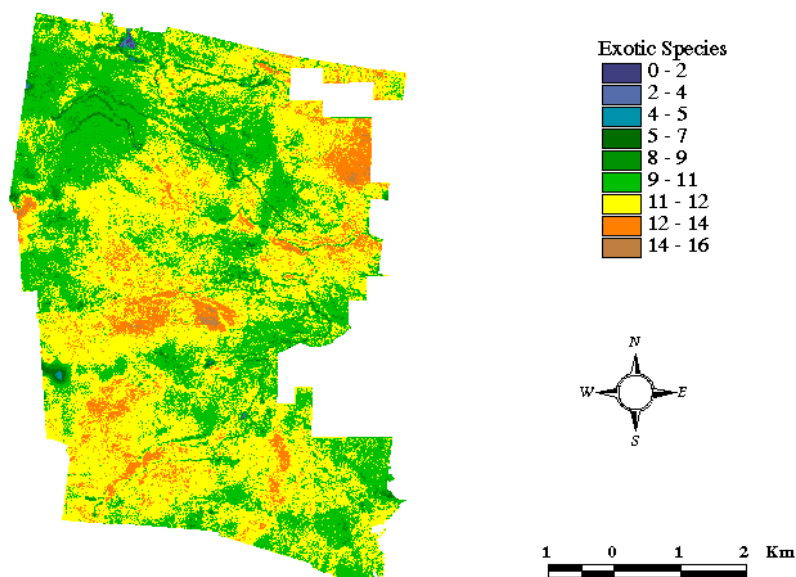


Figure 8. The potential distribution of exotic weed species for a section of Rocky Mountain National Park.

4. The newly collected data is incorporated into the model to improve the model.
5. The improved model directs further inventory efforts by indicating areas of high uncertainty or regions that may support high concentrations of species of concern that may need more quantitative investigation.

Importing collected data into the spatial modeling system early and often will increase the effectiveness and efficiency of the inventory as it directs further effort to insufficiently sampled areas and to regions that may be of concern.

While many spatial datasets describing land characteristics have proven reliable for macro-scale ecological monitoring, the coarse resolution of the data fall short in providing the precision required by more refined ecosystem models (Gown et al. 1994). Furthermore, these coarse models often do not provide adequate accuracy or detail required for the inventory, monitoring, and especially management of vascular plants and vertebrate species. Modeling small-scale variability of species distribution requires the generation of full-coverage maps that depict characteristics measured at points in the field (Reich and Bravo 1998). Not only do the models require field data, the data must be spatially referenced. Careful attention must be devoted to where data is collected and that adequate data is collected in all habitats, rare and small habitats must be sampled intensively to provide accurate predictions across unsampled regions. Data collected by search techniques or random expert walks often accounts for the presence or absence of a species, but when the location nor the location of further encounters is not recorded the data can not be used in the spatial modeling process. Because many data sets from previous studies have a spatial component, the data from many studies may be used in the

model, even if the data have bias associated with the sample design.

The ability of the model to integrate previous investigation provides the link to evaluations of percent completeness. Together the two are the backbone of the iterative inventory. For example, a spatial model may be generated prior to initial investigation. The uncertainty associated with specific regions of the model may direct the placement of independent plots that will assess species lists for completeness. Or, when evaluated, an initial investigation might detect approximately 50% of the species. Modeling the distribution and abundance of the data will direct the next phase of the study in an effective and efficient manner. The use of the spatial modeling tools provides not only distribution and spatial abundance, but also provides an effective and informative decisions and data presentation tool.

III.J.3.a. *Methods*

The process begins with stepwise regression to identify important variables to include in a trend surface model of geographical variables and measures of species richness to describe large scale spatial variability in the study area. The functional form of this model is defined as:

$$\Phi_0 = \sum_{i=1}^p \sum_{j=1}^p \beta_{ij} x_{10}^i x_{20}^j + \sum_{k=1}^q \gamma_k y_{k0} + \eta_0$$

where, β_{ij} are the regression coefficients associated with the trend surface component of the model, γ_k are the regression coefficients associated with the q auxiliary variables, y_{k0} , available as a coverage in the GIS data base, and η_0 is the error term which may or may not be spatially correlated with its neighbors (Kallas 1997, Metzger 1997).

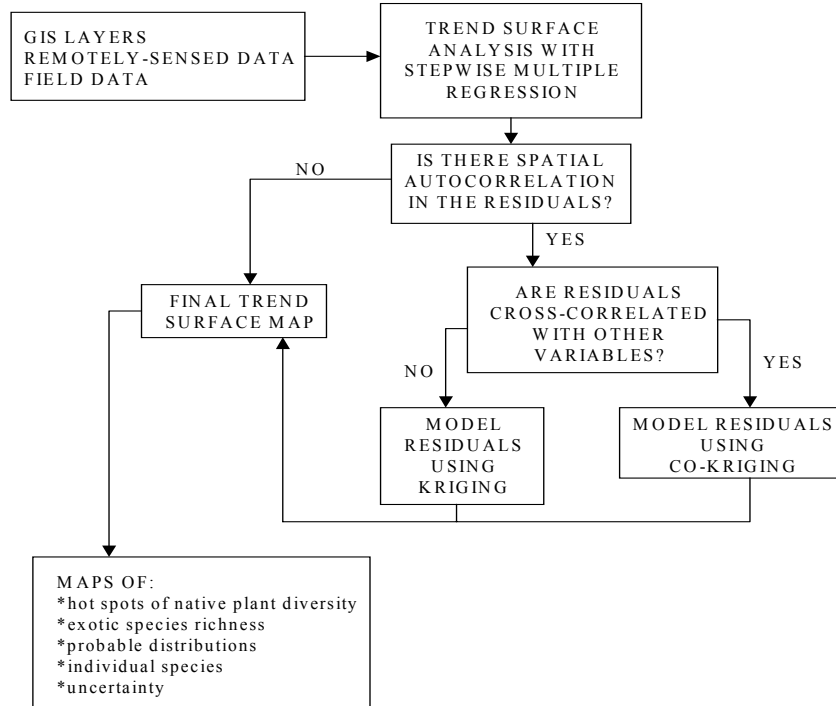


Figure 9. Flow diagram of statistical procedures.

If the included variables are spatially or temporally correlated with the variable of interest, this information can be used to improve estimates (Isaaks and Srivastava 1989) by interpolating values for points not measured (Robertson 1987). The use of auxiliary information in spatial prediction is referred to as co-kriging. The usefulness of auxiliary information is enhanced by the fact that the variable of interest is generally under-sampled (Isaaks and Srivastava 1989).

To account for spatial autocorrelation in the residuals of the model developed to describe large-scale spatial variability, we model the small scale spatial variability (i.e. spatial noise) using the co-kriging model:

$$\eta_0 = \sum_{r=1}^n w_r \eta_r + \sum_{t=1}^m \sum_{r=1}^n v_{tr} u_{tr} + \varepsilon_0$$

subject to the linear constraints:

$$\sum_{r=1}^n w_r = 1, \quad \sum_{t=1}^m \sum_{r=1}^n v_{tr} = 0$$

Here, w_r are the kriging weights associated with the n -nearest residuals; v_{tr} are the co-kriging weights associated with the m auxiliary variables, u_{tr} , that are spatially correlated to the residuals; and E_0 is the error term which we will assume to be spatially independent and normally distributed with mean 0 and variance σ^2 . One of the appealing features of co-kriging is that the auxiliary information does not have to be collected at the same data points as the variable of interest. This allows us to combine remote sensing and field data to provide a full coverage map with a higher resolution than would have been possible by using remote sensing or field data alone. In essence, predictive models provide information on large scale spatial variability, while field data provide information on small scale spatial variability.

Prior to fitting the co-kriging model, the residuals of the model describing the large scale spatial variability were analyzed for anisotropy (spatial autocorrelation changes with direction). The residuals were also evaluated for the presence of spatial cross-correlation (Bonham *et al.* 1995, Czaplewski and Reich 1993, Reich *et al.* 1994) with the independent variables included in the trend surface model, and variables for which only data associated with field plot locations are available. Complete coverage of the variables associated with the field data is usually not available in the GIS database because one can only afford to sample points. If no spatial cross-correlation is detected, the residuals can be modeled using ordinary kriging otherwise the residuals are modeled using co-kriging (Fig. 9).

The ability to spatially model field data allows integration over any specified geographical region (i.e., point- and plot-level field data, management unit, watershed, region) to obtain a point estimate and associated standard error of prediction. This is accomplished by integrating the three dimension response surface representing the variable of interest over the area of interest and dividing by the area. Since the spatially modeled response surfaces can be represented as a grid in ARC/INFO (ESRI 1997), any specified region will contain a finite number (n) of grid cells of uniform size (i.e., 30 m x 30 m). Our point estimate of a resource in some bounded region A , is obtained by summing the point estimates associated with each cell, Φ_i , and dividing by the number of cells in the bounded region:

$$\bar{\Phi} = \frac{1}{n} \sum_{i=1}^n \Phi_i, \quad \Phi_i \in A$$

The estimated variance is given by

$$V(\Phi) = \frac{1}{n^2} \sum_{i=1}^n V(\varepsilon_i) + \frac{1}{n^2} \sum_{i+j}^n \sum_{i+j}^n \rho_{ij}(h) V(\varepsilon_i)^{1/2} V(\varepsilon_j)^{1/2}$$

where $\hat{V}(\varepsilon_i)$ is the estimated variance associated with cell i , and $\hat{\rho}_{ij}(h)$ is the spatial correlation

between cells i and j , which are separated by distance h . The spatial correlation is estimated using the appropriate variogram function. Resource managers can use the error maps to determine what areas warrant further field data collection to increase model accuracy.

IV. PROJECT STATEMENTS

IV.A. Project Statement 1:

Augment and Assess Completeness of Biological Inventories in Terrestrial Habitats: Integrated Surveys of Native and Alien Plants, Mammals and Birds at GRKO, FLFO, GRSA, LIBI

IV.A.1. Problem statement

Managers at GRKO, LIBI, FLFO and GRSA are hampered by inadequate knowledge of vascular plant and vertebrate animal species occurrence. A coordinated, random-stratified sampling effort in terrestrial habitats is the most efficient strategy to achieve a baseline of information to address management concerns and guide future monitoring efforts.

IV.A.2. Objectives

Priority upland and riparian habitats will be sampled using a stratified random sampling design. The goal of this project is to bring the parks to the primary goal of 90% species documentation for vascular plants and vertebrate animals through efficient, coordinated field surveys. An unbiased stratified sample design will provide the basis for valid extrapolation on the distribution and abundance of species of concern and will lead into an effective monitoring program.

IV.A.3. FY01 Funded Project

The Rocky Mountain Network intends to initiate this terrestrial inventory in the first fiscal year of funding FY01. The following project outline defines the details of how this project will be implemented. Challenges relevant to this project facing each of the four parks are briefly addressed. Each of the taxonomic groups to be inventoried includes a brief outline of the principal investigator, an outline of previously detailed methods, and the sampling timeline. These are followed by a brief description of methods for handling data, further detail on when sampling will occur in each of the four parks, a budget itemized by taxa, management needs, and fiscal year.

The planning of the fieldwork is outlined. Before fieldwork can begin, sample sites must be located according to the previous discussion. Once funding has been allocated, this work will occur prior to the field season as funded by leadership positions funded by FY01 projects 1 and 5.

IV.A.4. Sampling Framework

Park managers need to make informed decisions that reflect the diversity of biological resources within jurisdictional boundaries, as well as assess the influence of numerous external factors. These parks will benefit from a coordinated field sampling effort to supplement valuable but incomplete existing information relating to terrestrial habitats of concern. It would be

impossible to thoroughly sample all areas of the parks due to timing and funding constraints. Therefore, unbiased selection of sample sites will be necessary to ensure valid extrapolation to the many unsampled areas.

Although each park is characterized by a unique natural heritage, habitats of concern (riparian areas, native vegetation remnants, etc.) reflect the common suite of threats and stressors that plague the parks (altered disturbance regimes, non-native species invasion, etc.). Common stressors and habitats of concern lend themselves to similar stratification of common and rare but important terrestrial habitats. In addition to dry meadow, conifer forest, aspen, wetland and riparian areas, important terrestrial strata at FLFO include potential sources of alien species invasions (e.g. Smooth brome meadows historically managed for hay production). Priority strata at GRKO include riparian areas and native upland range threatened by invasive alien plant species, as well as the areas managed for cattle and hay production. GRSA anticipates overwhelming inventory needs in all strata of proposed areas of expansion (e.g., aspen, conifer, vegetated and open dune areas, etc.). GRSA is particularly concerned about riparian areas and alien plant species encroachment in the areas of interdune ponds. Important strata at LIBI include the cottonwood stands along the Little Bighorn River, shrub-lined ravines and high quality and unique upland habitats (e.g., Side-oats grama grassland).

Although sampling methods and schedules differ for mammals, birds and vegetation, priority strata and habitats of concern overlap in many cases. Birds, small mammals and vegetation will be surveyed in the same terrestrial strata (all with riparian and unique upland habitats as a focus). For efficiency and repeatability, the established unbiased sample locations will be used by field biologists whenever possible, and additional strata can be defined and sampled to include particular taxa of concern. In cases where the sampling of particular unique habitats is justified (e.g. unique geologic features suspected to support rare plant populations, etc.), focal sampling and targeted rare species surveys can be used to supplement the standardized design.

Occurrence and distribution information will be processed within a geographic information system (GIS). GPS units will be used to document sample locations and occurrences of species of concern in the field. Information managers will coordinate with field biologists for early data processing in MSAccess and ArcView. All inventory projects will be designed to facilitate NPS database development, including NRBibliography, NPSpecies, Dataset Catalog and the GIS Databrowser. This high quality GIS and associated metadata (meeting FGDC standards) will serve as a valuable tool for mapping and modeling distribution and abundance of species of concern and assessing efficiency and completeness of inventories.

IV.A.5. Field Surveys

IV.A.5.a. *Birds*

Principal Investigators:

Barry Noon, CSU- project coordinator
Steve Fancy, NPS- advisory PI

Methods:

This inventory will serve as the pilot year of a monitoring program for birds. The

random-stratified sample locations will be well-documented so that surveys can be repeated and extended to include additional taxa (including vegetation and small mammals in this project) and habitat features. Distance sampling will be conducted by sight and sound at the documented sample locations in the early morning. Please refer to the methods section for a detailed description of methods that will be used to sample populations of avian species. These studies will provide information on distribution and density on both breeding residents and Neotropical migrants. In the afternoons focal sampling will be conducted in wetland areas and other priority strata to document breeding occurrences for species of concern.

Surveys will be conducted during the breeding season (mainly May through June). Voucher specimens will not be necessary as most birds can be reliably identified in the field. Recordings and photographs will be encouraged for documentation of unusual species. Nests will be documented with minimal disruption to the birds and their habitats.

Sampling Schedule:

GRKO - 3 visits during Breeding Season (May-June), 2-3 days each.

LIBI -3 visits during Breeding Season (May-June), 2-3 days each.

FLFO - 3 sampling visits (May-June), 4-5 days each.

GRSA - Need several weeks effort: 3 sampling visits (May-June), 5-6 days each

Coordination and Logistics:

The FY01 budget includes money to hire expert field ornithologists and incidental equipment under the guidance of Barry Noon at Colorado State University. Park personnel will provide local knowledge and expertise, and will assist in securing accommodations that will facilitate the early morning surveys.

IV.A.5.b. Mammals

Principal Investigators:

Barry Noon, Colorado and Montana Natural Heritage Programs - small and large mammals

Tom O'Shea and USGS-BRD personnel - bats

Methods:

Mammal surveys in terrestrial habitats will focus on small mammals (live traps and conspicuous den surveys) and will include some inventory effort for bats (e.g documentation of important roost sites) and large mammals (track and scat/pellet surveys at GRSA). Experienced field technicians will follow professional ethics on the proper capture and handling of small mammals (Jones et al. 1996). Voucher specimens are often required for reliable identification of small mammals and bats, although expertise sharply reduces the need for destructive sampling (Jones et al. 1996, Tom O'Shea personal communication). Photographs will be favored for documentation, and supplemented by necessary voucher collections. Voucher collections will be properly curated and deposited in the appropriate maintained collections, and supported by a commitment of funds for personnel, supplies, etc. based on total funding for mammal fieldwork in the four parks (see project 2 budget below). Please refer to the mammals method section for detailed description of mammal inventory methods to be used by the Rocky Mountain Network.

Sampling Schedule:

GRKO: 1-2 weeks - mostly small mammals (live traps and conspicuous den surveys) and 1 week bats

LIBI: 1-2 weeks - mostly small mammals and 1 week bats

FLFO: 2 weeks - mostly small mammals and 1 week bats

GRSA: 3-4 weeks - small mammals, 1-2 weeks bats, 1 week large mammal sign surveys (track and pellet) searches at established plots.

Coordination and Logistics:

The budget includes funding for biological field technicians that will be coordinated and hired by the principal investigators. The parks involved will provide support in terms of personnel (expertise, local knowledge, contacts, assistance), lab space, lodging opportunities and valuable resources.

IV.A.5.c. *Plants***Principal Investigators:**

Tom Stohlgren and NREL taxonomists

Methods:

Inventory vascular plant species using a multiscale, nested plot at the unbiased terrestrial sample locations. Please see the vascular plants methods section for a detailed description and justification of the methods to be used. The approach to doing this is to define priority strata, sample in rare but important habitats, and then move to common habitats. The rare and unique strata typically contain both common and rare species. Targeting strata predicted to contain the highest vascular plant diversity will also provide information on critical areas of alien species invasion. Regardless of the stratification, document with GPS and mark as permanent plots for potential monitoring.

Necessary voucher specimens will be curated and deposited in the appropriate collections. Plot data will be analyzed for native species richness, cover and uniqueness. Distribution and cover maps and models will be developed for invasive alien species and other species of concern. Species area curves and other modeling techniques will be used to assess completeness and return for additional effort

Coordination and Logistics:

The parks will provide support in terms of personnel (expertise, local knowledge, contacts, assistance), lab space, lodging opportunities and valuable resources.

Reptiles:

Opportunistic surveys in priority terrestrial habitats to be conducted in cooperation with amphibian survey teams - Erin Muths and Lauren Livo in Colorado, Steve Corn in Montana.

IV.A.6. Preliminary schedule of field crew effort

	May	June	July
Bird	FLFO, GRSA	LIBI, GRKO	
Mammal		LIBI, GRKO	FLFO, GRSA
Plant		LIBI, GRKO	FLFO, GRSA

IV.A.7. Data Management

The data collected from the project will be handled by the project leader for the entire terrestrial group and the GIS data manager. These two individuals will coordinate to ensure that the data is entered into the appropriate National Park Service databases (please refer to sections on data management in methods section for greater detail. The terrestrial project leader will also deliver the data to, and coordinate with the leader associated with project 5. This individual will have the data analyzed and assessed with models to evaluate the quality of the methodology, sample design, degree of completeness (90%), and spatial completeness. These results will direct and inform the remainder of the inventory efforts for FY01 and inventories the next year. This is the iterative process that is the backbone of an efficient and credible inventory program. Please see relevant method sections and project 5 for more details.

IV.A.8. Products/Deliverables:

1. Identification of priority strata and selection of unbiased sample locations using aerial photos and/or satellite images for the four parks.
2. Annual reports and electronic data submission (using MS Access and Arcview) to document results of coordinated field investigations, with iterative analysis to assess completeness.
3. Useful synthesis and modeling on distribution and abundance of species of concern.

IV.A.9. Budget

The budget for project 1, itemized by terrestrial taxa and fiscal year, appears on the following page.

Project 1 budget.

Project 1: Augmentation and Assessment of Terrestrial Habitats in FLFO, GRSA, GRKO, and LIBI															TERRESTRIAL PROJECT TOTALS
Project Component	Vegetation	Mammals	Birds	Vegetation	Mammals	Birds	Vegetation	Mammals	Birds	Vegetation	Mammals	Birds	Vegetation	Mammals	
Principal Investigator	Stohlgren	Noon	Noon / Fancy	Stohlgren	Noon	Noon / Fancy	Stohlgren	Noon	Noon / Fancy	Stohlgren	Noon	Noon / Fancy	Stohlgren	Mammals	Birds
Fiscal Year/Total	FY01			FY02			FY03			FY04			SUB PROJECT TOTALS		
Field Biologists	\$ 8,571.00	\$ 5,714.00	\$ 5,714.00	\$ 8,571.00	\$ 5,714.00	\$ 5,714.00							\$17,142.00	\$ 11,428.00	\$ 11,428.00
Benefits	\$ 1,542.78	\$ 1,028.52	\$ 1,028.52	\$ 1,542.78	\$ 1,028.52	\$ 1,028.52							\$ 3,085.56	\$ 2,057.04	\$ 2,057.04
Travel	\$ 3,428.00	\$ 2,857.00	\$ 2,857.00	\$ 3,428.00	\$ 2,857.00	\$ 2,857.00	\$ 1,714.00						\$ 8,570.00	\$ 5,714.00	\$ 5,714.00
Supplies	\$ 1,000.00	\$ 1,000.00	\$ 1,200.00	\$ 833.00	\$ 833.00	\$ 1,133.00							\$ 1,833.00	\$ 1,833.00	\$ 2,333.00
Curation	\$ 200.00	\$ 200.00		\$ 300.00	\$ 300.00		\$ 333.00	\$ 333.00	\$ 333.00				\$ 833.00	\$ 833.00	\$ 333.00
Equipment	\$ 1,000.00	\$ 1,000.00	\$ 1,000.00	\$ 666.00	\$ 666.00	\$ 666.00							\$ 1,666.00	\$ 1,666.00	\$ 1,666.00
Overhead	\$ 2,361.27	\$ 1,769.93	\$ 1,769.93	\$ 2,301.12	\$ 1,709.78	\$ 1,709.78	\$ 307.05	\$ 49.95	\$ 49.95				\$ 4,969.43	\$ 3,529.66	\$ 3,529.66
SUBTOTAL	18103.047	13569.448	13569.45	17641.9	13108.298	13108.3	2354.05	382.95	382.95				38098.99	27060.696	27060.7
Terrestrial Project Management															
Project Leader		14000			14000									28000	
GIS / data mgr		4000			4000									8000	
Benefits		3240			3240									6480	
Overhead		3186			3186									6372	
FY SUBTOTALS		24426			24426		Incorporated in aquatic project management							48852	
GRAND TOTALS		\$ 69,667.94			\$ 68,284.49		\$ 3,119.95							\$ 141,072.39	\$ 141,072.39

V.B. Project Statement 2

Augment Existing Information and Assess Completeness of Biological Inventory in Aquatic Habitats: Integrated Surveys of Amphibians (and some Reptiles), Fish and Bats at GRKO, FLFO, GRSA, and LIBI.

IV.B.1. Problem Statement

Inadequate information on fish, amphibian, and bat species hampers management of aquatic habitats at Florissant Fossil Beds, Grant Kohrs, Little Bighorn, and Great Sand Dunes National Monuments. Priority aquatic strata in these parks include rivers, streams, ponds and adjacent riparian areas and wetlands. A systematic, coordinated community-based sampling effort is the most efficient strategy to achieve a baseline of information to address management concerns and guide future monitoring efforts.

IV.B.2. Objectives

The primary objective of this project is to bring FLFO, LIBI, GRKO and GRSA to the goal of 90% species documentation for vertebrate species associated with aquatic habitats through efficient, coordinated field surveys. An unbiased stratified sampling design will provide the basis for valid extrapolation on distribution of species of concern and will lead into an effective monitoring program. Abundances of species of concern will be estimated using frequency of occurrence (reptiles, bats, fish) and population turnover (amphibians). The aquatic project is scheduled to begin FY02 to allow for further preparation and planning of principal investigators.

IV.B.3. Field Surveys

Although use of sampling methods and schedules differ among taxa associated with aquatic habitats, priority strata in the parks overlap in many cases. Sampling will take place at aquatic sites selected using the random-stratified sample design described in section III. Fish, amphibians and bats will be surveyed at locations in and/or near the selected ponds, streams, rivers and associated wetland and riparian areas.

Priority aquatic strata at Florissant Fossil Beds include streams and riparian habitats, particularly in areas of recent dam removal. At Grant-Kohrs Ranch, riparian areas other than those associated with the Superfund site along the Clark Fork River are highest priority for inventory. Great Sand Dunes personnel expect to have additional inventory needs related to the proposed areas of expansion and have long been concerned with the threat of water development upon the hydrology of the area; priority strata include riparian areas and unique interdune ponds. At Little Bighorn Battlefield, primary strata of concern include the cottonwood stands along the Little Bighorn River, and ephemeral water sources in the shrub-lined ravines.

Occurrence and distribution information will be processed within a geographic information system (GIS). GPS units will be used to document sample locations and species detected or measured, allowing for presentation of distribution data as well as spatial modeling on species of concern. Information managers will collect data from field biologists between sampling efforts to assess data for completeness with stop rules, and to facilitate spatial modeling of species of concern. At this time data will also be incorporated into the various inventory databases and documented with associated metadata.

IV.B.3.a Amphibians

Implementation/Cooperation:

The amphibian surveys will be carried out and supervised by USGS personnel running the ARMI amphibian inventory. Assistance from the parks will be requested, including local expertise, opportunities for lodging, lab space, equipment storage, and other logistic details.

Field Methods:

Most amphibian species in our area occur in ponds and riparian areas, which will be priority strata for aquatic sample site selection (e.g. unique interdune ponds at GRSA).

ARMI is developing standardized basic survey techniques that will be used for the survey of aquatic habitats. These methods have been outlined in detail in methods section III.D. Visual Encounter Surveys will be repeated through the season at random-stratified aquatic sample locations to provide occurrence and distribution information. For abundance modeling, the teams will look at turnover in populations.

Photography, tissue samples and other non-lethal methods will be favored for documentation. Qualified field biologists will make judgements on the need for any traditional voucher specimens. Habitat destruction will be avoided and all aquatic teams will follow strict equipment isolation and disinfection protocol to prevent spread of disease and pathogens across parks as well as drainages. This is critical with a coordinated team approach and established sample sites.

Distribution maps and abundance models will be produced for species of concern documented at each park. All amphibian and several reptile species are considered to be of concern due to pathogen and disease related declines (Corn, Livo and Muths; March 2000 Missoula Workshop). Bullfrog invasion is also a concern in these parks (e.g. known populations at GRSA boundary).

Schedule:

ARMI project leaders Erin Muths and Steve Corn have already initiated inventory work in GRKO, FLFO, and GRSA in FY00. Field sampling efforts will take place during the first two years of the inventory effort, FY01 and FY02. The surveys will be conducted through repeated visits during the breeding season (mostly May-June). Special trips may be arranged to take advantage of seasonal events that reveal additional species (e.g. large thunderstorm events at GRSA). The potential schedule for each park unit follows:

GRKO - May-June.

FLFO - April-May before ephemeral wetlands dry.

GRSA - Flexibility and repeated visits will be required in early spring and summer as detection of some species is dependant on seasonal conditions, water levels, weather, etc. The sampling effort will begin in April and continue periodically at the discretion of the field biologists through September.

LIBI - May-June.

IV.B.3.b. Fish

Implementation/Cooperation:

Leo Marnel at Glacier National Park will coordinate and carry out fish survey efforts at Grant Kohrs and Little Bighorn National Battlefield. This cooperative effort will save the Network money in materials and leverage expertise of individuals involved in the Network.

Bruce Roselund and John Alvarez of the US Fish and Wildlife Service are qualified to coordinate the fish inventories at FLFO and GRSA. John Alvarez has conducted a significant amount of fish investigation at Great Sand Dunes National Monument. Bruce Roselund, the USFWS biologist who has managed fish inventory and monitoring projects at Rocky Mountain National Park for many years, could also efficiently conduct fish inventories at both of these parks. The parks will provide assistance wherever possible in terms of equipment, local expertise, opportunities of lodging etc.

Field Methods:

A variety of techniques will be employed in order maximize species detection and obtain a robust estimate of composition and relative abundance. At each aquatic sample location a variety of techniques will be combined to target potential fish taxa.

Electrofishing allows for careful identification and measurement of captured individuals at each site, and allows for the return of most individuals to the stream unharmed (Fausch and Bestgen 1999, Michels pers comm.). Where electrofishing is inappropriate due to location, other trap and net methods (e.g. seine nets) will be used. Lake habitats will be sampled either with experimental gill nets (Michels pers comm.), baited traps, or hand seining (Tilmant pers comm.) depending on the site to be sampled at a given lake. Baited trap nets and gill nets will be left in place overnight, including trap nets specifically designed for minnow species.

Schedule:

The fish sampling effort will take place over all three years of the sampling effort, yet each part unit will only be sampled over two years in order to capture temporal heterogeneity and to spread out the effort and time required by cooperators. Park visits will be spread across the season to account for movement and variation in detectability. The exact sampling schedule will depend on availability of personnel, field crews and tribe, state and federal cooperators.

GRKO – FY01, FY02. 1-2 weeks throughout summer field season.

FLFO – FY02, FY03. 2 weeks throughout summer field season.

GRSA – FY01, FY02. 2-3 weeks throughout summer field season.

LIBI – FY02, FY03. 1-2 weeks throughout summer field season.

IV.B.3.c. Bats

Implementation/Cooperation:

Tom O'Shea and personnel of the US Geologic Survey-Biological Resource Division will coordinate and implement bat surveys. The parks will provide assistance wherever possible in terms of local expertise, additional labor, etc., and lodging or camping opportunities that will facilitate the night surveys.

Field Methods:

Bats will be surveyed at aquatic feeding habitats using ultrasonic detectors, mist nets and telemetry. The location of bat sampling will be determined by the sampling design established for the inventory (section III). Established aquatic sample locations will be used for bat surveys when possible for efficiency and to assure replication in the different habitats of concern. Mid-summer fieldwork will improve chances for documenting breeding occurrences through the capture of lactating females and juveniles. Efforts will be made to document roosting and breeding sites that are of management concern. This standardized design will be supplemented by focal sampling for species of concern at known roosting areas and other unique habitats.

Experienced field biologists will follow professional ethics on the proper capturing and handling of bats (Jones et al 1996). Voucher specimens are often required for reliable identification, although expertise sharply reduces the need for destructive sampling (Tom O'Shea, personal communication). Photographs will be favored for documentation, and supplemented by necessary voucher collections. Voucher collections will be properly curated and deposited in maintained collections, supported by a commitment of funds for personnel and supplies.

Sampling Schedule:

Bats will be sampled at each park unit for one field season. The sampling effort at each park will take place in the first two years of inventory. Mid-summer surveys (ultrasonic detectors, mist nets and some telemetry) will be conducted in the four parks, most likely spread across the first and second years of field inventory. LIBI and GRKO surveys could potentially be complete within two weeks, while FLFO and GRSA efforts will be more intensive (estimate 3 weeks and FLFO, 4 weeks at GRSA) due to increased area and variety of habitats represented.

GRKO – 1-2 weeks.

LIBI – 1-2 weeks.

FLFO – 2-3 weeks.

GRSA – 3-4 weeks.

IV.B.4. Principal Investigators and Key Personnel

Steve Corn, Lauren Livo, Erin Muths and ARMI – amphibians and reptiles

Tom O'Shea and USGS-BRD – bats

Leo Marnell, Bruce Roselund and John Alvarez - fish

IV.B.6. Products/Deliverables

1. Identification of priority strata and selection of unbiased sample locations using aerial photos and/or satellite images and existing information for the four parks.
2. Annual reports and electronic data submission (using MS Access and Arcview) to document results of coordinated field investigations, with iterative analysis to assess completeness.
3. Synthesis and modeling on the distribution and abundance of species of concern to develop an effective monitoring program tailored to park specific threats and concerns.

IV.B.7. Budget

The budget for project 2, itemized by fiscal year and taxa, appears on the following page.

Project 2 budget.

Project 2: Augmentation and Assessment of Aquatic Habitats in FLFO, GRSA, GRKO, and LIBI															AQUATIC PROJECT TOTALS	
Project Component	Amphibians		Fish		Bats	Amphibians		Fish		Bats	Amphibians		Fish			Bats
Principal Investigator	Corn/ Muths	Marnell / Rosenlund	O'Shea	J. Corn / E. Muth	Marnell / B. Rosenlund	T. O'Shea	Corn / E. Muth	Marnell / B. Rosenlund	T. O'Shea	Corn / E. Muth	Marnell / B. Rosenlund	T. O'Shea	Corn / E. Muth	Marnell / B. Rosenlund		T. O'Shea
Fiscal Year/Total	FY01			FY02			FY03			FY04			SUB PROJECT TOTALS			
Field Biologists							\$ 2,640.00	\$ 6,000.00	\$ 3,500.00	\$ 2,640.00	\$ 6,000.00	\$ 3,500.00	\$ 5,280.00	\$ 12,000.00	\$ 7,000.00	\$ 24,280.00
Benefits							\$ 475.20	\$ 1,080.00	\$ 630.00	\$ 475.20	\$ 1,080.00	\$ 630.00	\$ 950.40	\$ 2,160.00	\$ 1,260.00	\$ 4,370.40
Travel							\$ 2,450.00	\$ 4,000.00	\$ 2,863.82	\$ 2,450.00	\$ 4,000.00	\$ 2,863.82	\$ 4,900.00	\$ 8,000.00	\$ 5,727.64	\$ 18,627.64
Supplies							\$ 1,500.00	\$ 2,000.00	\$ 2,000.00	\$ 1,500.00	\$ 2,000.00	\$ 2,000.00	\$ 3,000.00	\$ 4,000.00	\$ 4,000.00	\$ 11,000.00
Curation							\$ 630.45	\$ 1,000.00	\$ 600.00	\$ 630.45	\$ 1,000.00	\$ 600.00	\$ 1,260.90	\$ 2,000.00	\$ 1,200.00	\$ 4,460.90
Equipment							\$ 1,000.00	\$ 3,000.00	\$ 2,000.00	\$ 1,000.00	\$ 3,000.00	\$ 2,000.00	\$ 2,000.00	\$ 6,000.00	\$ 4,000.00	\$ 12,000.00
Overhead							\$ 1,304.35	\$ 2,562.00	\$ 1,739.07	\$ 1,304.35	\$ 2,562.00	\$ 1,739.07	\$ 2,608.70	\$ 5,124.00	\$ 3,478.15	\$ 11,210.84
SUBTOTAL							\$10,000.00	\$ 19,642.00	\$13,332.89	\$10,000.00	\$ 19,642.00	\$13,332.89	\$20,000.00	\$ 39,284.00	\$ 26,665.79	\$ 85,949.78
Aquatic Project Management																
Project Leader								14000			14000			28000		28000
GIS/ data mgr								4000			4000			8000		8000
Benefits								3240			3240			6480		6480
Overhead								3186			3186			6372		6372
FY SUBTOTALS								24426			24426			48852		48852
TOTAL							\$ 67,400.89			\$ 67,400.89						\$ 134,801.78

IV.C. Project Statement 3

Conversion of Existing Data to Modern Formats and Assessment of Species of Concern in Rocky Mountain National Park

IV.C.1. Problem statement

Much of the existing natural resource data documenting vertebrate and vascular plant species in Rocky Mountain National Park is not easily accessible to park managers, hindering the development of future monitoring efforts. Although many of the taxa in the Park have been documented to 90% of estimated species richness, efforts to improve abundance and distribution data on species of concern will create a framework for a valuable monitoring program.

IV.C.2. Objectives

1. Improve documentation for species in Rocky Mountain National Park by updating existing data into modern and accessible databases.
2. Quantify completeness of inventories through species-area curves, analysis of species detection for additional effort, identification of information gaps, and other methods and models.
3. Collect distribution and abundance data on select species of concern in an effort to enable effective future monitoring.

IV.C.3. FY01 Funded Project

The data management and updating inventory tasks that exist at Rocky Mountain National Park mandate that the project begin the first year. It is difficult to predict how long updating antiquated data will take, if it takes less time and money than allotted in the budget, then these funds can support other priority projects at Rocky Mountain National Park. The details of this project and how they will be carried out are described below.

IV.C.4. Inventory Projects

Given the funding available to the Rocky Mountain Network, support and implementation of all priority inventory projects in Rocky Mountain National Park is impossible. The desired projects are listed below with indication of the Networks intention to carry out given current funding situation. Less detail on plans for implementation, methods, and schedule is provided for projects that will not be funded given resources currently available to the Rocky Mountain Network.

IV.C.4.a. *Data Modernization and Synthesis (funded)*

Implementation and Cooperation:

Rocky Mountain National Park will divide resources for this initiative among three main categories: Support for existing data management programs (e.g. extending seasonal employees), coordinating with subject experts (i.e. Denver Botanic Gardens), and working with a centralized inventory program at CSU to provide synthesis, modeling and assessment of completeness.

Methods:

The process of updating antiquated data at Rocky Mountain National Park will involve interviewing scientists, meeting with resource managers, processing and analyzing existing data files and documenting collections. Evaluating data quality will be essential as some existing information may not merit effort of modernization for inventory and monitoring purposes.

Data managers and technicians will convert data from previous and ongoing projects by electronic transfer and manual entry into NPS databases. The GIS Data Browser is a relational database that makes a diversity of information easily accessible and functional, allowing managers to view metadata in a spatial context. The data will also be entered to update other NPS inventory databases, NPSpecies, NRBibliography, and Dataset Catalog. This information will allow for assessment of completeness as well as distribution and abundance of species of concern.

Schedule:

The process of updating antiquated data will be an iterative process. Rocky Mountain National Park chooses not to hire a full time employee just dedicated to updating data as they are not sure how long the process will take, it will become clear with progress. The process is estimated to take approximately two years of part to full time effort. If the data management is completed before the summer field season of FY03, Rocky Mountain National Park will be able to dedicate funds to other unfunded priority projects.

IV.C.4.b. Distribution and Abundance of Plants of Concern (funded)

Goals and Objectives:

Existing plant information should be formatted for use within three main categories:

1. Abundance and distribution of rare or threatened and endangered plant species
2. Current and potential distributions and abundance of exotic invasive plant species
3. Abundance and distribution of plant species as they define habitats of concern (e.g. rare plant associations, also in relation to other taxa of concern)

Implementation and Cooperation:

Rocky Mountain National Park staff will organize this project by carrying out necessary fieldwork and organizing cooperative efforts with the Denver Botanical Garden and groups from Colorado State University.

Field Methods:

Steps to achieve the listed goals and objectives:

1. Combine databases with location information (e.g., Landscape-scale Gap Analysis Project and the Denver Botanical Garden).
2. Map the known distributions of all prioritized species of concern.
3. Conduct correlation analyses and develop spatial models (when enough data exist) to

predict additional locations.

4. Ground-truth at randomly selected points to test predictive distribution models and assess completeness.
5. Prioritize species and habitats of concern for new, focused sampling based on results from 3 and 4.

IV.C.4.c. *Bird Distribution and Abundance (not funded)*
(current project led by Tasha Kotliar USGS-BRD and Jeff Connor ROMO)

The long-term bird data that already exist for ROMO still require:

1. Development of an effective monitoring program that accounts for detectability, particularly in alpine, subalpine, riparian, and lakeshore habitats.
2. Distribution and abundance information for owls and raptors.

IV.C.4.c. *Mammal Distribution and Abundance (not funded)*

Priorities for mammal inventory include:

1. Systematic survey for bats.
2. Distribution and abundance of lynx, wolverine, and American marten.
3. Distribution of mountain lion and black bear in relation to visitor use.
4. Distribution and abundance of beaver, moose, elk and deer in relation to effects on woody vegetation.
5. Distribution and abundance of introduced mountain goats in relation to effects on the native vegetation of the alpine tundra.

IV.C.4.d. *Inventory Fish Genetic Diversity (not directly funded)*

1. Augment fish species documentation with available genetic information (e.g. on cutthroat hybridization).
2. Map the distribution of sculpin and cutthroat trout in aquatic environments in the Park.

IV.C.5. Principal Investigators and Key Personnel

Terry Terrel, RMNP Research Coordinator

Ken Czarnowski, and ROMO personnel

Tom Stohlgren, Geneva Chong, USGS-BRD and NREL ecologists

IV.C.6. Budget

The budget appears on the following page.

Project 3 budget.

Project 3: Conversion of Existing Data to Modern Formats and Special Concern Inventory Projects at ROMO															PROJECT 3 TOTALS			
Project Component	Data Management in ROMO				Data Management in ROMO				Data Management in ROMO									
Principal Investigator	T. Terrel				T. Terrel				T. Terrel									
Fiscal Year/Total	FY01				FY02				FY03				FY04					
Data Techs / GIS		\$	20,000.00			\$	15,000.00				\$	15,000.00					\$	50,000.00
Research Contracts		\$	10,000.00			\$	10,000.00				\$	10,000.00					\$	30,000.00
Benefits		\$	3,600.00			\$	5,400.00				\$	4,500.00					\$	13,500.00
Travel		\$	3,000.00			\$	2,000.00				\$	2,000.00					\$	7,000.00
Workshop Training		\$	3,000.00			\$	2,500.00										\$	5,500.00
Supplies		\$	1,000.00			\$	1,000.00				\$	1,000.00					\$	3,000.00
Equipment		\$	5,000.00														\$	5,000.00
TOTAL		\$	45,600.00			\$	35,900.00				\$	32,500.00					\$	114,000.00

IV.D. Project Statement 4

Conversion of Existing Data to Modern Formats and Assessment of Species of Concern In Glacier National Park

IV.D.1. Problem statement

Although inventories are at 90% for most vertebrate animal and vascular plant taxa in Glacier National Park, much existing information and associated documentation is not in an accessible format for Park managers and therefore not suitable for future monitoring.

IV.D.2. Objectives

Improve the condition and accessibility of previously collected inventory data at Glacier National Park. Assess the distribution and abundance of species of concern to develop an effective monitoring program that reflects specific park threats and resource issues.

IV.D.3. FY01 Funded Project

The data management and updating inventory tasks that exist at Glacier National Park mandate that the project begin the first year. It is difficult to predict how long updating antiquated data will take, if it takes less time and money than allotted in the budget, then these funds can support other priority projects at Glacier National Park. The details of this project and how they will be carried out are described below.

IV.D.4. Inventory Projects

The highest priority for inventory identified by managers at Glacier National Park involves conversion of an abundance of inaccessible data into modern, standardized formats. This will provide the baseline information needed to develop a sensitive and informative monitoring program. Several field inventory projects have also been identified as important and pressing issues that would add great value and effectiveness to the future monitoring effort.

IV.D.4.a. *Data Modernization and Synthesis (funded)*

Implementation and Cooperation:

Glacier National Park will hire a term employee that will work at the Park to develop and update data into useable formats.

Methods:

The process of updating antiquated data will involve considerable time talking with resource managers at Glacier National Park, investigating data files, and evaluating data quality; some data may not be useful for inventory and monitoring purposes and therefore not merit effort of modernization.

The data manager will convert existing data files either by electronic transfer or manual entry into Microsoft Access databases. The primary database that makes the data functional is the GIS Data Browser. This database makes the information easily accessible and incorporates it directly into a medium that allows managers to view it in a spatial context. The data will also be entered into other NPS inventory databases, NPSpecies, NRBibliography, and the Data Set Catalog. The inventory will also document the data with metadata.

Schedule:

The data manager will first cooperate with various staff and scientists to complete the substantial remaining tasks to update Dataset Catalog and NRBibliography.

IV.D.4.b. *Distribution and Abundance of Plant Species of Concern (not funded)*

Priority inventory projects for vascular plants fall in two main categories:

1. Understanding abundance and current and potential distributions of invasive plant species. Estimated cost: \$25,000/year for two years.
2. Understanding abundance and distribution of plant species as they define habitats of concern such as wetland fens. Estimated cost: \$30,000/year for two years.

Implementation and Cooperation:

Tara Williams and seasonal employees have worked with researchers to conduct a variety of botanical surveys in Glacier National Park. Integrating this project with other ongoing vegetation projects may allow opportunities for high priority inventory projects to be completed.

Methods:

1. Assess existing data and compile databases of location information related to priority projects:
 - Noxious weed distribution
 - Wetlands, fens, rare plant surveys (for locations)
2. Map the known distributions of all prioritized species and habitats of concern that have sufficient data (from 1).
3. Conduct correlation analyses and develop spatial models (when enough data exist) to predict likely locations. Include use of satellite imagery.
4. Ground-truth randomly selected points to test spatial models (from 3).
5. Prioritize species and habitats of concern for new sampling based on results from the previous steps.

IV.D.4.c. *Mammal Species of Concern (not funded)*

Distribution of forest carnivores – Continue track surveys to determine the distribution of lynx, wolverine, American marten, and fisher utilizing standardized methodology. Coordinate with existing programs (e.g. Grizzly Bears and Lynx, Kate Kendall USGS-BRD) to document mid-sized carnivores, especially in N and mid Fork. Estimated cost: \$30,000/year for two years.

Distribution of bat species in selected habitats – Expand inventories to determine species and habitat utilization, particularly in developed areas. Estimated cost: \$20,000/year for two years.

IV.D.4.d. *Fish Species of Concern (not funded)*

Status, trend and distribution of fish in selected lakes, including genetic analysis – Focus on bull trout and west-slope cutthroat. Estimated cost: \$50,000/year for two years.

IV.D.4.e. *Amphibians (not funded)*

Coordinate fully with ARMI to integrate existing and new information in mapping and modeling amphibian distribution and abundance. Coordinate with fisheries personnel to document distribution of tailed river frog adults and larvae.

IV.D.4.f. *Birds (not funded)*

Coordination with Colorado Bird Observatory and partner organizations and agencies to participate in Montana statewide songbird surveys - Historic bird data will be assessed and incorporated with ongoing surveys that effectively account for detectability using distance sampling. Results will guide future monitoring efforts. Estimated cost: \$30,000/year for two years.

Distribution of raptors and owls – Species occurrence and nesting, particularly near developed areas. Estimated cost: \$40,000/year for two years.

IV.D.5. Products and Deliverables

1. Annual reports and updated NPS databases.
2. Distribution maps and predictive models for distribution and abundance.
3. Assessment of existing inventories to guide future monitoring.

IV.D.6. Coordination and Logistics

Park personnel and cooperators will coordinate with the appropriate experts and research groups to update the backlog of information needed to address inventory goals and address management concerns.

IV.D.7. Budget

The budget for project 4, itemized by fiscal year and data management, is outlined on the following page.

Project 4 budget.

Project 4: Conversion of Existing Data to Modern Formats and Species of Concern Inventory Projects at GLAC															PROJECT 4 TOTALS			
Project Component		Data Management in GLAC				Data Management in GLAC				Data Management in GLAC								
Principal Investigator		T. Williams / J. Potter				T. Williams / J. Potter				T. Williams / J. Potter								
Fiscal Year/Total		FY01				FY02				FY03				FY04				
Data Manager		\$	35,000.00			\$	35,000.00										\$	70,000.00
Field Biologists / GIS Managers		\$	5,000.00			\$	5,000.00										\$	10,000.00
Benefits @ 30%		\$	12,000.00			\$	12,000.00										\$	24,000.00
Travel		\$	3,000.00			\$	2,000.00			\$	1,000.00						\$	6,000.00
Supplies		\$	1,000.00			\$	1,000.00			\$	1,000.00						\$	3,000.00
Equipment		\$	5,000.00														\$	5,000.00
TOTAL		\$	61,000.00			\$	55,000.00			\$	2,000.00						\$	118,000.00

IV.E. Project Statement 5

Management, Modeling and Synthesis of Collected and Existing Data: Iterative analysis and presentation of informative management tools based on multiple biological groups

IV.E.1. Problem Statement

Data collected or updated in other inventory projects requires management, analysis and synthesis to guide further cost effective inventory, management, and future monitoring efforts.

IV.E.2. Objectives

Extensive data on multiple biological groups will be collected at FLFO, GKO, GRSA, and LIBI. This data will be modeled, managed, synthesized and returned to the Park units in a useful and informative form. Both GLAC and ROMO will have an abundance of newly formatted data that may require modeling and will be used to direct inventory efforts focused on species of concern. The goals of this project will be to:

1. Model completeness of spatial distribution and abundance, and assess the completeness of biotic inventories.
2. Develop spatial models of species of concern.
3. Prepare a state of the network report based on information collected that will also support the impending monitoring effort.

IV.E.3. FY01 Funded Project

This project provides the glue of the Rocky Mountain Inventory. This project funds a leader that coordinates cooperators for projects 1 and 2. Individuals associated with this project also facilitate the progression of the inventory in the iterative sense. The preparation of sample design, data entry, data assessment of species completeness, and spatial modeling of a combination of both new and old data. This project needs to be funded for some of the projects to be initiated. This project provides the synthesis and reporting that generates information that guides management of land in a useful and scientifically sound way.

IV.E.4. Field Inventory Data Collected on Multiple Biological Groups at FLFO, GRKO, GRSA, and LIBI

Data from the multiple biological inventories will be collected in centralized databases early and often to assure quality control, to update data management tools, and to allow for the continued reassessment of inventory completeness and distribution, abundance, and cover in an iterative and cost efficient manner. The data will be collected in centralized databases at the Natural Resource Ecology Laboratory.

New species information will be entered into the NPSpecies database. Field data, collected electronically on palm top computers, will be transferred directly into an Access database using software (Plot View) developed specifically for the purpose by Pacific Meridian Resources. This streamlined data management system has been tested effectively implemented for rapid assessment plant inventories at the Natural Resource Ecology Lab for several years. Once in the Access database, this data will be integrated into the GIS Data Browser that allows

for easy display of the various taxa and how they relate to one another in a spatial context. The tool could help further define habitats of concern and facilitate management decisions.

The data will be frequently assessed for completeness both in distribution and in relation to the goal of 90% completeness. After periods of investigation at a park on specific taxa, the data will be integrated into models using spatial and geostatistics. These models, outlined in detail in the data management section, have the ability incorporate field data with satellite imagery to model fine scale variability of species across a landscape. Products include detailed distribution maps and maps of abundance of both native and exotic species. Each cell in the predictive model has an error bar associated with it that provides an estimation of the spatial confidence of the map at each location. When incorporated iteratively with inventory sampling efforts, output from these models can be integrated with the sampling design to direct field efforts to regions where more knowledge will be most useful and where further investigation is likely to reveal a greater proportion of new species.

Assessment of the degree of completeness will also occur in an iterative manner. By using models that plot the number of species obtained in surveys against time or sample effort, results can be translated into an estimate of the percent of species detected. These estimates will also incorporate previously identified species in respective park units. Furthermore, a cost evaluation can estimate the costs associated with sampling for new species. These tools are outlined in detail in the data management methods section. This tool can facilitate decisions regarding the need to continue to sample for new species, or perhaps to shift a focus species of concern or even to signal when a sampling effort is complete.

IV.E.4.a. *Previously Collected Data*

These parks will also need to continue to have data previously collected data entered in National Park Service data bases that will make this data more accessible to managers. A good deal of this has already occurred during the preproposal phase but will need to continue. This will be part of the responsibility of the data managers associated with project 5.

IV.E.5. Analysis of Percent Completeness and Spatial Modeling of Species of Concern at GLAC and ROMO

GLAC and ROMO will have a data manager not only working to modernize antiquated data, but also handling data collected on species of concern. However, assistance will be required for evaluating inventory completeness and developing distribution and abundance maps for species of concern.

Both GLAC and ROMO have a list of species of concern that will require extra sampling to obtain data suitable for monitoring and to fill holes in data inventories. These efforts will benefit from modeling prior to the actual field inventories. The development of spatial models based on existing data will direct the effort to areas of greater uncertainty, perhaps where little data has been collected on a species of concern because it may be an inaccessible location. The inventory effort may also be directed to regions where abundance or cover data are uncertain due to a lack of quantitative effort in that area. Like the efforts in the other four parks modeling efforts will continue to interact with the collection of field data and sample design to refine the effort and to obtain the best coverage of data possible.

To conduct spatial modeling of species of concern, available data will be transferred from

the onsite park data manager to data managers on site at NREL. The data will be analyzed and modeled. Distribution and associated abundance maps with recommendations for further sampling will be returned to both GLAC and ROMO to guide sampling of species and habitats of concern.

As in the modeling of data in the four other park units, the process will occur iteratively with the actual data collection. The data that is collected after the first round of inventory will be used to improve and test the model, as well as direct the next round of sampling. This data will also be used to evaluate the completeness of previous species lists. These data will be collected in a variety of habitats, mainly focused on rare and vulnerable habitats. Many of the methods, although focusing on a particular species or a group of species will also produce data on other species encountered. The lists generated from these investigations will be compared as independent data to assess completeness by comparison. If new species are detected a species list may not be at 90% as previously thought. Lists not exposed to comparative sampling may also be evaluated by plotting effort or time against collection history to evaluate completeness.

IV.E. 6. Products: Data Synthesis, Presentation and Inventory Report

The goal of the inventory is to provide managers with information, and tools to extract information from data that will assist management and create a platform from which to launch a monitoring program. A majority of the inventory practices that take place at GLAC and ROMO will already be in the hands of managers, it will be the responsibility of the data manager to provide decision makers with the information and tools such as a functioning GIS Data Browser. NREL, as part of the iterative process, will supply refined predictive distribution and abundance maps to both Parks.

As mentioned, data from the comprehensive inventories collected at FLFO, GRKO, GRSA, and LIBI will be housed and manipulated at NREL. As products such as distribution maps are developed they will not only be used to guide inventories, but they will be distributed to managers to be immediately available to management. With the completion of the inventory, the data and the tools to manage and continue to evaluate the data such as the GIS Data Browser will be turned over to the Park units so that the information can be used to make decisions regarding management of natural resources.

In addition to providing the Park units with products derived from the data collected, NREL will draft a summary report, “the state of the Rocky Mountain Network.” This will incorporate the results and conclusions from efforts in the larger, data rich parks and the inventory work at the smaller parks. The report will include the results of the alterations that were made as dictated by the feedback from the iterative process, species lists, and final distribution and abundance maps. The status of species and habitats of concern, and the common links between the parks will be stressed in the report. In this way the report will serve as a primary reference and baseline for the impending monitoring effort.

IV.E.7. Schedule

Annual reports and database updates will be completed and summarized in a final report that assesses “the state of the Rocky Mountain Network.” The iterative nature of the inventory makes the specific schedule for developing the spatial models difficult to define. For FLFO, GRKO, GRSA, and LIBI, the first round will occur after the initial inventory effort, or prior to initiating the effort if data exists that can be utilized in the model. The number of iterations

required to accurately describe the resources and obtain detailed information on species of concern, and thus the modeling and completeness repetitions, will depend on the effectiveness of the sampling and the richness and distribution of species at each unit.

The exact timing of modeling of distribution of species of concern at both ROMO and GLAC will depend on the status of the data, and effort required for conversion into the Access and Arcview databases. Here too, the modeling process will be repetitious.

IV.E.8. Principal Investigators and Key Personnel

Tom Stohlgren- USGS/ BRD and Natural Resource Ecology Laboratory, Colorado State University

Barry Noon- Department of Fishery and Wildlife Biology, Colorado State University

Robin Reich- Department of Forestry, Colorado State University

Mohammed Kalkhan- Natural Resource Ecology Laboratory, Colorado State University

IV.E.9. Budget

The budget for project 5, itemized by fiscal year appears on the following page.

Project 5: Management, Modeling, and Synthesis of Existing Data																		
Project Component	Data Analysis, RMN Coordination				Data Analysis, RMN Coordination				Data Analysis, RMN Coordination									
Principal Investigator	T. Stohlgren / B. R. Noon				T. Stohlgren / B. R. Noon				T. Stohlgren / B. R. Noon									
Fiscal Year/Total	FY01				FY02				FY03				FY04					
Leader		\$	21,000.00			\$	21,000.00			\$	21,000.00			\$	21,000.00		\$	84,000.00
GIS/datamgt		\$	6,000.00			\$	6,000.00			\$	6,000.00			\$	6,000.00		\$	24,000.00
Noon and Reich		\$	13,500.00			\$	13,500.00			\$	13,500.00			\$	13,500.00		\$	54,000.00
Benefits		\$	4,860.00			\$	4,860.00			\$	4,860.00			\$	4,860.00		\$	19,440.00
Travel		\$	1,875.00			\$	1,875.00			\$	1,875.00			\$	1,875.00		\$	7,500.00
Supplies		\$	750.00			\$	750.00			\$	750.00			\$	750.00		\$	3,000.00
Equipment																		
Overhead		\$	7,197.75			\$	7,197.75			\$	7,197.75			\$	7,197.75		\$	28,791.00
TOTAL		\$	55,182.75			\$	55,182.75			\$	55,182.75			\$	55,182.75		\$	220,731.00

V. TOTAL BUDGET

The budget includes an overall summary, as well as fiscal year totals for all projects including field components. Itemized budgets are provided for five priority Project Statements over four fiscal years. Project 1 includes priority fieldwork and information management for terrestrial habitats at FLFO, GRKO, GRSA, and LIBI. Project 2 follows with priority fieldwork in aquatic habitats in these parks, as well as continuing data management for both aquatic and terrestrial sampling efforts. Projects 3 and 4 address pressing data management needs for ROMO and GLAC, respectively. Data management for efficient information transfer is included within each project, although project 5 will be an essential component of data synthesis, assessment of completeness and efficient coordination for the network. Continuity for this project will also provide the training and integration needed by managers to maintain and use the NPS databases.

Detailed study plans are included for FY1 funded field and data management inventory project statements. The proposed Principle Investigators have been identified as the most qualified subject experts and parks personnel to efficiently coordinate the proposed work. Implementation will depend on commitment of funds and will be subject to change based on future availability of individuals and justification for alternatives. The network Steering Committee and cooperators will develop detailed task agreements based on the funding allotted.

The proposed budget reflects coordinated efforts that are funded in part by other programs. Vascular plant work is partially subsidized by ongoing projects on invasive species (USGS-BRD, Stohlgren). Amphibian work as proposed is subsidized to a great extent by nationwide and regional amphibian monitoring efforts (Corn and Muths). Bat survey equipment and expertise is contributed by Tom O'Shea (USGS-BRD). The design of modern data management and synthesis capabilities is well under way at CSU, gaining expertise through other funded projects by National Parks Conservation Association and the Forest Health Monitoring Program (USDA). Opportunities exist for linking datasets at park, network, agency and national levels. If alternate investigators are selected for work these benefits will no longer be included.

Project 1: Augmentation and Assessment of Terrestrial Habitats in FLFO, GRSA, GRKO, and LIBI					
Fiscal Year/Total	FY01	FY02	FY03	FY04	total
Vegetation Component	\$ 18,103.05	\$ 17,641.90	\$ 2,354.05	\$ -	\$ 38,098.99
Mammals Component	\$ 13,569.45	\$ 13,108.30	\$ 382.95	\$ -	\$ 27,060.70
Bird Component	\$ 13,569.45	\$ 13,108.30	\$ 382.95	\$ -	\$ 27,060.70
Project Management	\$ 24,426.00	\$ 24,426.00	\$ -	\$ -	\$ 48,852.00
PROJECT 1 TOTALS	\$ 69,667.94	\$ 68,284.49	\$ 3,119.95	\$ -	\$ 141,072.39
Project 2: Augmentation and Assessment of Aquatic Habitats in FLFO, GRSA, GRKO, and LIBI					
Fiscal Year/Total	FY01	FY02	FY03	FY04	total
AMPHIBIAN TOTAL	\$ -	\$ -	\$ 10,000.00	\$ 10,000.00	\$ 20,000.00
FISH TOTAL	\$ -	\$ -	\$ 19,642.00	\$ 19,642.00	\$ 39,284.00
BATS TOTAL	\$ -	\$ -	\$ 13,332.89	\$ 13,332.89	\$ 26,665.79
Project management	\$ -	\$ -	\$ 24,426.00	\$ 24,426.00	\$ 48,852.00
PROJECT 2 TOTALS	\$ -	\$ -	\$ 67,400.89	\$ 67,400.89	\$ 134,801.78
Project 3: Conversion of Existing Data to Modern Formats and Special Concern Inventory Projects at ROMO					
Fiscal Year/Total	FY01	FY02	FY03	FY04	Total
PROJECT 3 TOTALS	\$ 45,600.00	\$ 35,900.00	\$ 32,500.00	\$ -	\$ 114,000.00
Project 4: Conversion of Existing Data to Modern Formats and Species of Concern Inventory Projects at GLAC					
Fiscal Year/Total	FY01	FY02	FY03	FY04	Total
PROJECT 4 TOTALS	\$ 61,000.00	\$ 55,000.00	\$ 2,000.00	\$ -	\$ 118,000.00
Project 5: Management, Modeling, and Synthesis of Existing Data					
Fiscal Year/Total	FY01	FY02	FY03	FY04	Total
PROJECT 5 TOTAL	\$ 55,182.75	\$ 55,182.75	\$ 55,182.75	\$ 55,182.75	\$ 220,731.00
GRAND TOTALS	\$ 231,450.69	\$ 214,367.24	\$ 160,203.59	\$ 122,583.64	\$ 728,605.17

References: (incomplete)

- Barnett, D. and T. J. Stohlgren. 1999. Aspen regeneration in southeast Greater Yellowstone Ecosystem. *Landscape Ecology* (Draft Manuscript).
- Baker, F.S. 1925. Aspen in the central Rocky Mountain region. Bulletin No. 1291, U.S. Department of Agriculture, Washington, D.C.
- Bonham, C.D., R.M. Reich, and K.K. Leader. 1995. A spatial cross-correlation of *Bouteloua gracilis* with site factors. *Grasslands Science* 41:196-201.
- Boulinier, T., J.D. Nichols, J.R. Sauer, J.E. Hines, and K.H. Pollock. 1998. Estimating species richness: the importance of heterogeneity in species detectability. *Ecology* 79:1018-1028.
- Burnham, K.P., and W.S. Overton. 1979. Robust estimation of population size when capture probabilities vary among individuals. *Ecology* 60:927-936
- Burnham, K.P. and E.A. Rexstad. 1991. Modeling heterogeneity in survival rates of banded waterfowl. *Biometrics* 49:1194-1208.
- Bull, K., K. Stolte, and T. Stohlgren. 1998. 1998 Guidelines for Forest Health Monitoring. USDA Forest Service, Washington, D.C.
- Bunge, J., and M. Fitzpatrick. 1993. *Journal of the American Statistical Association* 88(421): 364-373.
- Bury, R.B. and P.S. Corn 1991. Sampling Methods for Amphibians in Streams in the Pacific Northwest. USDA/USFS Pacific Northwest Research Station. Portland, Oregon. PNW-GTR-275.
- Chong, G.W., R.M. Reich, M.A. Kalkhan, and T.J. Stohlgren. 1999. New approaches for sampling and modeling native and exotic plant species richness. ?????
- Crump, M.L. and N.J. Scott. 1994. Inventory and Monitoring: Visual Encounter Surveys. Pp 84-91. In Heyer et al. eds. *Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians*. Smithsonian Institution Press, Washington, D.C.
- Czaplewski, R.L. and R.M. Reich. 1993. Expected value and variance of Moran's bivariate spatial autocorrelation statistic under permutation. Research Paper RM-309. U.S. Department of Agriculture, Rocky Mountain Experimental Range Station, Fort Collins, CO.
- Dallmeier, F. 1992, (ed.). Long-term Monitoring of Biological Diversity in Tropical Forest Areas: Methods For Establishment and Inventory of Permanent Plots. MAB Digest 11. United Nations Educational, Scientific, and Cultural Organization (UNESCO), Paris, France.
- Davis, G.E. . Measuring and monitoring biodiversity for conservation science and adaptive management-Smithsonian Institution. U.S. National Park Service, Ventura California.
- ESRI. 1997. Environmental Systems Research Institute, Inc. 380 New York St., Redlands, CA 97373 USA.
- Daubenmire, R.F. 1959. Canopy coverage method of vegetation analysis. *Northwest Science*. 33:43-46.
- Falkner, M.B., and T.J. Stohlgren. 1997. Evaluating the contribution of small parks to regional biodiversity. *Natural Areas Journal* 17:324-330.
- Fancy, S. G. 1997. A new approach for analyzing bird densities from variable circular-plot

- counts. *Pacific Science* 51:107-114.
- Fancy, S.G., and J. R. Sauer. 2000. Recommended methods for inventorying and monitoring landbirds in National Parks. Unpublished report.
- Fausch, K.D., and K.R. Bestgen. 1999. Why and how to collect high-quality data on plains stream fishes. Colorado Water???
- Fellers, G.M. and K.L. Freel 1995. A Standardized Protocol for Surveying Aquatic Amphibians. US Department of the Interior, National Park Service, Western Region Cooperative Studies Unit, University of California, Davis, CA. GTR-NPS/WRUC/NRTR-95-01.
- Franklin, J.F., C.S. Bledsoe, and J.T. Callahan. 1990, Contributions of the Long-Term Ecological Research Program. *BioScience*. 40. 509-523.
- Franklin, J.F., and D.S. DeBell. 1988. Thirty-six years of tree population change in an old-growth *Pseudotsuga-Tsuga* forest. *Canada Journal Forest Restoration*. 18:633-639.
- Fritts, H.C. 1976. *Tree-Rings and Climate*. Academic Press, New York, NY.
- Gown, S.N., R.H. Waring, D.G. Dye, and J. Yang. 1994. Ecological remote sensing at OTTER: Satellite Macroscale Observation. *Ecological Applications* 4:322-343.
- Hansen, A.J. and F. di Castri (eds.). 1993. *Landscape boundaries*. Springer-Verlag, New York, NY.
- Harwell, M.A., V. Meyers, T. Young, A. Bartuska, N. Gassman, J.H. Gentile, C.C. Harwell, S. Appelbaum, J. Barko, B. Causey, C. Johnson, A. McLean, R. Smola, P. Templet, and S. Tosini. 1999. A framework for an ecosystem integrity report card: Examples from South Florida show how an ecosystem report card links societal values and scientific information. *Bioscience* 49(7): 543-556.
- Hawk, G.M., J.F. Franklin, W.A. McKee, and R.B. Brown. 1978. H.J. Andrews Experimental Forest reference stand system: establish and use history. USDA Forest Service Bulletin 12. U.S. International Biosphere Program.
- Heyer, W.R., Donnelly, M.A., McDiramid R.W., Hayek, L.C. and M.S. Foster. 1994. *Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians*. Smithsonian Institution Press, Washington, D.C.
- Hinds, W.T.: 1984. Towards monitoring of long-term trends in terrestrial ecosystems. *Environmental Conservation*. 11:11-18.
- Hines, J.E., T. Boulinier, J.D. Nichols, J.R. Sauer, and K.H. Pollock. 1999. COMDYN: software to study the dynamics of animal communities using a capture-recapture approach. *Bird Study* 46 (suppl.): S209-217.
- Holland, M.M., P.G. Risser, and R.J. Naiman (Eds.). 1991. *Ecotones*. Chapman and Hall, New York, NY. 142 p.
- Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. *Ecological Monographs*. 54:187-211.
- Isaaks, E.H. and R.M. Srivastava. 1989. *An introduction to applied geostatistics*. Oxford University Press, New York, NY.
- Kalkhan, M. A., R.M. Reich, and T. J. Stohlgren. 1998. Assessing the accuracy of Landsat Thematic Mapper classification using double sampling. *International Journal of Remote Sensing* 19: 2049-2060.
- Kalkhan, M. A. and T. J. Stohlgren. 1999. Using spatial cross-correlation to assess patterns of plant diversity and species richness. *Environmental Monitoring and Assessment* (In Press).

- Kallas, M. 1997. Hazard rating of *Armillaria* root rot on the Black Hills National Forest. Masters thesis, Dept. of Forest Sciences, Colorado State University, Fort Collins, CO.
- Keating, K.A., J.F. Quinn, M.A. Ivie, and L.L. Ivie. 1998. Ecological Applications 8(4): 1239-1249.
- Krebill, R. G. 1972. Mortality of aspen on the Gros Ventre winter range. USDA Forest Service Research Paper INT-129, Ogden, Utah, 16p.
- Krebs, C.J. 1989. Ecological Methodology. Harper & Row, New York, NY.
- Labbe, T.R., and K.D. Fausch. 1999. Dynamics of intermittent stream habitat regulate persistence of a threatened fish at multiple scales. Ecological Applications (In Press).
- Levin, S.A. 1992. The problem of pattern and scale in ecology. Ecology. 73:1943-1967.
- Likens, G.E., F.H. Bormann, R.S. Pierce, and J.S. Eaton. 1985. The Hubbard Brook Valley, an ecosystem approach to aquatic ecology: Mirror Lake and its environment. (G.E. Likens, ed). Springer-Verlag, New York Inc., New York, pp. 9-39.
- Lint, J., B.R. Noon, R. Anthony, E. Forsman, M. Raphael, M. Collopy, and E. Starkey. 1999. Northern spotted owl effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-440. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 43p.
- Lohr, S.C., and K. D. Fausch. 1997. Multiscale analysis of Natural Variability in Stream Fish Assemblages of a Western Great Plains watershed. Copeia 4:706-724.
- Metzger, K. 1997. Modeling small-scale spatial variability in stand structure using remote sensing and field data. Masters thesis, Dept. of Forest Sciences, Colorado State University, Fort Collins, CO.
- Mulder, B.S., B.R. Noon, T.A. Spies, M.G. Raphael, C.J. Palmer, A.R. Olsen, G.H. Reeves, H.H. Welsh. The strategy and design of the effectiveness monitoring program for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-437. 1999. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 138 p.
- Nichols, J.D., T. Boulonier, J.E. Hines, K.H. pollock, and J.R. Sauer. 1998. Estimating rates of local species extinction, colonization, and turnover in animal communities. Ecological Applications 8:1213-1225.
- Nichols, J.D., and M.J. Conroy. 1996. Estimation of species richness. Pages 226-234 in D.E. Wilson, F.R. Cole, J.D. Nichols, R. Rudran, and M. Foster, editors. Measuring and monitoring biological diversity. Standard methods for mammals. Smithsonian Institution Press, Washington, DC.
- Noon, B.R., T.A. Spies, and M.G. Raphael. 1999. Chapter 2: Conceptual basis for designing an effectiveness monitoring program *In*: The strategy and design of the effectiveness monitoring program for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-437. 1999. Mulder, B.S., B.R. Noon, T.A. Spies, M.G. Raphael, C.J. Palmer, A.R. Olsen, G.H. Reeves, H.H. Welsh. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 138 p.
- Otis, D.L., K.P. Burnham, G.C. White, and D.R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monograph 62.
- Overlin, A., G.W. Chong, T.J. Stohlgren, and J. Rodgers. 1999. Monitoring vegetation and soil crusts in areas used by climbers: an example from Joshua Tree National Park, California, USA. *Environmental Management*. (Draft Manuscript).
- Palmer, M.W. 1993. Potential biases in site and species selection for ecological monitoring.

- Environmental Monitoring and Assessment. 26. 277-282.
- Parker, K.W. 1951. A method for measuring trend in range condition in National Forest Ranges. USDA Forest Service, Washington, D.C., USA.
- Pickett, S.T.A. 1989. Space-for-time substitution as an alternative to long-term studies. In: G.E. Likens (ed.). Long-term Studies in Ecology: Approaches and Alternatives. Springer-Verlag, New York, NY, pp. 110-135.
- Peterson, D.L., D.G. Silsbee, and D.L. Schmoltdt. 1995. A planning approach for developing inventory and monitoring programs in national parks. U.S. National Park Service, Natural Resources Report NPS/NRUW/NRR-95/16.
- Preston, F.W. 1948. The commonness, and rarity, of species. *Ecology* 29:254-283.
- Ralph, C.J., G.R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook of field methods for monitoring landbirds. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR144.
- Reich, R.M. and V.A. Bravo. 1998. Integrating spatial statistics with GIS and remote sensing in designing multi-resource inventories. Proceedings of the North American Symposium Toward a Unified Framework for Inventorying and Monitoring Forest Ecosystem Resources, Guadalajara, Mexico.
- Reich, R.M., R.L. Czaplewski, and W.A. Bechtold. 1994. Spatial cross-correlation in growth of undisturbed natural shortleaf pine stands in northern Georgia. *Journal of Environmental and Ecological Statistics* 1:201-217.
- Riegel, G.M., S.E. Green, M.E. Harmon, and J.F. Franklin. 1988. Characteristics of mixed conifer forest reference stands at Sequoia National Park, California. USDI National Park Service CPSU Technical Report No. 32. University of California, Davis, CA.
- Robertson, G.P. 1987. Geostatistics in ecology: interpolating with known variance. *Ecology* 68:744-748.
- Rosenlund, B.D., C. Hudson, and T. Johnson. 1996. Occurrence of *Myxobolus cerebralis* and changes in distribution of fish species within Rocky Mountain National Park. Proceedings of Whirling Disease Workshop, Denver, CO.
- Shampine, W.J. 1993. Quality assurance and quality control in monitoring programs. *Environmental Monitoring and Assessment*. 26. 143-151.
- Silsbee, D.G., and D.L. Peterson. 1991. Design and Implementing comprehensive long-term inventory and monitoring programs for national park system lands. U.S. National Park Service, Natural Resources Report NPS/NRUW/NRR-91/04.
- Stafford, S.G. 1993. Data, data everywhere but not a byte to read: managing monitoring information. *Environmental Monitoring and Assessment*. 26. 125-141.
- Stohlgren, T.J. 1994. Planning Long-Term Vegetation Studies at Landscape Scales. Pages 209-241 in: *Ecological Time Series*. J.H. Steele and T.M. Powell (eds). Chapman and Hall, NY.
- Stohlgren, T.J., D. Binkley, T.T. Veblen, and W.L. Baker. 1995a. Attributes of Reliable Long-Term Landscape-Scale Studies: Malpractice Insurance for Landscape Ecologists. *Environmental Monitoring and Assessment* 36:1-25
- Stohlgren, T.J., M.B. Falkner, and L.D. Schell. 1995b. A Modified-Whittaker nested vegetation sampling method. *Vegetatio* 117:113-121.
- Stohlgren, T. J., G. W. Chong, M. A. Kalkhan, and L. D. Schell. 1997a. Rapid assessment of plant diversity patterns: A methodology for landscapes. *Environmental Monitoring and*

- Assessment* 48: 25-43.
- Stohlgren, T. J., M. B. Coughenour, G. W. Chong, D. Binkley, M. Kalkhan, L. D. Schell, D. Buckley, and J. Berry. 1997b. Landscape analysis of plant diversity. *Landscape Ecology* 12: 155-170.
- Stohlgren, T. J., G. W. Chong, M. A. Kalkhan, and L. D. Schell. 1997c. Multi-scale sampling of plant diversity: Effects of minimum mapping unit size. *Ecological Applications* 7:1064-1074.
- Stohlgren, T. J., K. A. Bull, Y. Otsuki. 1998a. Comparison of rangeland vegetation sampling techniques in the Central Grasslands. *Journal of Range Management* 51:164-172.
- Stohlgren, T.J., T. N. Chase, R.A. Pielke, T.G. F. Kittel, and J. Baron. 1998b. Evidence that local land use practices influence regional climate, vegetation, and stream flow patterns in adjacent natural areas. *Global Change Biology* 4:495-504.
- Stohlgren, T.J., K.A. Bull, Y. Otsuki, C. Villa, and M. Lee. 1998c. Riparian zones as havens for exotic plant species in the central grasslands. *Plant Ecology* 138:113-125.
- Stohlgren, T. J. 1999a. Rapid assessments prior to long-term monitoring. Book chapter for "Measuring and Monitoring Plant Diversity" Smithsonian Institution. (In Press).
- Stohlgren, T.J. 1999b. Data acquisition for ecological assessments. Invited Book Chapter, Ecological Assessments. Patrick Bougeron, Editor, Springer-Verlag (In Press).
- Stohlgren, T.J. 1999c. The Rocky Mountains. Pages 473-504 in: Mac, M.J., P.A. Opler, C.E. Puckett Haecker, and P.D. Doran (eds.). Status and Trends of the Nation's Biological Resources. Biological Resources Division, U.S. Geological Survey, Reston, Va. Volume 2.
- Stohlgren, T.J. 1999d. Endangered plants. S. Levin (ed). Encyclopedia of Biodiversity. Academic Press. (In Press).
- Stohlgren, T.J. 1999e. Measuring and monitoring biodiversity in forests and grasslands in the United States. In: Proceedings of the North American Symposium Toward a Unified Framework for Inventory and Monitoring Forest Ecosystem Resources. USDA Forest Service Rocky Mountain Forest and Range Experiment Station General Technical Report, Fort Collins, CO (In Review).
- Stohlgren, T.J., D. Binkley, G.W. Chong, M.A. Kalkhan, L.D. Schell, K.A. Bull, Y. Otsuki, G. Newman, M. Bashkin, and Y. Son. 1999f. Exotic plant species invade hot spots of native plant diversity. *Ecological Monographs* 69:25-46.
- Stohlgren, T.J., L.D. Schell, and B. Vanden Heuvel. 1999g. How grazing and soil quality affect native and exotic plant diversity in Rocky Mountain grasslands. *Ecological Applications* 9:45-64.
- Stohlgren, T.J., A. Owen, and M. Lee. 1999h. Monitoring shifts in plant diversity in response to climate change: a method for landscapes. *Biodiversity and Conservation* (In Press).
- Stohlgren, T.J., J. Belnap, G.W. Chong, and R. Reich. 1999i. A plan to assess native and exotic plant diversity and cryptobiotic crusts in the Grand Staircase-Escalante National Monument. Pages 269-276 in: Learning From The Land Conference Proceedings, Salt Lake City, Utah.
- Stohlgren, T.J., M. Kaye, A.D. McCrumb, Y. Otsuki, B. Pfister, and C. Villa. 1999j. Using new video mapping technology in landscape ecology. *BioScience* (In Press).
- Stohlgren, T.J., G.W. Chong, L.D. Schell, K.A. Rimar, Y. Otsuki, M. Lee, M.A. Kalkhan, and C. Villa. 1999k. Assessing vulnerability to invasion by exotic plant species at multiple

- spatial scales. *Biological Invasions* (In Review).
- Stohlgren, T.J., K.A. Rimar, and K. W. Stolte. 1999l. Monitoring native and exotic plant diversity in the National Forests in the U.S. *Environmental Monitoring and Assessment*. (In Review).
- Stohlgren, T.J., Y. Otsuki, C. Villa, M. Lee, and J. Belnap. 1999m. Exotic plant invasions in southeast Grand Staircase-Escalante National Monument, Utah. *Biological Invasions* (In Review).
- Stout, B.B. 1993. The good, the bad and the ugly of monitoring programs: defining questions and establishing objectives. *Environmental Monitoring and Assessment*. 26. 91-98.
- Strayer, D., J.S. Glitzenstein, C.G. Jones, J. Kolasa, G.E. Lichens, M.J. McDonnell, G.G. Parker, and S.T.A. Pickett.: 1986, 'Long-term ecological studies: an illustrated account of their design, operation, and importance to ecology.' Institute of Ecosystem Studies Occasional Publication Number 2. Millbrook, NY.
- Suzuki, K., H. Suzuki, D. Binkley, and T.J. Stohlgren. 1999. Aspen regeneration in the Colorado Front Range: Differences at local and landscape scales. *Landscape Ecology* 14:231-237.
- Thompson, W.L., G.C. White, and C. Gowan. 1998. *Monitoring Vertebrate Populations*. Academic Press, London.
- Tilman, D. 1989. Ecological experiments: strengths and conceptual problems. In: G.E. Likens (ed.). *Long-term Studies in Ecology: Approaches and Alternatives*. Springer-Verlag, New York, NY, pp. 136-157.
- U.S. Department of the Interior, National Park Service. 1992. *Natural Resources inventory and monitoring guideline*. Publication NPS-75, Washington D.C.

Appendix A: Lists of species of concern by Mountain National Park Service unit in the Rocky Mountain Network:

Florissant Fossil Beds National Monument (FLFO)

<u>PRIORITIZED SPECIES OF CONCERN</u>	<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
Taxa: Amphibian				
Tiger Salamander (<i>Ambystoma tigrinum</i>)	Native	Riparian, Wetland	imperiled	habitat loss
Taxa: Bird				
Golden Eagle (<i>Aquila chrysaetos</i>)	Native	All	Nesting Pair	habitat loss/human interactions
Northern Goshawk (<i>Accipiter gentilis</i>)	Native	All	rapidly shrinking (native)	habitat loss
Brown-headed Cowbird (<i>Molothrus ater</i>)	Exotic	All	rapidly expanding (exotic)/land use	exotic species competition
Taxa: Mammal				
Beaver (<i>Castor canadensis</i>)	Native	riparian	possibly imperiled/ extirpated in Monument	Habitat loss & history of trapping
Bobcat (<i>Lynx rufus</i>)	Native	All	possibly imperiled, predator	habitat loss
Black Bear (<i>Ursus americanus</i>)	Native	All	possibly imperiled, top predator	Habitat loss & Human-Bear interactions
Mountain Lion (<i>Felis concolor</i>)	Native	All	possibly imperiled, Top Predator	Habitat loss & Human-Lion interactions
Pronghorn (<i>Antilocapra americana</i>)	Native	grassland	rapidly shrinking/public interest	habitat loss
Elk (<i>Cervus elaphus</i>)	Native	All	Public interest & hunting	habitat loss
Mule Deer (<i>Odocoileus hemionus</i>)	Native	All	Public interest & hunting	habitat loss
Taxa: Plant				
Cirsium arvense (canada thistle)	Exotic	wetland/grassland	rapidly expanding (exotic)	exotic species competition
Linaria vulgaris (yellow toadflax)	Exotic	grassland/wetland	rapidly expanding (exotic)	exotic species competition
Convolvulus arvensis (field bindweed)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
Bromus inermis (smooth brome)	Exotic	grassland	was seeded and now displaces native grassland species	exotic species competition
Carduus nutans (musk thistle)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
Unamia alba (white upland aster)	Native	grassland	imperiled	habitat loss /CNHP species of concern
Calypso bulbosa (fairy slipper orchid)	Native	damp woods	imperiled	habitat loss /Colorado orchids should be considered endangered
Cystopteris reevesiana	Native	wetland/riparian	considered rare in Colorado	habitat loss/limited occurrence in state
Cheilanthes cancellata (zigzag cloak fern)	Native	wetland/riparian	considered rare in Colorado	habitat loss/limited occurrence in state
Chielanthes fendleri (fendler cloak fern)	Native	wetland/riparian	considered rare in Colorado	habitat loss/limited occurrence in state
Linnaea borealis (twin-flower)	Native	woodland	uncommon	habitat loss/uncommon species
Catabrosa aquatica (brook-grass)	Native	wetland	limited occurrence in Front Range	habitat loss/limited occurrence
Bromus tectorum (cheatgrass)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
Melilotus officinalis (yellow sweetclover)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition

Florissant Fossil Beds National Monument (FLFO)

<u>PRIORITIZED SPECIES OF CONCERN</u>	<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
Taxa: Plants (cont.)				
Myriophyllum sibiricum (water milfoil)	Native	wetland	unusual submerged aquatic plant	habitat loss/unusual species
Cardaria draba (hoary cress)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
Erodium cicutarium (redstem filaree)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
Thlaspi arvense (field pennycress)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
Descurainia sophia (tansy mustard)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
Euphorbia esula (leafy spurge)	Exotic	grassland	Reportedly in Park, none found	exotic species competition
Cystopteris fragilis (brittle fern)	Native	wetland/riparian	considered rare in Colorado	habitat loss/limited occurrence in state
Orthilia secunda (one-sided wintergreen)	Native	mesic forests	possibly imperiled	climate change - on sensitive or unusual list
Habitat of Special Concern				
previous land-use			Impacts of terracing, smooth brome seeding & grazing	alteration of native species habitat/species composition
grassland			rapidly shrinking (native)	fire suppression, exotic species competition, previous land use
wetlands			rapidly shrinking (native)	exotic species competition, beaver exclusion, altered flood intervals & geomorphic processes
riparian			imperiled	beaver exclusion, earthen dams, altered flood intervals & geomorphic processes
aspen			rapidly shrinking (native)	fire suppression, elk?
ponderosa pine			rapidly expanding	fire suppression

Glacier National Park (GLAC)

<u>PRIORITIZED SPECIES OF CONCERN</u>	<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
Taxa: Amphibian				

long-toed salamander (<i>Ambystoma macrodactylum</i>)	Native	valley/mid-elev forest	declining	climate change
boreal toad (<i>Bufo boreas</i>)	Native	riparian/wet meadow/marsh	declining	climate change
Taxa: Bird				
Common loon (<i>Gavia immer</i>)	Native	lakes	vulnerable	external threats
Harlequin duck (<i>Histrionicus histrionicus</i>)	Native	fast water; rivers/streams/lakes	vulnerable	recreation
Black-backed woodpecker (<i>Picoides arcticus</i>)	Native	recently burned forest stands	vulnerable	fire suppression
Brown creeper (<i>Certhia americana</i>)	Native	coniferous forest	lack of data	habitat loss
Olive-sided Flycatcher (<i>Nattallornis borealis</i>)	Native	coniferous forests/bogs	lack of data	fire suppression
Bald eagle (<i>Haliaeetus leucocephalus</i>)	Native	near open fields/water bodies	vulnerable	disturbance
Northern goshawk (<i>Accipiter gentilis</i>)	Native	dense forest	vulnerable	habitat loss
Timberline Sparrow (<i>Spizella breweri</i>)	Native	mountain meadows	lack of data	climate change
Black swift (<i>Cypseloides niger</i>)	Native	waterfalls/cliffs	vulnerable	
Red-naped sapsucker (<i>Sphyrapicus nuchalis</i>)	Native	riparian/deciduous forest	lack of data	
Three-toed woodpecker (<i>Picoides tridactylus</i>)	Native	coniferous forest	lack of data	
Winter wren (<i>Troglodytes troglodytes</i>)	Native	coniferous forest	lack of data	
Lazuli bunting (<i>Passerina amoena</i>)	Native	open mixed woodland	lack of data	
Pileated Woodpecker (<i>Dryocopus pileatus</i>)	Native	dense mature forest	may be good indicator	habitat loss
White-tailed ptarmigan (<i>Lagopus leucurus</i>)	Native	alpine/subalpine	vulnerable	recreation/climate change
Boreal Owl (<i>Aegolius funereus</i>)	Native	dense subalpine forest	lack of data	habitat loss
Great Gray Owl (<i>Strix nebulosa</i>)	Native	dense coniferous forest	lack of data	habitat loss
Clay-colored Sparrow (<i>Spizella pallida</i>)	Native	brushy meadow/riparian	lack of data	
LeConte's Sparrow (<i>Ammodramus leconteii</i>)	Native	wet meadow/marsh	lack of data	
Golden eagle (<i>Aquila chrysaetos</i>)	Native	open/trees and cliffs	lack of data	
Prairie falcon (<i>Falco mexicanus</i>)	Native	grasslands	lack of data	
European Starling (<i>Sturnis vulgaris</i>)	Exotic	variety	expanding	
Brown-headed Cowbird (<i>Molothrus ater</i>)		open woodland	expanding range	

Glacier National Park (GLAC)

PRIORITIZED SPECIES OF CONCERN

Taxa: Fish

<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
Native	aquatic	imperiled	exotic species competition
Native	aquatic	possibly imperiled	genetic loss
Exotic	aquatic	rapidly expanding	

shorthead sculpin (<i>Cottus confusus</i>)	Native	aquatic	vulnerable	exotic species competition
spoonhead sculpin (<i>Cottus ricei</i>)	Native	aquatic	vulnerable	exotic species competition
Troutperch (<i>Percopsis omiscomaycus</i>)	Native	aquatic	vulnerable	exotic species competition
Yellowstone cutthroat trout (<i>Clarki bouieri</i>) ?	Exotic	aquatic	competition	
arctic grayling (<i>Thymallus arcticus</i>)	Exotic	aquatic	competition	
lake whitefish (<i>Coreogus clupeaformis</i>)	Exotic	aquatic	competition	
rainbow trout (<i>Oncorhynchus myciss</i>)	Exotic	aquatic	competition	
brook trout (<i>Salvelinus fortimis</i>)	Exotic	aquatic	competition	
kokanee salmon (<i>Oncorhynchus nerlea</i>)	Exotic	aquatic	competition	

Taxa: Mammal

lynx (<i>Lynx canadensis</i>)	Native	coniferous forest	vulnerable	
wolverine (<i>Gulo luscus</i>)	Native	coniferous forest/alpine meadow	vulnerable	
fisher (<i>Martes pennanti</i>)	Native	coniferous forest	vulnerable	
northern Bog Lemming (<i>Synaptomys borealis</i>)	Native	coniferous forest	vulnerable	
bats (as a group)	Native	coniferous forest	lack of data	
gray wolf (<i>Canis lupus</i>)	Native	coniferous forest	imperiled	external hunting
grizzly bear (<i>Ursus horribilis</i>)	Native	forest/chutes/alpine meadow	imperiled	habitat loss/human caused mortality
bighorn sheep (<i>Ovis canadensis</i>)	Native	mountain meadows/cliffs	lack of data	poaching/disease
black bear (<i>Ursus americanus</i>)	Native	conf. forest/shrub flds/meadow	lack of data	habitat loss/external hunting
marten (<i>Martes americana</i>)	Native	coniferous forest	may be good indicator	

Taxa: Plant

<i>Centaurea maculosa</i>	Exotic	grassland	rapidly expanding	vegetation disturbance
<i>Hieracium aurantiacum</i>	Exotic	grassland	rapidly expanding	vegetation disturbance
<i>Hieracium piloseloides</i>	Exotic	grassland	rapidly expanding	vegetation disturbance
<i>Hypericum perforatum</i>	Exotic	grassland	rapidly expanding	vegetation disturbance
<i>Euphorbia esula</i>	Exotic	grassland	expanding	vegetation disturbance
<i>Chrysanthemum leucanthemum</i>	Exotic	grassland	expanding	vegetation disturbance
<i>Potentilla recta</i>	Exotic	grassland	expansion potential	vegetation disturbance
<i>Ranunculus acris</i>	Exotic	wetland	expansion potential	vegetation disturbance
<i>Linaria dalmatica</i>	Exotic	grassland	expansion potential	vegetation disturbance
<i>Linaria vulgaris</i>	Exotic	grassland	rapidly expanding	vegetation disturbance

Glacier National Park (GLAC)**PRIORITIZED SPECIES OF CONCERN****Taxa: Plant (cont.)**

	<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
<i>Cirsium arvense</i>	Exotic	riparian	expanding	vegetation disturbance
<i>Phleum pratense</i>	Exotic	grassland	widespread	vegetation disturbance
<i>Gentiana glauca</i>	Native	tundra	vulnerable	recreation
<i>Scirpus hudsonius</i>	Native	fens	vulnerable	recreation
<i>Kalmia polifolia</i>	Native	fens	vulnerable	recreation
<i>Euphrasia arctica</i> var. <i>disjuncta</i>	Native	subalpine meadow	vulnerable	recreation
<i>Vaccinium myrtilloides</i>	Native	forest	vulnerable	development
<i>Draba macounii</i>	Native	subalpine meadow	vulnerable	recreation

<i>Thelypteris phegopteris</i>	Native	moist banks	vulnerable	recreation
<i>Carex chordorhiza</i>	Native	fens	vulnerable	recreation
<i>Festuca vivipara</i>	Native	subalpine meadow	vulnerable	recreation
<i>Ranunculus verecundus</i>	Native	subalpine meadow	vulnerable	recreation
<i>Juncus albescens</i>	Native	subalpine meadow	vulnerable	recreation
<i>Tofieldia pusilla</i>	Native	subalpine meadow	vulnerable	recreation
<i>Carex lenticularis</i> var. <i>dolia</i>	Native	subalpine meadow	vulnerable	recreation
<i>Scheuchzeria palustris</i>	Native	fens	vulnerable	recreation
<i>Kobresia simpliciuscula</i>	Native	subalpine meadow	vulnerable	recreation
<i>Carex livida</i>	Native	fens	vulnerable	recreation
<i>Amerorchis rotundifolia</i>	Native	riparian	vulnerable	trail development
<i>Papaver pygmaeum</i>	Native	alpine talus	vulnerable	recreation
<i>Pinus flexilis</i>	Native	forest	rapidly shrinking	disease/fire suppression
<i>Pinus albicaulis</i>	Native	forest	rapidly shrinking	disease/fire suppression

Habitat

Alpine/subalpine meadows	vulnerable	recreation	
Cedar/devil's club	possibly imperiled	development	rare in MT
Old growth spruce	possibly imperiled	development	
Old growth cedar/hemlock	possibly imperiled	development	
Aspen	not rejuvenating	fire suppression	
Floristic zone convergence	vulnerable	climate change	
Wetlands	vulnerable	exotics	
Riparian	vulnerable	exotics	
Mature western larch	vulnerable	habitat loss	
Ponderosa pine	possibly imperiled	fire suppression	
Grasslands	loss of integrity	fire suppression/exotics	
Whitebark & limber pine	imperiled	fire suppression/disease	

Grant-Kohrs Ranch Historic Site (GRKO)**PRIORITIZED SPECIES OF CONCERN ORIGIN HABITAT REASON FOR URGENCY STRESS****Taxa: Bird**

Bald Eagle, seasonal migrant	Native	riparian		unknown
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Taxa: Fish

Bull Trout	Native	Clark Fork River	unknown population	overgrazing, metals, sedimentation
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Habitat

riparian		fire suppression, past over-grazing, stream bank erosion, metals contaminations, exotic species
native range lands		exotic species competition, past over-grazing, possible metals contamination from irrigation ditches
tame pastures and hayfields		exotic species competition

Great Sand Dunes National Monument (GRSA)

<u>PRIORITIZED SPECIES OF CONCERN</u>	<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
Taxa: Amphibians				
Northern Leopard frog (<i>Rana pipiens</i>)	Native	Wetland	last sighted in 1959	unknown - research needed to determine status
Great plains toad (<i>Bufo cognatus</i>)	Native	Wetland	shrinking habitat	habitat loss
Plains spadefoot (<i>Scaphiopus bombifrons</i>)	Native	Wetland	shrinking habitat	habitat loss
Striped Chorus frog (<i>Pseudacris triseriata</i>)	Native	Wetland	shrinking habitat (unconfirmed sightings)	habitat loss
Taxa: Birds				
Western snowy plover (<i>Charadrius alexandrinus nivosus</i>)	Native	Wetland	CNHP S1B, SZN, G4T3 rank	potentially threatened by water withdrawal, and vegetation management, adjacent land use, and exotic species competition?
Forster's tern (<i>Sterna forsteri</i>)	Native	Wetland	CNHP S2B, S4N, G5 rank	same
White-faced ibis (<i>Plegadis chihi</i>)	Native	Wetland	CNHP S2B, SZN, G5 rank	same
Long-billed curlew (<i>Numenius americanus</i>)	Native	wetland/grassland	CNHP S2B, SZN, G5 rank	same

Short-eared owl (<i>Asio flammeus</i>)	Native	wetland/grassland	CNHP S2B, SZN, G5 rank	same
Ferruginous hawk (<i>Buteo regalis</i>)	Native	all/grassland	CNHP S3B, S4N, G4 rank	land use
Sage sparrow (<i>Amphispiza belli</i>)	Native	grass- shrub-lands	CNHP S3B, SZN, G5	land use
Eared grebe (<i>Podiceps nigricollis</i>)	Native	wetland	CNHP S3B, SZN, G5	potentially threatened by water withdrawal, and vegetation management, adjacent land use, and exotic species competition?
Peregrine falcon (<i>Falco peregrinus</i>)	Native	pinyon-juniper	special concern (delisted)	human-bird interactions
Golden Eagle (<i>Aquila chrysaetos</i>)	Native	all	top predator	human-bird interactions
California condor (<i>Gymnogyps californianus</i>)	Native	sandsheet	endangered (one sighting)	human-bird interactions, land use
House sparrow (<i>Passer domesticus</i>)	Exotic	grass- shrub-lands	exotic	exotic species competition
European starling (<i>Sturnus vulgaris</i>)	Exotic	grass- shrub-lands	exotic	exotic species competition
Taxa: Fish				
Rio Grande sucker (<i>Catostomus plebeius</i>)	Native	stream	State endangered list	park is refuge for this species
Rio Grande cutthroat (<i>Oncorhynchus clarki virginalis</i>)	Native	stream	Special concern (delisted)	park is refuge for this species
Rio Grande chub (<i>Gila pandora</i>)	Native	stream	State endangered list (potential reintroduction)	park is refuge for this species
Rainbow trout (<i>Salmo gairdneri</i>)	Exotic	stream	exotic species - interbreeds with native species	exotic species competition
Brown trout (<i>Salmo trutta</i>)	Exotic	stream	aggressive exotic species	exotic species competition
Brook trout (<i>Salvelinus fontinalis</i>)	Exotic	stream	rapidly expanding (exotic)	exotic species competition

Great Sand Dunes National Monument (GRSA)

<u>PRIORITIZED SPECIES OF CONCERN</u>	<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
Taxa: Mammal				
Kangaroo rat (<i>Dipodomys ordii</i>)	Native	valley bottom	S1, G5T rank	habitat loss/land use changes
Silky pocket mouse subsp. (<i>Perognathus flavus sanluisi</i>)	Native	valley bottom	S3, G5T3 (endemic to San Luis Valley)	habitat loss/land use changes
Plains pocket mouse subsp. (<i>Perognathus flavescens relictus</i>)	Native	dune, grassland	S2, G5T2 rank	habitat loss/land use changes
Gunnison's prairie dog subsp. (<i>Cynomys gunnisoni gunnisoni</i>)	Native	valley bottom, foothills, montane	S3, G5T3	habitat loss/land use changes
Black bear (<i>Ursus americanus</i>)	Native	foothills, montane, mountains	human-animal interactions (Top predator)	human-animal interactions
Mule deer (<i>Odocoileus hemionus</i>)	Native	valley bottom, foothills, montane, mountains	human-animal interactions	human-animal interactions
Elk (<i>Cervus elaphus</i>)	Native	same as above	human-animal interactions	human-animal interactions
Coyote (<i>Canis latrans</i>)	Native	valley bottom, foothills, montane	human-animal interactions	human-animal interactions
Mountain lion (<i>Felis concolor</i>)	Native	foothills, montane, mountains	Top predator, human-animal interactions	human-animal interactions
pronghorn (<i>Antilocapra americana</i>)	Native	valley bottom, foothills	re-introduced	land use changes
beaver (<i>Castor canadensis</i>)	Native	wetland/riparian	historically heavily trapped	land use changes
bobcat (<i>Lynx rufus</i>)	Native	foothills, montane, mountains	top predator	land use changes
Bighorn sheep (<i>Ovis canadensis</i>)	Native	mountains	lung worm	human-animal interactions
wolf (<i>Canis lupus</i>)	Native	valley bottom, foothills, montane, mountains	extirpated	
bison (<i>Bison bison</i>)	Native	valley bottom, foothills	extirpated	

grizzly bear (<i>Ursus arctos</i>)	Native	montane, mountains	extirpated	
Taxa: Plant				
<i>Cleome multicaulis</i> (Slender spiderflower)	Native	alkaline soils	imperiled - Federal category 2; CNHP S2S3, G2G3 rank	potentially threatened by water withdrawal, and vegetation management, adjacent land use, and exotic species competition?
<i>Cryptantha cinerea</i> var <i>pustulosa</i> (James' cateye)	Native	dunes, grasslands	CNHP S1? G5T? Rank	same
<i>Astragalus bodinii</i> (Bodin's milkvetch)	Native	Wetland	CNHP S2,G4 rank	same
<i>Cirsium arvense</i> (Canada thistle)	Exotic	wet- grass- land	rapidly expanding (exotic)	exotic species competition
<i>Salsola kali</i> (Russian thistle)	Exotic	wet- grass- land	rapidly expanding (exotic)	exotic species competition
<i>Cardaria draba</i> (whitetop)	Exotic	wetland	rapidly expanding (exotic)	exotic species competition
<i>Convolvulus arvensis</i> (Field bindweed)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
<i>Bromus tectorum</i> (cheatgrass)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
<i>Verbascum thapsis</i> (Mullein)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
<i>Centaurea maculosa</i> (Spotted knapweed)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
<i>Carduus natans</i> (Musk thistle)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
<i>Erodium cicutarium</i> (filaree)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
<i>Ulmus pumila</i> (Siberian elm)	Exotic	wetland	rapidly expanding (exotic)	exotic species competition
<i>Sonchus oleraceus</i> (annual sow thistle)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition
<i>Sonchus arvensis</i> (perennial sow thistle)	Exotic	grassland	rapidly expanding (exotic)	exotic species competition

Great Sand Dunes National Monument (GRSA)

<u>PRIORITIZED SPECIES OF CONCERN</u>	<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
Taxa: Reptile				
Bullsnake (<i>Pituophis melanoleucus</i>)	Native	grassland	human-interaction	habitat loss
Western garter snake (<i>Thamnophis elegans</i>)	Native	wetland/riparian	human-interaction	habitat loss
Short-horned lizard (<i>Phrynosoma douglassii</i>)	Native	wetland/riparian	human-interaction	habitat loss
Plains blackhead snake (<i>Tantilla nigriceps</i>)	Native	wetland/riparian	human-interaction	habitat loss
Many-lined skink (<i>Eumeces multivirgatus</i>)	Native	grassland	shrinking population?	habitat loss/land use changes
Western ribbon snake (<i>Thamnophis proximus</i>)	Native	wetland/riparian	shrinking population?	habitat loss/land use changes
Western prairie rattler (<i>Crotalus viridis</i>)	Native	grassland	human-interaction (unconfirmed presence)	habitat loss

Habitat

dunes	water development	threatened by water withdrawal, adjacent land use, exotic species competition, and visitor impacts
sandsheet/grassland/shrubland	water development	potentially threatened by water withdrawal, and vegetation management, adjacent land use, and exotic species competition?
riparian	water development	same
wetlands	imperiled, many lost over last 60 years	same
pinyon-juniper	pre park uses likely altered p-j ratio	fire suppression
ponderosa pine	limited regeneration and numerous culturally scarred trees	fire suppression

aspen

limited regeneration? shrinking (native)? fire suppression

Little Bighorn Battlefield National Monument (LIBI)

<u>PRIORITIZED SPECIES OF CONCERN</u>	<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
Taxa: Plant				
Bromus japonicus	Exotic	Grassland	no data	no data
Poa pratensis	Exotic	Grassland	no data	no data
Melilotus officinalis	Exotic	Grassland	no data	no data
Lactuca serriola	Exotic	Grassland	no data	no data
Taraxacum officinale	Exotic	Grassland	no data	no data
Tragopogon dubius	Exotic	Grassland	no data	no data

Rocky Mountain National Park (ROMO)

<u>PRIORITIZED SPECIES OF CONCERN</u>	<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
Taxa: Amphibians				
Boreal Toad	Native	wetland	imperiled; candidate for federal listing; state endangered	unknown
Northern Leopard Frog	Native	wetland	imperiled; state special concern species	unknown
Wood Frog	Native	wetland	possibly imperiled	unknown
Taxa: Bird				
Bald Eagle	Native	lakes, rivers	Federal threatened	human disturbance, possible pesticide impacts
American Peregrine Falcon	Native	cliffs	state species of special concern	human disturbance, possible pesticide impacts
Greater Sandhill Crane	Native	open meadows	state threatened species	loss of breeding habitat, human disturbance
Barrow's Goldeneye	Native	wetland	state species of special concern	loss of breeding habitat
Black Swift	Native	waterfalls		human disturbance around breeding colonies
Bufflehead	Native	wetland		loss of breeding habitat
American Redstart	Native	ponderosa pine, aspen		habitat fragmentation, winter habitat impacts
Chestnut-Sided Warbler	Native	ponderosa pine, riparian, aspen		habitat fragmentation and loss of winter habitat
Boreal Owl	Native	ponderosa pine, aspen		habitat fragmentation and loss
Northern Goshawk	Native	ponderosa pine, lodgepole, spruce-fir, aspen		habitat fragmentation and loss
Sage Sparrow	Native	sagebrush, antelope bitterbrush		habitat fragmentation and loss
Great Blue Heron	Native	wetland		loss of breeding habitat
Northern Harrier	Native	open wet meadows, alpine		loss of breeding habitat
Red-Headed Woodpecker	Native	aspen, ponderosa pine		habitat fragmentation, winter habitat impacts
Osprey	Native	lakes, rivers		human disturbance, possible pesticide impacts

Red-Eyed Vireo	Native	aspen, ponderosa pine		habitat fragmentation, winter habitat impacts
European Starling	Exotic	aspen, ponderosa pine, cottonwood	expanding exotic	competition with native species
Taxa: Fish				
Greenback Cutthroat Trout	Native	aquatic	federal threatened, state threatened	exotic species competition
Colorado River Cutthroat Trout	Native	aquatic	state species special concern	exotic species competition
Mountain Sucker	Native	aquatic	state species special concern	exotic species competition
brook trout	Exotic	aquatic	exotic invasive	impacts to native species
rainbow trout	Exotic	aquatic	exotic invasive	impacts to native species
brown trout	Exotic	aquatic	exotic invasive	impacts to native species

Rocky Mountain National Park (ROMO)

<u>PRIORITIZED SPECIES OF CONCERN</u>	<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
Taxa: Mammal				
Elk	Native	parkwide	potential habitat impacts from growing population	potential over-grazing
Beaver	Native	riparian	rapidly shrinking (native)	habitat loss
Mountain Lion	Native	parkwide	keystone species, public safety	unknown
Bighorn Sheep	Native	parkwide	susceptible to dramatic decline	human encroachment and habitat loss
Northern River Otter	Native	riparian	possibly imperiled	unknown
Black Bear	Native	parkwide	possibly imperiled	unknown
Lynx	Native	parkwide	possibly extinct	habitat loss
Wolverine	Native	parkwide	possibly extinct	habitat loss
Dwarf Shrew	Native	parkwide	possibly imperiled	unknown
Pygmy Shrew	Native	parkwide	possibly imperiled	unknown
Rocky Mountain Goats	Exotic	tundra	exotic invasive	impacts to native species
Eastern Fox Squirrel	Exotic	cottonwoods, aspen	exotic invasive	impacts to native species
Taxa: Plant				
<i>Juncus Tweedyi</i> , Tweedy Rush	Native	wetland	critically imperiled in state	possible over-grazing by elk, nitrogen deposition
<i>Salix Serissima</i> , Autumn Willow	Native	wetland	critically imperiled in state	possible over-grazing by elk, nitrogen deposition
<i>Drymaria Effusa</i> var. <i>Depressa</i> , Pinewoods Drymary	Native	aspen-fir forest clearings	critically imperiled in state	fire suppression, possible over-grazing by elk, nitrogen deposition
<i>Bortychium Minganense</i> , Mingan Moonwort	Native	riparian, spruce-fir	critically imperiled in state	climate change, fire, nitrogen deposition
<i>Viola Selkirkii</i> , Selkirk Violet	Native	cold, moist montane woods	critically imperiled in state	climate change, fire, human impacts, possible over-grazing by elk, nitrogen deposition
<i>Cystopteris Montana</i> , Mountain Bladder Fern	Native	wet forested montane	critically imperiled in state	climate change, nitrogen deposition
<i>Dryopteris Expansa</i> , Spreading Wood Fern	Native	forested understory in montane	critically imperiled in state	climate change, nitrogen deposition
<i>Carex Leptalea</i> , Bristle-Stock Sedge	Native	wetland	critically imperiled in state	possible over-grazing by elk, nitrogen deposition
<i>Juncus Vaseyi</i> , Vasey Rush	Native	wetland	critically imperiled in state	possible over-grazing by elk, nitrogen deposition
<i>Liatris Ligulistylis</i> , Gay-Feather	Native	open fields	imperiled in state	possible over-grazing by elk, human

<i>Sisyrinchium Pallidum</i> , Pale Blue-Eyed Grass	Native	wetland meadows	imperiled in state	impacts, nitrogen deposition possible over-grazing by elk, development activities, nitrogen deposition
<i>Aletes Humilis</i> , Larimer aletes	Native	ponderosa pine, douglas fir	imperiled in state	habitat loss, nitrogen deposition
<i>Mimulus Gemmiparus</i> , Weber Monkeyflower	Native	moist rocky areas subalpine, montane	imperiled in state	human impacts, nitrogen deposition
<i>Potentilla Effusa</i> var. <i>Rupicola</i> , Rocky Mountain Cinquefoil	Native	rocky outcrops, lodgepole, spruce-fir	imperiled in state	human impacts, nitrogen deposition
<i>Draba Grayana</i> , Gray's Peak Whitlow-Grass	Native	gravel in alpine	imperiled in state	possible over-grazing by elk, nitrogen deposition

Rocky Mountain National Park (ROMO)

<u>PRIORITIZED SPECIES OF CONCERN</u>	<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
Taxa: Plant (cont.)				
<i>Bortyichium Pallidum</i> , Pale Moonwort	Native	riparian, spruce-fir	imperiled in state	climate change, fire, nitrogen deposition
<i>Botrychium Echo</i> , Reflected Moonwort	Native	riparian, spruce-fir	imperiled in state	climate change, fire, nitrogen deposition
<i>Parnassia Kotzebuei</i> , Kotzebue Grass-of-Parnassus	Native	wet meadows	imperiled in state	possible over-grazing by elk, nitrogen deposition
<i>Listera Borealis</i> , Northern Twayblade	Native	wet shaded banks	imperiled in state	development activities, human impacts, nitrogen deposition
<i>Papaver Kluanense Occidentale</i> , Alpine Poppy	Native	alpine	imperiled in state	possible over-grazing by elk, human impacts, impacts, nitrogen deposition
<i>Bortyichium Lanceolatum</i> var. <i>Lanceolatum</i> , Lanceleaf Moonwort	Native	riparian, spruce-fir	imperiled in state	climate change, fire, nitrogen deposition
<i>Bortyichium Lunaria</i> , Moonwort	Native	riparian, spruce-fir	imperiled in state	climate change, fire, nitrogen deposition
<i>Listera Convallarioides</i> , Broad-Leaved Twayblade	Native	wet shaded banks	imperiled in state	development activities, human impacts, nitrogen deposition
<i>Aquilegia Saximontana</i> , Rocky Mountain Columbine	Native	alpine, subalpine	vulnerable in state	human impacts, nitrogen deposition
<i>Penstemon cyathophorus</i> , Middle Park Pentstemon	Native	sagebrush	vulnerable in state	possible over-grazing by elk, human impacts, development, nitrogen deposition
<i>Cyripedium Fasciculatum</i> , Purple's Lady's-Slipper	Native	lodgepole, montane-subalpine	vulnerable in state	climate change, nitrogen deposition
<i>Lilium Philadelphicum</i> , Wood Lily	Native	moist understory in montane	vulnerable in state	loss of habitat, nitrogen deposition
first 5 have same #1 priority ranking	Native			
Yellow Toadflax	Exotic	open meadows, ponderosa, riparian areas	exotic invasive	impacts to native species
Dalmatian Toadflax	Exotic	ponderosa pine, open meadows	exotic invasive	impacts to native species
Leafy Spurge	Exotic	ponderosa pine, meadows, riparian areas	exotic invasive	impacts to native species
Spotted Knapweed	Exotic	meadows, ponderosa pine, aspen	exotic invasive	impacts to native species
Diffuse Knapweed	Exotic	open meadows in montane	exotic invasive	impacts to native species
Orange Hawkweed	Exotic	open meadows in riparian areas	exotic invasive	impacts to native species
Houndstongue	Exotic	ponderosa pine, open meadows	exotic invasive	impacts to native species
Sulfur Cinquefoil	Exotic	open meadows, riparian areas	exotic invasive	impacts to native species
Bull Thistle	Exotic	ponderosa pine, meadows,	exotic invasive	impacts to native species

		riparian areas		
Musk Thistle	Exotic	open meadows, ponderosa pine	exotic invasive	impacts to native species
Common Burdock	Exotic	ponderosa pine, open meadows	exotic invasive	impacts to native species
Canada Thistle	Exotic	meadows in montane, riparian	exotic invasive	impacts to native species
Common Mullien	Exotic	ponderosa pine, open meadows	exotic invasive	impacts to native species
Bouncingbet	Exotic	ponderosa pine, open meadows	exotic invasive	impacts to native species
Hoary Alyssum	Exotic	ponderosa pine, open meadows	exotic invasive	impacts to native species

Rocky Mountain National Park (ROMO)

PRIORITIZED SPECIES OF CONCERN

Taxa: Plant (cont.)

	<u>ORIGIN</u>	<u>HABITAT</u>	<u>REASON FOR URGENCY</u>	<u>STRESS</u>
Oxeye Daisy	Exotic	meadows, riparian, lodgepole	exotic invasive	impacts to native species
Mayweed Chamomile	Exotic	meadows, lodgepole edges	exotic invasive	impacts to native species
Yellow Sweetclover	Exotic	meadows, ponderosa pine	exotic invasive	impacts to native species
White Sweetclover	Exotic	open meadows, ponderosa pine	exotic invasive	impacts to native species
Quack Grass	Exotic	open meadows, ponderosa pine	exotic invasive	impacts to native species
Common St. John's Wort	Exotic	open meadows in montane	exotic invasive	impacts to native species
Baby's Breath	Exotic	open meadows in montane	exotic invasive	impacts to native species
Smooth Brome	Exotic	open meadows, ponderosa pine	exotic invasive	impacts to native species
Cheat Grass	Exotic	ponderosa pine, open meadows	exotic invasive	impacts to native species
Field Bindweed	Exotic	open meadows in montane	exotic invasive	impacts to native species
Dame's Rocket	Exotic	ponderosa, meadows, lodgepole, riparian	exotic invasive	impacts to native species
Russian Thistle	Exotic	open meadows	exotic invasive	impacts to native species

Habitat

Alpine wetland	critically imperiled in state	possible over-grazing by elk, nitrogen deposition, climate change, water diversions
Montane wetland	critically imperiled in state	possible over-grazing by elk, exotic species competition, boundary development, climate change, fire, beaver, water diversions
Willow Carr	vulnerable in state	possible over-grazing by elk, exotic species competition, boundary development, climate change, fire, beaver, water diversions
Mixed foothill shrubland	critically-imperiled in state	possible over-grazing by elk, exotic species competition, boundary development, climate change, fire
Montane grassland	imperiled in state	possible over-grazing by elk, exotic species competition, boundary development, climate change, fire
Aspen forest	imperiled-vulnerable in state	possible over-grazing by elk, exotic species competition, boundary development, climate change, fire
Sagebrush shrubland	imperiled-vulnerable in state	possible over-grazing by elk, exotic species competition, boundary development, climate change, fire
Ponderosa Pine	vulnerable in state	possible over-grazing by elk, exotic species competition, boundary development, climate change, fire

Montane riparian forest	vulnerable in state	possible over-grazing by elk, exotic species competition, boundary development, climate change, fire, beaver, water diversions
Krummholz	vulnerable in state	possible over-grazing by elk, nitrogen deposition,

Appendix B: Contact list for the steering committee of the Rocky Mountain Network.

Park Unit¹	Contact	Title	Email / Phone	Mailing Address
Rocky Mtn. Network	Dr. Thomas J. Stohlgren	Steering committee coordinator	Tom_Stohlgren@usgs.gov (970) 491-1980	Natural Resource Ecology Lab Natural & Environmental Sciences Building Colorado State Univ., Ft. Collins, CO 80523
Rocky Mtn. Network	Dr. Barry Noon	PI, Conceptual Plan, Project Coordination	Brnoon@cnr.colostate.edu (970) 491-7905	Dept. Wildlife and Fisheries 240 Wagar Building Colorado State Univ., Ft. Collins CO, 80523
ROMO NP	Ken Czarnowski	Hydrologist	Ken_Czarnowski@nps.gov (970) 586-1263	Rocky Mountain National Park Estes Park, CO 80517
GLAC NP	Tara Williams	Ecologist	Tara_Williams@nps.gov (406) 888-7919	Glacier National Park, PO Box 128 West Glacier, MT 59936
FLFO NM	Tom Ulrich	Chief, I, RM, and VP	Tom_Ulrich@nps.gov (719) 748-3253	PO Box 185 Florissant, CO 80816
GRSA NM	Fred Bunch	Resource Mgmt.	Fred_Bunch@nps.gov (719) 378-2312	11500 Highway 160 Mosca, CO 81146
GRKO NHS	Anita Arends	NR Manager	Anita_Arends@nps.gov (406) 846-2070	PO Box 790 Deer Lodge, MT 59722
LIBI NM	Michael Stops	NR Manager	Michael_Stops@nps.gov (406) 638-2621	PO Box 39 Crow Agency, MT 59022

Appendix C: Current NPS Database Status

NPSpecies

We started with a skeleton NPSpecies file in Access 97 for three parks (ROMO, GLAC, GRSA). Most records were incomplete and without documentation, and required cleanup (e.g., negative TSN's). We have worked with Mark Wottowa to convert electronic species information and related documentation from park databases and NP Flora and Fauna databases. Significant new information was gathered on every one of the recent park visits and more is expected to come in. We are currently merging updated files and incorporating hardcopy information. Most available lists and resources been converted to NPS standard format databases for the six parks but there will still be significant review and documentation tasks. We have taken a longterm approach to populating this database by using the scientific names as they were documented in various reports, collections and databases. This makes it difficult to report an accurate number of species for the taxa of interest in the short term, but is the recommended approach to stand the test of time and inevitable changes in taxonomy. The main goal for the remainder of the preproposal phase is to review the combined park species lists and park status fields in NPSpecies. Documentation will be improved throughout the inventory.

Table A. Summary of previous vascular plant and vertebrate animal inventories conducted in each park throughout the Rocky Mountain Network.

Park Unit ¹	Category	Existing Information: Biological Inventory	Conversion Status
ROMO	Birds	Species list include about 280 spp. Limited distribution information from previous surveys (including some multi-scale), Bird program transferring to multi-scale distance sampling.	Converted to NPspp, Recent update merge and review required
	Mammals	Species lists include 59 native species, 1 exotic species (fox squirrel)	Converted to NPspp, Recent update merge and review required
	Herps	1 reptile species (western garter snake) known , bullsnake reported. Amphibian checklist includes 5 species.	Converted to NPspp, Recent update merge and review required
	Fish	Species list complete: 6 native species, 4 exotic species	Converted to NPspp, Recent update merge and review required
	Plants	Current checklist of about 1200 species. Rare plants have been mapped and documented. Key exotic plant species have been identified and ranked by importance, but have not been mapped	Converted to NPspp, Recent update and documentation merge and review required.
GLAC	Birds	Species list includes around 300 bird species.	Converted to NPspp, needs review and documentation.
	Mammals	Species list includes more than 60 mammal species.	Converted to NPspp,

			needs review and documentation, especially observation database.
GLAC	Herps	Species list includes eight amphibians and one reptile sp. (Western Garter Snake).	Converted to NPSpp, needs review and documentation
	Fish	Species list includes about 25 fish species.	Converted to NPSpp, needs review and documentation
	Plants	Well-documented checklist of over 1400 species. From a list of 41 rare plants known from MT, 28 species are found only in Glacier NP (including 4 known endemic species).	Documentation updates and herbarium records converted to NPSpp, needs review.
FLFO	Birds	Anecdotal bird list compiled from wildlife biologists and local avid birders reports about 130 species.	
	Mammals	NPS fauna database at FLFO includes 27 species.	NPSpp, hardcopy info
	Herps	Tiger Salamander documented, Leopard Frog historic record, two snake species reported.	NPSpp
	Fish	No documented information.	
	Plants	Previous vascular plant inventories record about 450 species.	NPSpp, Some hard copy info not included
GRSA	Birds	Anecdotal bird surveys	NPSpecies, some hardcopy
	Mammals	Anecdotal list	NPSpecies, some hardcopy
	Herps	Anecdotal list	NPSpecies, some hardcopy
	Fish	No inventory	NPSpecies, some hardcopy
	Plants	Comprehensive, replicated inventory of plant species (estimated to be about 90% complete)	NPSpecies, some hardcopy
GRKO	Birds	List of birds compiled by Powell County High School	Recently acquired hard copy needs to be entered in NPSpp and reviewed.
	Mammals	List compiled by Peter Rice and Gary Ray (1984) (incomplete)	NPSpp, needs update and review
	Herps	Recent searches by Corn Group needed, No List.	
	Fish	Limited trout info related to contaminants.	Hardcopy
	Plants	List of plants in riparian areas (Rice and Ray 1984; incomplete), recently found missing NPFlora hardcopy of 146 spp.	NpSpp, Hardcopy
LIBI	Birds	22 birds listed.	Current NPSpp list (from Baseline Resources 1999 report) needs to be updated with hardcopy lists.
	Mammals	15 mammals listed.	Current NPSpp list (from Baseline Resources 1999 report) needs to be updated with hardcopy lists.
	Herps	5 reptile spp. listed	Current NPSpp list (from Baseline Resources 1999 report) needs to be updated with hardcopy lists.
	Fish	No inventory	Hardcopy lists for Little Bighorn River may apply.
	Plants	116 Spp listed, mostly from upland (Bock 1984-87) fire and vegetation survey; informal surveys of exotics.	Current NPSpp list (from Bock 1987 and Baseline Resources 1999 report) needs to be updated with recent survey data (in prep).

Natural Resources Bibliography

Marilyn Ostergren has recently provided the most recent version of NRBib to accurately cross-reference with Dataset Catalog and NPSpecies. We are also working to directly update NRBib with additional references.

Probably related to the significant problems in merging different efforts and versions, the most recent Natural Resources Bibliography versions from Mark Wotawa do not include GLAC. The significant work on combining previous NRBib efforts would be handled in part by the data manager in project 4, and supplemented in part by coordinated inhouse projects.

Dataset Catalog

The Dataset Catalog for the Rocky Mountain Network is currently in the initial stages of development. Throughout the preproposal phase and on recent park visits we have requested and searched for information on historic and current datasets of all types, maps, aerial photos and GIS layers. A great deal of information has recently been gathered (and is still coming in) that will be used to populate dataset catalog. The first step in documenting all historic and current datasets as well as geographic resources has been to incorporate electronic versions of NRBib, as well as existing database descriptions, GIS layers and associated metadata. We have converted a total of 1861 records to construct a skeleton dataset catalog for the six parks (FLFO, GLAC, GRKO, GRSA, LIBI, and ROMO). Most electronic resources have been converted as a first step in this significant task that will continue throughout the inventory process. The main goal for this preproposal phase is to review and refine the lists by merging duplicate entries and prioritizing for the ongoing population of metadata fields for critical biological inventory resources.

- **FLFO has 311 records**, converted from an NRBib version in Access from M. Wotowa.
 -Current GIS files from FLFO on Sept 6 are currently being incorporated.
 -All records will need to be reviewed.
- **GLAC has 368 records**, converted from two sources (27 records from GLAC DataCat files sent Sept 6), and Natural Resources Database.
 -Natural Resource Bibliography needs to be included, despite merging issues.
 -New records (28 – 368) will need to be reviewed, requiring a huge effort of time and communication with park personnel and researchers (a priority in Project 4).
- **GRKO has 129 records**, converted from two sources: an NRBib version in Access from M. Wotowa and hardcopy descriptions of GRKO GIS files. Direct communication with GIS data manager Ken Marchand was delayed due to the fires and is a priority for October.

-All records (129) need to be reviewed.

- **GRSA** has 499 records, converted from two sources: NRBib version in Access (received from M. Wotowa) and a hardcopy list of GIS layers.
 - Park updated procite files will need to be reviewed for additional records and descriptions.
 - Updated electronic GIS files and metadata have been requested (expected in early Oct.).
 - All records (499) need to be reviewed.
- **LIBI** has 39 records, converted from the NRBib version in Access (received from M. Wotowa).
 - All records (39) need to be reviewed and updated with hardcopy information from LIBI.
- **ROMO** has 515 records, they came from two sources (an NRBib version in Access (received from M. Wotowa) and ROMO 'HTML' meta-data files from Ron Thomas.
 - All records (515) need to be reviewed and updated with the complete metadata (Some fields must be transferred individually).

Updating DataCat from electronic sources:

Once the electronic information was in either an Excel spread sheet or an Access table it was then imported as a table into the desired DataCat database and given a unique name. Then a new 'Append Query' was run appending selected fields from the newly imported table into the 'Datacat' table. The new records can then be updated from either the table view or form view.

NRBib files – all had three fields 'NRBibID', 'Author', and 'Reference'. The 'NRBibID' field was matched to the 'Related Documents' field in DataCat. The 'Author' field was matched to the 'Contact' field. The 'Reference' field was matched to the 'Description' field.

GLAC DataCat files – Most information was already in corresponding fields and the rest were matched to the correct fields in the current dataset catalog version.

GLAC Natural Resource Database files – had eight fields, the following six were used 'Database Content', 'Subject', 'Status', 'Time Period', 'Data Manager', and 'Native format'. The 'Database Content' field was matched to the 'Description' field. The 'Subject' field was matched to the 'Subject' field. The 'Status' field was matched to the 'Status' field. The 'Time Period' field was matched to the 'Begin_Date' and 'End_Date' fields. The 'Data Manager' field was matched to the 'Contact' field. The 'Native Format' field was matched to the 'Format' field.

GRKO, GRSA, FLFO GIS – GRKO has the name, description and status of ~43 GIS shape files. GRSA had only the name of the ~42 GIS shape files. FLFO files have limited descriptions and related metadata that could be improved with interviews.

ROMO 'HTML' meta-data files – are formally created meta-data based on one of the USGS standards created with one of their meta-data creation programs. The index was used, and three fields were used 'Data Description', 'Dataset Name', and 'Data Type'. The 'Data Description' field was matched to the 'Description' field. The 'Dataset Name' field was matched to the 'RelatedDocs' field. The 'Data Type' field was matched to the 'RelatedData' field. All imported files need to be reviewed because additional information can be mined from the description and the appropriate fields in the DataCat table can be filed in.