THE WYOMING BIOINFORMATION NODE:
A STATE-LEVEL IMPLEMENTATION OF THE
NATIONAL BIOLOGICAL INFORMATION INFRASTRUCTURE

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ABSTRACT

The Wyoming BioInformation Node (WBN) Project was initiated in September 1996. The project aimed to develop a National Biological Information Infrastructure (NBII) data node for biological and related resource data in Wyoming. Originally conceived as a long-term maintenance and implementation solution for the Wyoming Gap Analysis Project, the WBN primarily facilitates increased access to significant state-level biological data through standards implementation, data delivery infrastructure development, and related information transfer activities. This publication summarizes the principal products of the original WBN project, including the WBN World Wide Web site and data clearinghouse, the Biological Expert Systems Land-Use Planning Tool (BEST), and the biological extension activities undertaken by WBN personnel over the two-year implementation of the project. Details of clearinghouse design and application development are provided as in-sight for similar state-based NBII implementation activities.

CHAPTER I: INTRODUCTION

ADVANCING THE NATIONAL BIOLOGICAL INFORMATION INFRASTRUCTURE

Scientists have been collecting data on Earth's biosphere for hundreds of years. In this century, researchers and resource managers from government, academia, and conservation groups concerned with better understanding our biological resources collected vast amounts of data from across the United States. Today, systematic inventories of biodiversity such as The Nature Conservancy's Natural Heritage Programs (Noss 1987) and the US Geological Survey (USGS) National Gap Analysis Program (Scott and Jennings 1997) have generated a wealth of knowledge on the patterns and dynamics of plant and animal species across the nation. Combining such information with other existing biological data sources through technologies like geographic information systems (GIS) and the Internet holds great potential for pro-active biological conservation planning.

Unfortunately, such data often reside in disparate locations and/or formats. In every state, multiple efforts at all levels of government are underway, "… to survey animals, plants, and habitats. Differences between and within [agencies and] states have resulted in varied taxonomic priorities, funding levels, data availability, data distribution policies, and data quality. Efforts to make these valuable biological data more accessible are often hamstrung by a lack of funding, personnel, data standards, a data distribution mechanism, and other problems. In many cases, information has not yet been computerized and is therefore exceptionally difficult to share effectively" (Cotter et al. 1996).

As part of the federal government's efforts to advance a national information infrastructure, the USGS is leading "a broad cooperative effort to make data and information on biological resources more accessible"

More Information About NBII

Find out more about the National Biological Information Infrastructure by visiting www.nbii.gov on the Internet. The site provides an overview of the NBII and information on the NBII Metadata Clearinghouse and Biological Metadata Standard, as well as access to NBII publications and white papers, metadata tools, and current topics in biological resource information.

through a National Biological Information Infrastructure (NBII) (Cotter et al. 1996). The goal of the NBII is to establish a "distributed electronic federation" through which biological data from a wide variety of government and non-government entities is made available for distribution, sharing, integration, and application (D'Erchia et al. 1998).

ORIGINS OF THE WYOMING BIOINFORMATION NODE

A coordinated, statewide biodiversity planning effort for Wyoming was first proposed in 1994 by the Wyoming Gap Analysis Project (WY-GAP) at the University of Wyoming. At that time, a need was identified for a consortium of state entities structured to address both biodiversity conservation policy and the long-term sustainable existence and expansion of the biological resource data products developed by WY-GAP.

Following WY-GAP cooperator meetings in December 1994 and July 1995, a proposal was developed for establishment of a "Wyoming Gap Analysis Biological Data Center" (WWRC 1995). Jointly distributed to WY-GAP cooperators by the Wyoming Water Resources Center (WWRC) and the Wyoming Natural Diversity Database (WYNDD), the proposal called for creation of an NBII data node to be developed around the completed WY-GAP databases in combination with the WYNDD repository. Modeled after similar state initiatives described by Vickerman and Smith (1995), the proposed goals for the data center included establishing one centralized "clearinghouse" of biological data and information, improving efficiency in biological data management, and providing of a framework for future integration of other spatial and non-spatial databases important to the management and planning of biological resources in Wyoming.

In December 1995, WY-GAP cooperators again met to discuss issues concerning the long-term maintenance and use of the project's databases and implementation of its recommendations. The cooperators in attendance agreed that problems associated with the dissemination and use of the databases needed to be addressed before moving forward with comprehensive, statewide conservation planning. These problems included the need for an established facility to store, maintain, and distribute the databases and the need for additional natural resource and socioeconomic data to be incorporated with the WY-GAP databases to develop a more comprehensive planning, management, and education tool.

With seed money provided by the Natural Resource Conservation Service and the Bureau of Land Management, a revised proposal based on the original WWRC "biological data center concept" was drafted and submitted in April 1996 to the State Partnerships program of the U.S. National Biological Service (NBS). In September 1996, the NBS awarded matching funds to the University of Wyoming's newly formed Spatial Data and Visualization Center (SDVC) and the NBS National Gap Analysis Program (Moscow, Idaho) for development of the Wyoming BioInformation Node (WBN) (Kohley et al. 1996).

> **More Information About Gap**
>
> *Find out more information about Gap by visiting www.gap.uidaho.edu/gap on the Internet. The site includes a description of Gap as well as information about annual meetings, research and applications, projects, tools, and bulletin boards.*

The WBN project aimed to develop a National Biological Information Infrastructure (NBII) data node for biological and related resource data in Wyoming. The primary objective in establishing the WBN was to facilitate increased access to significant state-level biological data by providing NBII-compliant WBN data layers to the public both electronically and through an integrated extension program.

HOW THIS REPORT IS ORGANIZED

This publication summarizes the principal products of the Wyoming BioInformation Node project. Chapter Two describes the WBN World Wide Web homepage that provides Internet users with access to WBN information and data, including NBII-compliant metadata. Chapter Three describes a prototype decision support tool known as the Biological Expert Systems Tool (BEST), which promotes biological considerations in local land use planning. Chapter Four discusses some of the biological extension activities that were conducted by the WBN project team and describes the CDROM product that was produced for continued advancement of the WBN. Chapter Five summarizes the project's accomplishments and outlines recommendations for future enhancements.

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CHAPTER II: THE WYOMING BIOINFORMATION NODE WORLD WIDE WEB SITE AND DATA CLEARINGHOUSE

BACKGROUND

The Wyoming Bioinformation Node's (WBN) World Wide Web home page and associated links provide increased access to biological information and related data of significance to Wyoming, as part of the National Biological Information Infrastructure (NBII 1998a). NBII intends to help people make better decisions about managing Wyoming's biological resources by documenting data and making it more accessible over the World Wide Web. An NBII data node also aims to prevent duplicative data collection, to identify important biological data gaps for future development, and to foster partnerships among different governmental, educational, and private and business entities concerned with the development and utilization of biological information.

At the core of this on-line data center are the Wyoming Gap Analysis (WY-GAP) databases and report (Merrill et al. 1996). The WY-GAP project developed three statewide spatial databases and procedures to assess the biological diversity and conservation status of terrestrial vertebrate species and vegetation systems in Wyoming. The information produced by this project was recognized as a valuable resource planning, management, and education tool for federal, state, and local governments, educational institutions, businesses, and citizens. To make the information useful and accessible to as wide an audience as possible, an on-line data node was created in which the information could be documented and packaged for dissemination in several different formats.

The scope of the data node goes beyond the initial databases developed by WY-GAP. Additional biological and related natural resource data were also identified as important to complement and supplement WY-GAP data. Because the WY-GAP data were developed at the statewide level, they are too coarse to provide appropriate information for site-specific planning or other large-scale analyses. WY-GAP data provides a comprehensive overview of Wyoming's biological elements that can be supplemented by more detailed regional or project-specific data. Integration of abiotic data, such as watershed or ecoregion delineations, oil, gas, and mineral deposit locations, and socioeconomic and demographic information, is also important for resource planning, management, and education.

INTEGRATION OF WBN WITH NBII AND NSDI

NBII is a broad cooperative effort, led by the US Geological Survey, to create an electronic “federation” of biological data and information sources. Its goal is to provide swift user access to biological databases, information products, directories, and guides maintained by government and non-government agencies and private organizations (NBII 1998a). Its success rests on a growing network of partners who share biological information. Large statewide and regional projects like WY-GAP would not be possible without data sharing among organizations; this is often true at the larger scale, as well as among counties, cities, and state and federal resource managers who are all responsible for managing resources with often overlapping jurisdictions. The majority of the data needed for projects such as these aren’t usually found in journal articles but are located in the huge, unwieldy, and often undocumented mass of information broadly known as “gray literature”, including unpublished reports, agency databases, theses and dissertations, etc. The NBII was created for this sort of information. Not only does this vision of NBII reduce data duplication, focus future data development in needed areas, and encourage partnerships between data-producers and users, it also seeks to provide the researchers and technicians working on projects like WY-GAP a more efficient way to locate, assimilate, and update a wide array of data almost entirely off the Web.

The National Spatial Data Infrastructure (NSDI), is similar to the NBII, in that it supports a National Information Infrastructure objective to increase access, sharing, and application of data among a broad set of public and private cooperators and partners (NBII 1998b). Established in 1994 by Executive Order 12096, the NSDI is defined as “the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data" (Executive Office of the President 1994). Further, the Executive Order charged the Federal Geographic Data Committee (FGDC; www.fgdc.gov) with advancing development of the NSDI through three major activities: establishing a National Geospatial Data Clearinghouse; developing standards for geospatial data documentation, collection, and exchange; and developing of procedures and partnerships to create a National Digital Geospatial Data Framework (Hoch 1995; Tosta 1997).

While the NBII centers on biological information, the NSDI's focus is on geospatial data (i.e., explicitly relating the thematic information to specified locations on the surface of the Earth). "To the extent that some types of geospatial data relate to biological themes — and some types of biological data are spatially oriented, such as data on the geographic distribution of biological species or ecosystems — the linkage between the NBII and the NSDI becomes explicit. But the two efforts also support and complement each other in other less obvious ways; for instance, in the use of common standards and tools that help support the goals of increased access, sharing, and application of data" and in a shared commitment to involving many partner agencies and organizations in building and using these information infrastructures" (NBII 1998b).

The Federal Geographic Data Committee (FGDC) and NBII federation established metadata standards and clearinghouse protocols to improve access to and exchange of biological information. The President's Committee of Advisors on Science and Technology (PCAST) identified several challenges facing the NBII in their 1998 report, *Teaming with Life: Investing in Science to Understand and Use America's Living Capital*:

- Databases that are on-line are not as numerous as they ought to be,
- Those databases that do exist on-line do not hold standardized types of data,
- Standards for data exchange have yet to be widely adopted, and
- A "next generation" of NBII is needed to automate the collation, correlation, analysis, and synthesis of data (PCAST 1998)

These problems are closely related to the fact that many organizations that create, update, and maintain biological and geospatial data often do not have sufficient resources or incentive to document their projects and data according to standards or to make the documentation available through on-line servers. The availability of tools to increase the efficiency of data access and to provide integration among different sources of information (the "next generation" of NBII) would be a great incentive for support, both from the data providers' and the users' perspectives.

The WBN data clearinghouse was developed as a research project to tackle some of these issues. The objectives of the WBN web pages were to make existing biological data, such as those produced by WY-GAP, readily accessible and documented, to advertise the availability of the data, and to educate people about the data and its potential uses by creating a series of on-line applications using the data. Along with extension and outreach activities (see Chapter 4), these three objectives point toward another, indirect goal: to encourage other organizations and data-producers to document their data according to standards and make them available on an NBII data node.

DEVELOPMENT OF THE WBN CLEARINGHOUSE

The project team took a three-pronged approach to making the WY-GAP data for Wyoming available on the Web along with on-line applications:

- Create a data node, serving spatial data and metadata, along with a metadata search engine connected to the National Geospatial Data Clearinghouse,
- Create an on-line vertebrate species atlas containing distribution maps for all species and information converted from the final report and appendices, and
- Create an Internet Map Server containing live maps of land cover, land ownership and stewardship, and species distributions which can be queried as well as overlaid with additional information.

The Data Node

The first goal of the WBN was to document the WY-GAP data sets (land cover, predicted vertebrate species distributions, and land stewardship) according to the FGDC and NBII metadata standards and make them available on the WBN web site for download along with the WY-GAP final report. The WBN aimed to include other available data sets, such as biological, non-biological, and non-geospatial data sets (databases and reports) that might be pertinent to natural resources management and conservation. To accomplish this, the project team integrated the biological data node with the Wyoming Natural Resources Data Clearinghouse (WNRDC; www.sdvc.uwyo.edu/clearinghouse), a broader spatial data clearinghouse maintained by the University of Wyoming Spatial Data and Visualization Center containing a wide range of base data themes (roads, hydrography, and elevation) as well as other water- and geological-related data.

The WBN proposal identified several specific tasks pertaining to the development of the WBN data node:

- Identify and prioritize existing databases to be incorporated into the data node,
- Develop metadata documentation for databases in accordance with the FGDC Content Standard for Digital Geospatial Metadata and NBII metadata standards,
- Establish a server supporting the Z39.50 protocol v.2/3, utilizing I-Site and I-Search "browse and search" software, and
- Develop web pages and forms to enable client access to WBN data sets and information.

In February 1997, a precursor to the WBN data node went on-line. This web page contained a brief description of the WY-GAP project and data sets, FGDC-compliant metadata for the three WY-GAP statewide GIS data sets (land cover, land stewardship, and terrestrial vertebrate species distributions) and links to an ftp server containing the data sets in ARC/INFO format. The ARC/INFO data sets were available for download. Shortly afterward, the WY-GAP data were incorporated as one "node" of the WNRDC. Because the WNRDC followed the same four guidelines described above, the WBN data node was included as part of the larger clearinghouse to provide a much broader base of on-line data for users interested in natural resources information. As part of WNRDC, the WBN followed the same formatting guidelines:

- GIS data in ARC/INFO export files and ArcView shapefiles,
- Metadata conform to Content Standards for Digital Geospatial Metadata and, where applicable, the Biological Data Profile of the Content Standard for Digital Geospatial Metadata,
- The large data sets divided into 30 by 60 minute tiles (1:100,000 quadrangles) for downloading (there are 56 tiles within the state of Wyoming), and
- Data compressed using INFOZIP, freeware software compatible with PKZIP, which is available both for PC and various UNIX platforms.

The WNRDC's on-line lists of the data sets and links to download areas are organized by their subject or theme (biological, land, water, climate), by their source scale (1:24,000, 1:100,000, 1:250,000, etc.), and by their source (SDVC, other University of Wyoming departments, state offices, federal agencies, etc.). The lists are alphabetized by the data sets' tiles and include preview images of the data sets, links to the metadata, links to download the data (if available), and both the compressed and uncompressed size of the download files.

By organizing the data lists by these three categories, the WBN data could be kept under the *Biological* theme but could simultaneously be listed with other data sets by scale and by source. The WBN home page contains a direct link to the biological data sets within WNRDC, bypassing the WNRDC home page, as well as links to all the functionality of the WNRDC (*Search* function, *"What's new"* page, and *"Instructions for Downloading and Importing Data*).

In addition to listings available for browsing, the WNRDC also provides users with access to data by two other means: a metadata search engine and a data atlas.

The metadata search engine is based on a server supporting the Z39.50 protocol v.2/3, utilizing I-Site and I-Search "browse and search" software (Figure 2.1) (CNIDR 1998). Users can type in multiple keywords with "AND" "OR and "XOR" operators, and they can define certain fields to search within, such as title, abstract and thematic and geographic keywords, in addition to the default search based on the full

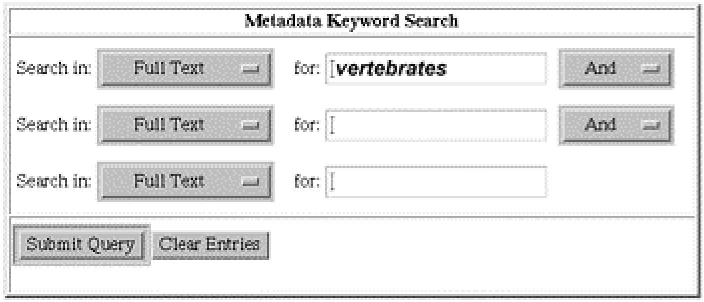

Figure 2.1. Example of the metadata search engine menu.

metadata text.

The search returns a list of all metadata documents matching the search criteria. Each metadata document contains a direct link to the data set's download page if the data is available for download. The WNRDC's policy is to provide metadata for as many data sets as possible, even those that are not available on-line. Data sets that are not available may be in draft form, in development, or proprietary or contain sensitive data that restricts their distribution. Metadata is provided about these data sets to avoid data duplication and to provide contact information.

Currently, the metadata search function searches all metadata documents within the WNRDC. Functionality has not yet been added to the search engine to limit the search to specific nodes within the clearinghouse, such as the biological node.

The data atlas, the third component of the WNRDC, was designed to allow the users easier access to large, statewide data sets and their tiles (Figure 2.2). In addition to the three WY-GAP data sets, the atlas provides images of statewide maps of digital elevation, hydrography, roads, geology, and National Wetlands Inventory data.

These statewide maps are image-mapped so that the users can click on the part of the state they are interested in and "zoom into" and download data for that particular tile.

The Species Atlas

Most of the available data sets, both in the WNRDC and specifically in the WBN node, are fairly straightforward to use. With the metadata document, even a non-GIS user with minimal knowledge of desktop mapping packages can view and query these data sets. However, it quickly became apparent that the complexity of the vertebrate database,

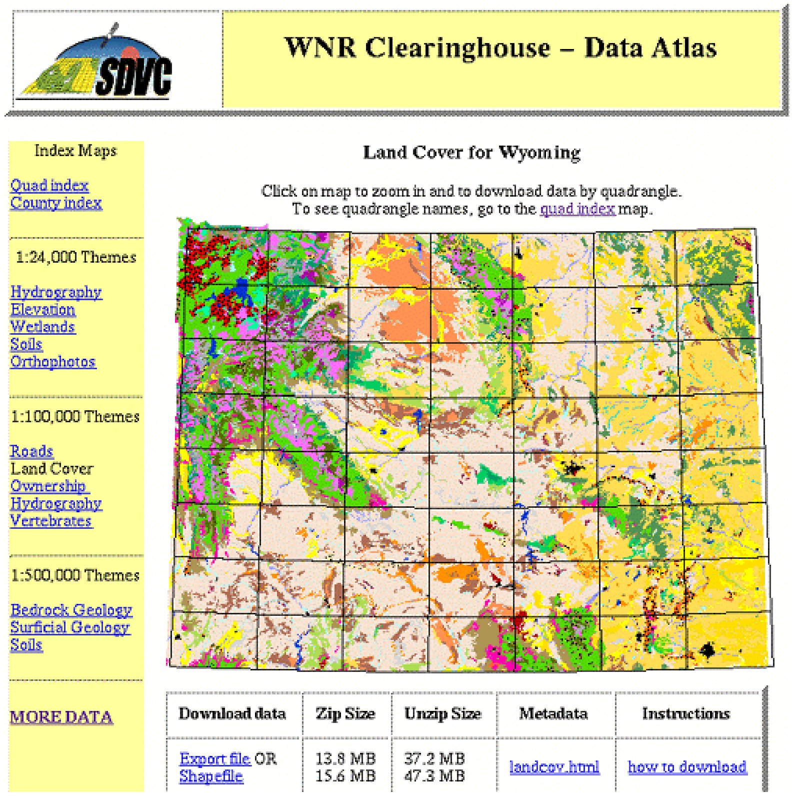

Figure 2.2. Sample page from the data atlas of the Wyoming Natural Resources Data Clearinghouse.

with 445 different species distributions represented in one enormous polygon file for the state of Wyoming, was not readily useable, even with detailed documentation. As a result, a simple ArcView desktop interface was developed to facilitate access to the vertebrate database (see Chapter 4). Because of the number of potential users of the WY-GAP vertebrate data without access to ArcView, we converted the information into a web-based Species Atlas. The Species Atlas uses snapshots of each individual species' distribution map, along with ecological and reference information, attached to a simple search engine by CGI scripts (Figure 2.3).

The Internet Map Server

While the Species Atlas contains static maps (snapshots), the project required an actual application using the data, an on-line tool with some limited GIS capabilities. Under a separate SDVC project, a simple Internet map server, the Wyoming Geological Database, was developed for geologic and mining interests in Wyoming as a sort of spatial library that

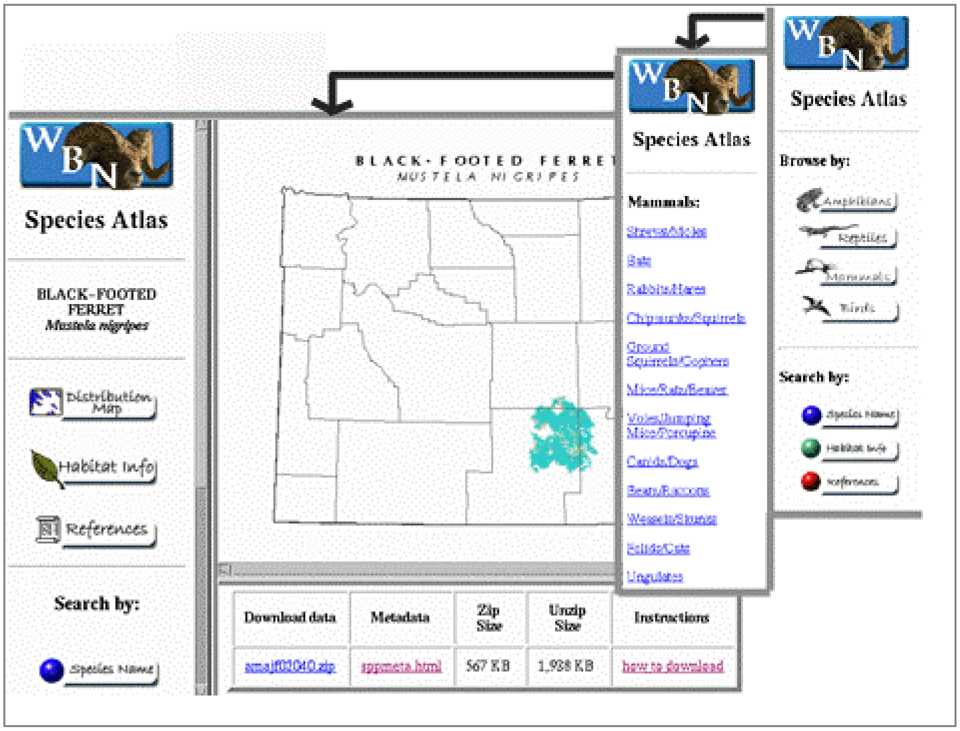

Figure 2.3. Example of the WBN Species Atlas.

allowed users to define an area of interest within the state and retrieve a listing of all the publications and data available for that area (Davis, Heasler and Polzer 1998). The tool uses ArcView Internet Map Server with a Java front-end to provide simple GIS capability to web users with no GIS experience. The tool walks users through the basics of working

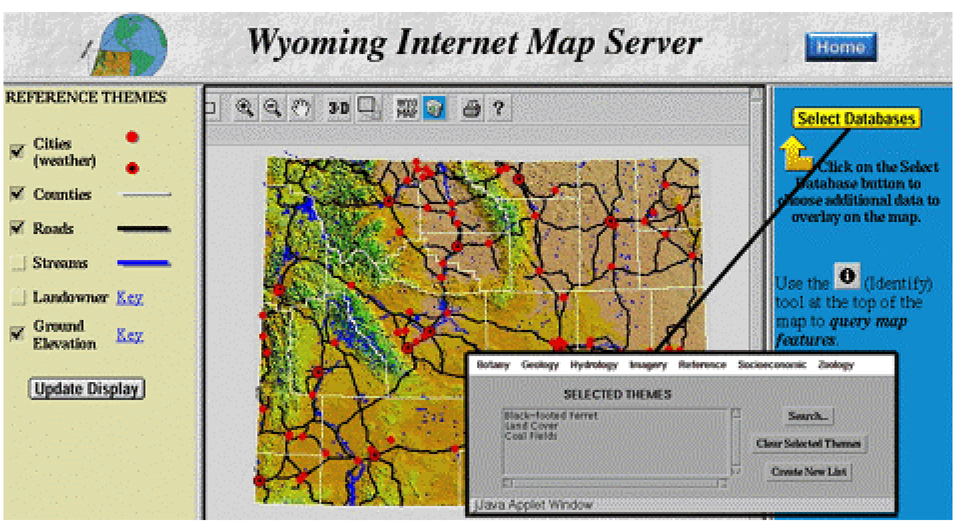

Figure 2.4. Example of the Wyoming Internet Map Server.

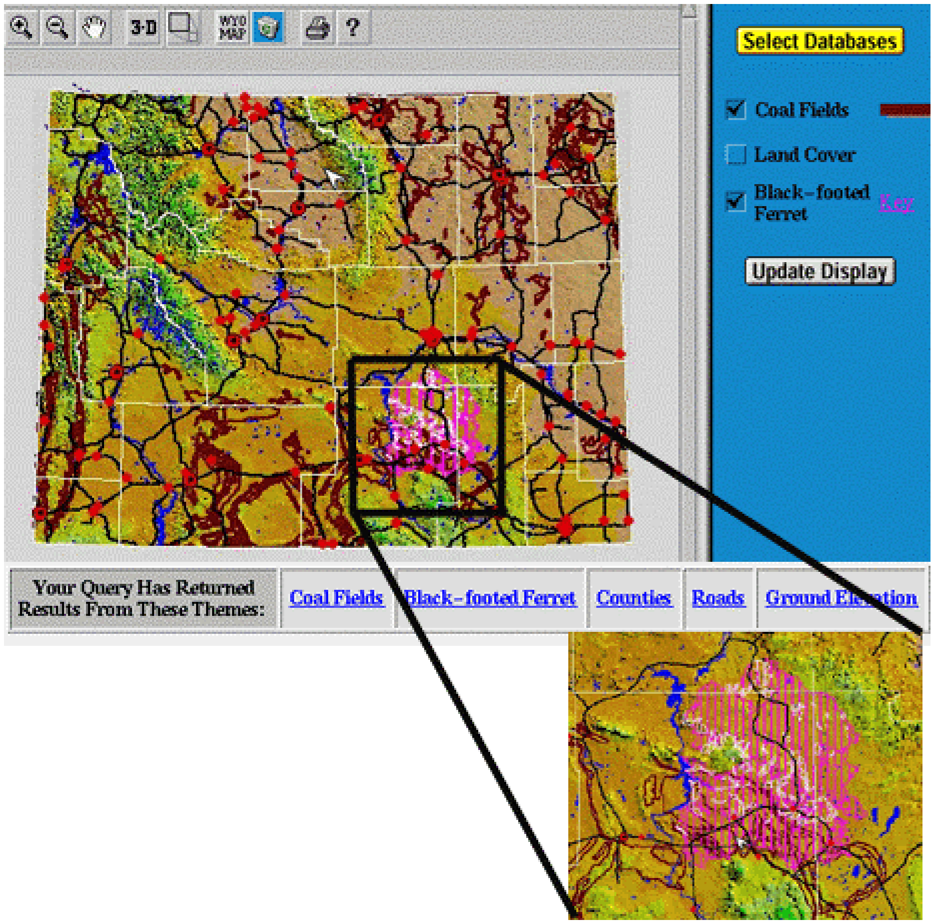

Figure 2.5. Example of a species distribution map created within the Wyoming Internet Map Server.

with a "live" map, such as zooming, panning, adding layers of information, and querying. The overwhelming response from a broad audience changed the focus of development from just geologic interests to other interests as well, so that it has been renamed the Wyoming Internet Map Server (WIMS) (Figure 2.4, found at *www.wims.sdvc.uwyo.edu*). Because the WY-GAP data were readily available for Wyoming, it was the next theme added to the map server, followed by some basic hydrological data and socioeconomic data (Figure 2.5).

This on-line application starts out as an image of a map of Wyoming, containing basic reference information, such as elevation and shaded relief, major roads, streams and water bodies, cities, and county boundaries. Other reference information, including the WY-GAP land ownership map, and township/range/section lines can be added to the image map by filling in the check boxes in the map's legend. The bulk of the application's power, however, is within its "databases" button. When you click on this button, a Java-generated menu pops up with headings including*: Earth Resources, Human Resources, Plants and Animals,* and *Reference*. From each of these menus, the users can select as many individual data sets as they are interested in viewing and querying.

All the WY-GAP vertebrate distributions, and the WY-GAP land cover map are available under *Plants and Animals*. Conceivably, many other information themes could be added to the system, allowing users to mix and match any type of data for Wyoming that they might have an interest in exploring. Tools also exist for zooming, panning, and identifying features on the map. Since the full functionality of ArcView GIS lies underneath the web application, more advanced GIS capabilities could be made available to users of the system who are interested in correlating and analyzing different data layers and their corresponding databases. The goal is to turn the Wyoming Internet Map Server into a general "Wyoming Information Database", a one-stop shop where everyone from geologists and county planners to new businesses and tourists can find out where to go for further information and to discover useful information that they might not even have been looking for initially, such as the WY-GAP data.

RESPONSE TO THE WBN

Since going on-line in August of 1997, the WBN WWW pages have received considerable attention from outside sources. This includes people visiting the web pages and people requesting their data be placed on the data node for redistribution.

Web Statistics

The WBN web site received 111,944 hits in its first year of operation, averaging 218 unique user per week. Most of these visits have been from commercial entities (i.e., .com domains including AOL.com) as illustrated in Figure 2.6. People from other educational institutions make up almost a quarter of all visits to the WBN. A significant portion of visitors is from unknown domains (e.g., those recognized only by their IP

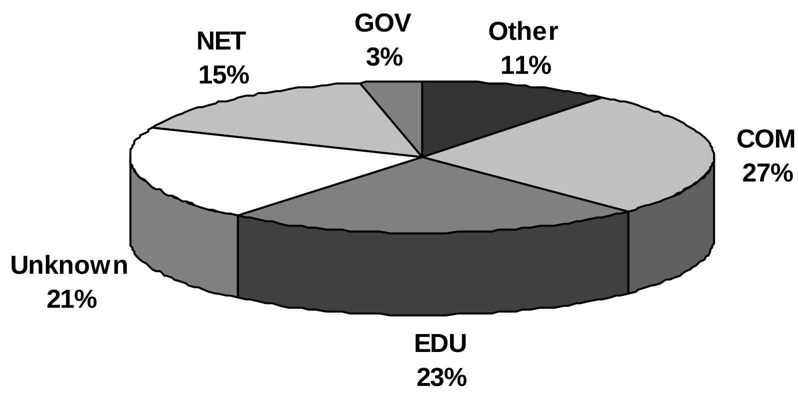

Figure 2.6. Percent of WBN users by Internet domain.

address). Surprisingly, very few government entities (3%) have visited the WBN.

The species atlas, in operation since October 1998, has been the most popular web site within the WBN, with 11,112 unique users (218 average per week) visiting the site during this period (Figure 2.7). The data download pages have been on-line since August 1997, and have averaged 18 unique users per week. One of the newest components of the WBN is the pages describing the Biological Expert System Tool (BEST) (see Chapter 3). These pages have an average of 16 unique visitors per week.

Data Providers to the WBN

Other departments and organizations wanting to make their data available on the Web approached WBN as a result of making the WY-GAP data more accessible via these Web-based tools. One of the conditions of serving data on the WBN is that it must be accompanied by fully compliant metadata, which the following contributors agreed to create and to maintain in exchange for having their data served and "advertised" on the WBN.

- The Rocky Mountain Herbarium provided a database of over 2,800 vascular plant taxa and their locations in Wyoming that were collected over a 100-year period.
- The United States Forest Service (USFS) Fish Habitat Relationships Unit for the Rocky Mountain Region provided their spatial data-

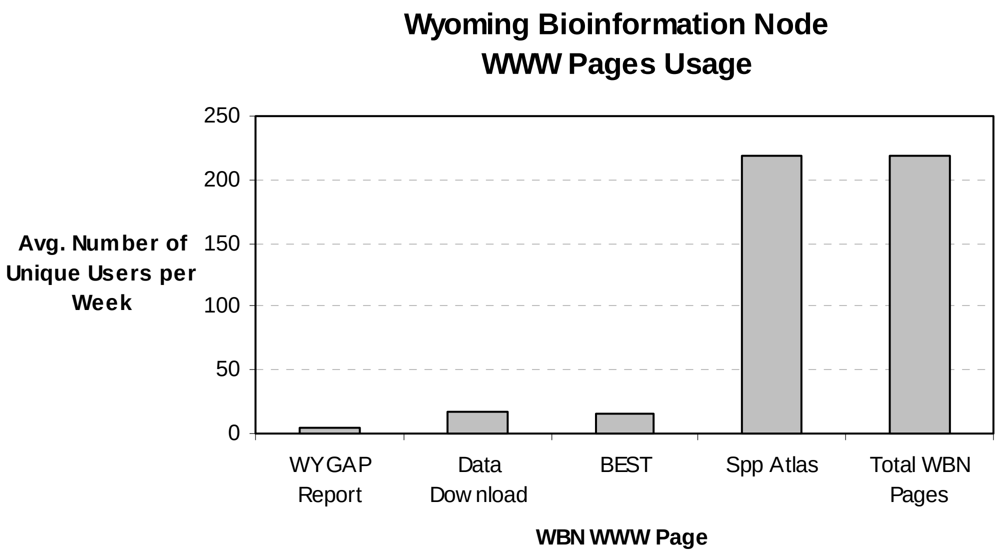

Figure 2.7. Average number of unique users of the WBN web pages per week.

base on the threatened species, the Colorado Cutthroat Trout, to the WBN.

- The University of Wyoming's Department of Renewable Resources is providing spatial and ecological data on Wyoming grasshopper species and infestations. The Internet Map Server is also incorporating spatial information on grasshopper infestations in Wyoming.
- The University of Wyoming's Department of Botany is providing spatial data from several of their projects, including land type association delineation for the state of Wyoming.
- The Wyoming Partners in Flight organization has made arrangements to have some of its information made available on the WBN web-site.

The USFS Fish Habitat Relationships Unit for the Rocky Mountain Region also provided money to purchase an NT workstation to provide an ArcView Internet Map Server dedicated specifically to serving WBN data, in particular the Colorado Cutthroat Trout database. A similar Internet Map Server application for the Rocky Mountain Herbarium plant collection atlas also was developed thanks to the acquisition of the machine. These two applications are described in greater detail in the following sections.

The Colorado Cutthroat Trout Database

The objective of this project was to develop a multi-state GIS database to assist watershed managers with the restoration of the Colorado River cutthroat trout (CRCT), *Oncorhynchus clarki pleuriticus*, in the Upper Colorado River Basin in Wyoming, Colorado, and Utah. Information on the distribution and status of cutthroat trout were imported into an ARC/INFO relational database, linked to mapped surficial hydrography, and incorporated into several other geographic layers of terrestrial information including land cover, land ownership and protection status, political and administrative boundaries, and topography. The Rocky Mountain Forest and Range Experiment Station published the results of this project as a General Technical Report (Young et. al. 1996).

The next phase of the project calls for the development of a prototype Internet Map Server for the cutthroat trout database focusing on the White-Yampa River Watershed in Colorado. The Cutthroat Internet Map Server (CIMS) will be accessible over the World Wide Web and will allow users to query and review information on the status of cutthroat populations (e.g., genetic purity, and presence of non-native fish species) located in the pilot watershed. Users of the CIMS will also be able to assess the risk of habitat degradation by overlaying stream reaches containing CRCT populations with existing information on land ownership, land cover, fire occurrences, stream gages, roads, and elevation. The CIMS will be accessible through the WBN by January 1999.

The Wyoming Plant Atlas

This application is based on the Rocky Mountain Herbarium's plant collection database, which contains over 180,000 plant specimens from approximately 2,800 different taxa collected in Wyoming. The location of the collections can give an approximate distribution map for the plant species, though like the WY-GAP vertebrate data, this distribution information is based on study locations and should not be considered representative of the species' actual statewide distributions. The on-line application, similar to the Wyoming Vertebrate Species Atlas, gives the user the option to search the database by typing in a species' common or scientific name to search for in the database or to browse through hierarchical lists of plant families, genus, and species. Once a species is selected, the Atlas will display a Wyoming map showing the recorded locations of that species. Unlike the Vertebrate Species Atlas, the distribution maps are not just static images but dynamic data layers powered by an ArcView Internet Map Server. Users can zoom and pan on the map and add other layers to the map such as land cover types, bedrock geology, shaded relief, elevation, roads, streams, and town locations. By clicking on the map, users can also identify what values are associated with the background layers, though information about the actual collection locations is not yet available.

In its current state, this tool is primarily of interest to botanists, though it could serve a broader range of users if additional information about the species could be linked into it, such as ecological information and references associated with the WY-GAP vertebrate database. In its current form, because of the complexity of the hierarchical menus required to browse for species, it has not been possible to incorporate this database within the comprehensive Wyoming Internet Map Server and so the plant data cannot be viewed and queried simultaneously with the WY-GAP data and other data layers.

IMPLEMENTATION CHALLENGES

Probably the most obvious difficulties associated with the implementation of a biological data node are the lack of initial fiscal resources for infrastructure development, and even more difficult, the lack of funds to sustain it over time. An intensive on-line application (Wyoming Internet Map Server) and a growing data node (the WNRDC) require a large amounts of hard drive space, a powerful computering array, and constant maintenance. The WBN currently houses nearly 5 gigabytes of data for downloading. Personnel are also needed for creating and updating web pages and web applications, processing data, and providing assistance with metadata.

There is no easy answer to finding support for this endeavor. The University of Wyoming's Spatial Data and Visualization Center has similar goals for documenting data and promoting data-sharing. This Center houses the WNRDC, which encompasses not only the Wyoming Bioinformation Node but several other "nodes", including the Snake River Corridor Geospatial Data Node. Funding continues to be an issue for each individual component as well as for the Center. However, placing the WBN within a larger clearinghouse does allow for sharing hardware, software, and personnel, which cuts down on costs. In addition to the WBN information, the SDVC's Wyoming Natural Resources Data Clearinghouse also provides information about water resources, geologic and mining interests, and is expanding into socio-economic data and applications, which provides for a larger user-base than just those interested in biological data. At the same time, integrating the biological data with these other types of information, as in the example of the Internet map server, showcases the utility of biological information to many new users. There are several possible avenues that the WBN and its parent clearinghouse could follow:

- The SDVC could charge for web services, hard drive space, and/or metadata services to maintain its cost of operations.
- The WBN and its parent clearinghouse may reach the point where it is perceived as a useful and needed tool by a large enough body of users that there will be direct support from the users or direct support from state or local governments recognizing its service to the public. The President's Committee of Advisors on Science and Technology suggests that the "next generation" of NBII, containing more extensive databases and tools to use and integrate them, would become at least in part self-sustaining – as did the Internet itself – but that the initial impetus for its creation must come from the Federal government (PCAST 1998).
- The WBN and its parent clearinghouse could switch over from a "centralized" to a "distributed" clearinghouse. The advantage of a distributed system is that the clearinghouse points to individual organizations who are responsible for providing and maintaining their own data, whereas a centralized clearinghouse requires a concentration of hard drive space and a "middle-man" to coordinate data updates. At this point, the WBN is constrained in its development as a centralized clearinghouse, simply because

potential partners do not have enough money to purchase required hardware and software or the time to prepare their data for on-line distribution. However, given the probability for such time and money in the future, such a distributed system will be unwieldy and unreliable without underlying standards to smooth out the data-sharing process. In this scenario, the WBN would still play the role of a motivator, educating organizations about the FGDC metadata standard for geospatial data and the NBII standard for biological data in exchange for increasing our own "metadata database" and increasing Wyoming's knowledge in general about various sources of available data.

Another obstacle to long-term continuation of the WBN is that not everyone wants to or is able to share their data. They've invested too much time and money in their data and want some kind of compensation for it, or they are constrained by other limitations within their organization's policy. Two big contributing sources to WY-GAP's vertebrate distributions were the Wyoming Natural Diversity Database and the Wyoming Game and Fish Department's Wildlife Observation System, both of which are proprietary databases containing sensitive information such as nesting locations of endangered or threatened species which should not be advertised freely on the Internet. While neither organization was willing to share their data, they were convinced of the utility of the Wyoming Bioinformation Node and willing to have their databases "advertised" on the WBN through metadata which contains a description of their data and contact information for how to obtain it. Not only does the metadata educate other people about available data, but it also educates the data providers about what other data providers are collecting, hopefully resulting in less data duplication and more focus on needed areas.

A final issue that the WBN encountered in its implementation relates to data sensitivity. Some biological data sets, most notably the Rocky Mountain Herbarium plant collection database and the Wyoming Natural Diversity Database, contain records of plant and animal species that were collected on private land. Permission was obtained from landowners prior to collection, but unfortunately, written documentation of permission rarely exists. As this data becomes more and more visible and accessible to both the public and to regulatory agencies, landowners' privacy and rights have become a heated issue in Wyoming. As a result of these growing concerns, the Wyoming State Legislature recently required that plant and animal specimens collected on private lands must possess documented landowner permission to be included in the Wyoming Natural Diversity Database. In order to avoid the same fate, the Rocky Mountain Herbarium database has not been allowed to go on-line in its present form. There are several possible scenarios for databases that contain information collected on private land. This information could be restricted (password protected) on-line to only registered users, records collected on private land could be removed from the on-line application, or the point records could be generalized within larger units in order to obscure their original location.

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CHAPTER III: BIOLOGICAL EXPERT SYSTEMS LAND-USE PLANNING TOOL (BEST)

INTRODUCTION

The Biological Expert System Tool (BEST) is a geographic information system (GIS)-based spatial decision support system designed to promote biological considerations in local land use planning. BEST is capable of reporting species and plant communities that are mapped on land parcels along with the type and degree of impact that is likely to occur with an associated land use change. It also provides the ability to overlay additional natural resource maps, generate reports, view documents related to how the data were developed, and most importantly, provide mitigation suggestions to minimize impacts.

In an ideal world, every human land use project (e.g., development) would be evaluated through the application of spatial analysis and field study for its likely impacts both onsite and offsite and cumulatively for all biotic elements (plant communities and animal species) in a region. Unfortunately, few local governments can even afford to update their comprehensive plans in a timely manner, let alone maintain staff biologists to conduct project assessments (Olshansky 1996). Attempts to put the burden of scientifically assessing impacts on development applicants in states such as California have failed, as virtually every project was assessed to be of negligible impact (Olshansky 1996). Conducting such assessments after investment has been made in land, acquisition, site planning, and consultants makes it nearly impossible, politically, to substantially alter or stop inappropriate projects.

BEST addresses these issues by creating a system that can be generalized to any land tract, land use, and biotic element (plant community or animal species), providing an early warning system of potential conflict prior to applicant investment in an unsuitable project (Longrie 1976) and aiding in the identification of mitigating features that will allow for less contentious project approval. The need for such a system was identified as early as 1976 by Thillman and Monasch who stated that wildlife biologists need to provide recommendations to land use planners consisting of:

- An inventory of wildlife specifically citing location and diversity,
- An analysis of the wildlife citing vulnerability, tolerance, and uniqueness, and
- A translation of the analysis to both area-wide planning criteria for general density and intensity of use and site specific animal tolerance to different kinds of development schemes (Thillman and Monasch 1976).

BEST takes an individual element and tract approach (Duncan 1986) rather than a traditional local government approach of identifying the "critical habitat areas" historically used to designate rare, unusual, or exceptional areas. In the past, such practices failed to keep "common species common" and lead to further loss of biodiversity (Hallock 1986). This is not to say that an "important habitat" concept in developing comprehensive plans is not useful. When used in conjunction with a biotic element analysis and spatial landscape ecological analyses, rather than as a focus on only a few charismatic species, it is a useful way to establish that collection of habitat areas most capable of sustaining local and regional biodiversity.

DEVELOPMENT OF BEST FOR TETON COUNTY, WYOMING

In September of 1997, the project team set out to create an operational BEST for a pilot county. A number of counties in Wyoming were considered under the following criteria: status of the county's comprehensive plan, degree of biodiversity, threats to biodiversity, diversity of land ownership and management status, GIS infrastructure, and interest in participation. The intent was to design and develop a database framework for BEST and program the necessary functionality to operate the system for one county, while making it easily adaptable to other counties.

Teton County, Wyoming, (Figure 3.1) was ultimately chosen as the pilot for a BEST prototype because of its biological diversity and the internationally-known reputation of its flora and fauna. Seventy-five percent of Wyoming's terrestrial vertebrates are present within the county and it is especially diverse in avian species (Merrill et. al. 1996). The county is dominated by mountainous landscapes and broad valleys shaped by both historic glaciers and present day fluvial systems. It is in these valley bottoms that the fauna diversity is highest and where human

Figure 3.1. Map of Wyoming highlighting Teton County (in Grey), the BEST pilot study.

settlement is most pronounced. Only four percent of the county is privately owned, yet it is experiencing the highest growth rate (24.6% between 1990 and 1997) of any county in Wyoming (U.S. Census Bureau 1998). For this reason, county officials face the challenge to balance the need for increased growth with maintaining the remaining privately-owned open space.

In addition, Teton County is one of the few Wyoming counties with a comprehensive land-use planning document and necessary spatial databases in place to develop BEST. BEST requires the GIS databases developed by the Wyoming Gap Analysis Program (WY-GAP) and a digital parcel layer or similar land grid with an appropriately sized analysis unit to perform the biological analyses. For Teton County, the project team used the recently completed databases from the WY-GAP and the county's digital parcel layer developed by Greenwood Mapping, Inc. of Jackson, Wyoming.

Three separate components comprise BEST. The first, land use categorization, ranks the impacts of the county's designated land uses. The biotic element databases combine both the animal species database and the land cover database. Both of these databases rank the sensitivities of individual animal species or vegetation communities to the land use impacts. Finally, all of these databases are brought together within the BEST interface, which allows the user to evaluate multiple land use scenarios.

Land Use Categorization

The Teton County Comprehensive Plan (Teton County 1994) provided the land use descriptions used to construct the land use database. The project team applied an ordinal-scaled ranking system (low, moderate, high, severe) to each of the 48 land use types listed in the plan. The rankings represent the expected impact on the natural land cover communities and the amount of direct human disturbance associated with the land use. Specifically, the team ranked the impact of each land use on five variables of land cover: vegetation structure, species composition, dominant species, hydrologic regime, and disturbance regime. The intensity, frequency, and duration of humans on the tract were also ranked. Impacts were based on an average tract size of 55 acres for subdivision uses (derived by the GIS using tracts in the county currently zoned as rural) or a minimum tract size for individual uses if specified in the comprehensive plan. Table 3.1 presents an example of the land use rankings for Teton County. Typically the planning department or consultant of the local government jurisdiction would be involved in this ranking process. However for this pilot study, the team completed the rankings using only the land use descriptions provided in the comprehensive plan.

Biotic Element Databases

The second component of BEST is the biotic element databases that

Table 3.1. An example of the land use rankings within the biological decision support system developed for Teton County, Wyoming. L=Low, M=Moderate, H=High, S=Severe.

	Land Cover Alteration						Human Presence Conflict			
land use	structure	spp comp	dominant	hydro	disturb	Rank	intensity	frequency	duration	Rank
agricultural employee housing	S	S	S	H	S	4	L	H	M	3
conventional single-family unit	L	L	L	L	M	2	L	M	M	2
conventional single-family subdivision	H	H	H	H	S	4	L	H	M	3
planned residential	H	H	H	S	S	5	M	H	M	3
planned unit development	0	0	0	0	0	0	0	0	0	0
mobile home	L	L	L	L	M	2	L	M	M	2
mobile home park	H	H	H	H	S	4	L	H	M	3
working ranch subdivision	M	H	H	L	M	2	L	M	M	2
guest house/guest unit	0	0	0	0	0	0	0	0	0	0
accessory residential unit	0	0	0	0	0	0	0	0	0	0
institutional residential	L	L	L	L	M	2	L	H	M	2
agriculture	S	S	S	M	S	4	L	M	L	2
nurseries	S	S	S	H	S	5	L	H	M	3
institutional	0	0	0	0	0	0	0	0	0	0
utilities	0	0	0	0	0	0	L	L	L	0
day care center, group day care home	L	L	L	L	M	2	L	H	H	3
office	0	0	0	0	0	0	0	0	0	0
planned commercial development	0	0	0	0	0	0	0	0	0	0
commercial retail	0	0	0	0	0	0	0	0	0	0

consist of both animal species and land cover sensitivity rankings. The design and construction of these databases was the most difficult and time-consuming portion of BEST. The development of these databases involved five unique phases: selection of biotic elements, animal species sensitivity rankings, land cover sensitivity rankings, literature review, and mitigation suggestions.

Selection of Biotic Elements

The first task in developing the biotic element databases was to choose which elements would populate BEST. For the land cover database, the project team included 17 of the 23 elements mapped within the county by WY-GAP. Land cover types like alpine exposed rock/soil, meadow tundra, and open water were excluded because they were not likely to be disturbed by human development using the criteria the project team established.

For the animal species, the team began with the total 331 species that were predicted to occur in the county based on the WY-GAP findings. Due to limited resources for the development of BEST, the team quickly eliminated species by excluding those that were not of management concern by state and federal agencies and conservation organizations. Initially, species were excluded if they were not "gaps" identified by WY-GAP, ranked as S1 or S2 by The Nature Conservancy (see Fertig 1997 for description of codes), Wyoming Game and Fish Department "species of special concern" (Oakleaf et. al. 1996), USFS Region 4 sensitive species, or U.S. Fish and Wildlife Service's candidate, threatened and endangered species. However, the resulting list of species was still too large to compile for this pilot project. Thus a second filter was applied which included only species that had at least 10% of the species habitat on private land within the county, assuming that these species would be of most concern to county officials.

At this point, a few individual species (House Finch, Red-eyed Vireo, and Ring-billed Gull) were removed from the animal species list because they appeared to benefit from human disturbance and would not be a meaningful addition to BEST.

Next, the list was cross-referenced with Luce et. al. (1997) to eliminate migratory birds from the list because BEST is not currently designed to address these species. Migratory birds that were not suspected to breed within most of Teton County were removed from further consideration. This filter removed a large number of "occasional" and "incidental" bird species that were not considered priority within Teton County by the Wyoming Game & Fish Department (Oakleaf 1998). Four exceptions were made to these decision rules. The Towsend's Big-eared Bat, Flammulated Owl, Eastern Screech Owl, and Spotted Frog were not documented as breeding in the area but were included in the list because some local biologists considered them likely breeders. The final animal species list contained 24 birds, 13 mammals, 2 amphibians, and 1 reptile for a total of 40 species.

Animal Species Sensitivity Ratings

Literature review, consultation with fellow biologists, and personal knowledge were used in combination to complete the subjective ranking of sensitivities to the land cover alteration and human presence categories. The sensitivities were ranked assuming that no mitigation efforts would take place, although the sensitivity of the animal species and vegetation communities may be lowered if appropriate mitigation techniques are applied.

Species sensitivities were ranked with regard to five animal behaviors: habitation, home range, breeding/rearing, foraging, and cover. An example of an animal species sensitivity rankings is presented in Table 3.2. The following are a series of comments detailing the assumptions made in the ranking of animal species behaviors:

> *Habitation:* Animals are affected during the development phases (e.g., construction of a house) and subsequent human habitation. Disturbance is greater on small mammals and amphibians without the capabilities to move away and occupy other areas than birds and large mammals with more mobility. (Habitation and home range behaviors were difficult to rank early on because the size of the tract was not clearly defined until about midway through the process when it was decided to use the average tract size of 55 acres as with the land use rankings.)
>
> *Home Range:* Less mobile animals are again more affected by impacts on home range. In addition, species with larger home

Table 3.2. An example of an animal species sensitivity rankings within BEST for Teton County, Wyoming.

	Water Vole								
	Habitation	Home Range	Breeding/Rearing	Foraging	Cover	Reference #	Mitigation #	Highest Sensitivity	Total Sensitivity
Land Cover Alterations									
Level 1	2	2	2	2	2	11,122,158,196-199	1,28,64-66	2	10
Level 2	2	2	2	2	2	11,122,158,196-199	1,28,64-66	2	10
Level 3	3	3	3	3	3	11,122,158,196-199	1,28,64-66	3	15
Level 4	4	4	4	4	4	11,122,158,196-199	1,28,64-66	4	20
Level 5	4	4	4	4	4	11,122,158,196-199	1,28,64-66	4	20
Human Presence									
Level 1	2	2	2	2	2	11,122,198	66	2	10
Level 2	2	2	2	2	2	11,122,198	66	2	10
Level 3	2	2	2	2	2	11,122,198	66	2	10
Level 4	3	3	4	3	3	11,122,198	66	4	16

ranges are less affected than those with smaller home ranges. For example, a 55-acre tract development may have minimal influence on a grizzly bear or wolf because of the large size of the home range. However, a similar development may destroy habitat for an entire breeding colony of water voles.

Breeding/Rearing: Species are most sensitive to this variable. Avian species that raise their young at a particular site and are tied to that site until fledging occurs are especially sensitive to impacts on breeding and rearing.

Foraging: Human presence has a minimal impact on foraging. Habitat degradation and removal of food sources impact animals' foraging strategies more. For example, animals that feed on insects are affected by human activities such as pesticide application. All other destruction is related directly to habitat degradation and the removal of food supplies.

Cover: Both hiding cover and thermal cover were considered within the classification scheme. Hiding cover was an important determination for prey species and any animal trying to escape human presence. Thermal cover is important for all species to effectively thermoregulate.

Land cover sensitivities were ranked in regard to five vegetation characteristics: structure, species composition, dominant species cover, hydrologic regime and disturbance regime. The following are a series of comments detailing the assumptions made in the ranking of the five land cover characteristics:

Structure: Sensitivity was determined by how many layers are in the plant community structure and how susceptible they are to human disturbance. Communities with tree and shrub structure are generally more susceptible to land cover alteration than human presence, whereas grass and riparian communities typically lose all structure in land cover alteration but not low to moderate levels of human presence.

Species Composition: Because interactions are generally unknown, any loss in species composition is harmful. More diverse communities can withstand a loss in species composition better than less diverse communities.

Dominant Species: The impact of human activities on the dominance of the plant community was estimated based on susceptibility and whether the existing community is co- or multi-dominant or single dominant (i.e., if it is grass or shrub it is more sensitive to human activities than tree canopy). Changes in dominance are less serious in mixed-dominant communities (e.g., mixed conifer) than in single-dominant ones (e.g., aspen).

Hydrologic Regime: The primary criterion is the dependence of the plant community on a stable hydrologic regime. Any disruption of the hydrologic regime would be harmful in a riparian community or one existing in a drainage. For arid type plant communities, supplemental water either through redirection of drainages or through irrigation may introduce invasive plant species that can outcompete those native to the community. Mesic upland communities are assumed to be more resilient to hydrologic change.

Disturbance: Whether the land cover change or human presence interferes with natural disturbance regimes, and whether the land uses cause or introduce disturbances to which the community is not adapted were assessed. The assessor had the least amount of knowledge of disturbance regimes for these types, so additional assessments by a local plant ecologist are recommended.

Literature Review

Once the biotic element lists were finalized, a literature review was conducted for each element. The biologist who conducted the review searched journal articles pertaining to human-related disturbances to wildlife and vegetation from libraries at the University of Wyoming and the Wyoming Game and Fish Department. However, due to the specific nature of the search, the best source of information often came from experienced field biologists who were willing to contribute their personal knowledge. A total of 214 references were compiled for the animal species database.

Mitigation Suggestions

While compiling literature references for each animal species, the biologist also recorded mitigation techniques that have been used to minimize or counteract negative impacts on wildlife species or vegetation. These mitigation techniques were added to the database as recommendations or suggestions for the end user of BEST. The statement, "Human disturbance should be restricted to at least 400 feet from a nest during the breeding period" is an example of a mitigation suggestion included in the animal species database. These suggestions may be helpful in the determination of whether the proposed land use is compatible with the biotic element or if, during the initial design phase of a development project, the impact of the development can somehow be mitigated through changes in the land use design. A total of 77 mitigation suggestions, based mainly on scientific studies and expert review, were compiled for the 40 species included in BEST.

BEST interface Design and Development

Upon completion of the land use and biotic element databases, the next step in the development of BEST was designing an interface that would allow the user to quickly and easily reference the information in the aforementioned databases. The BEST interface was initially designed for land use planners who might have limited knowledge of biology or GIS. BEST users are guided through a series of menus that allow them to evaluate multiple land use scenarios and their potential impact on sensitive biological elements for any given tract within the county.

The software chosen for the development of the interface was

BEST System Requirements

BEST requires ArcView 3.0x or above to operate. Users of ArcView 3.0x must have installed and loaded the Dialog Designer extension (see http://www.esri.com/software/arcview/avsoftware.html for free download of Dialog Designer extension). ESRI now packages the Dialog designer extension with ArcView 3.1 and above.

BEST and its associated Teton County, Wyoming, databases require approximately 65 Mb of hard drive space to operate. For optimum performance, BEST should be run on a 200+ Mhz pentium PC with a minimum of 64 Mb RAM.

ArcView 3.0a, a product from Environmental Systems Research Institute (ESRI) of Redlands, California. ArcView is a desktop GIS software product using a point-and-click interface that can be customized using ESRI's Avenue programming language. The project team did not remove any of the existing functionality of ArcView but added some new functions through drop-down menu choices that begin the operation of BEST. Most of the new functions added to BEST were constructed using the Dialog Designer extension within ArcView, which made it possible to customize menus for user input and data retrieval.

OPERATION OF BEST

BEST Components

The BEST interface consists of three windows within the ArcView desktop (Figure 3.2). The first is the project window located within the upper left of the desktop. The project window serves as the manager for all the various document types (e.g., views, tables, and scripts) within Arcview.

The second window located in the right half of the desktop is the tract window (Figure 3.2) and contains the county parcel map. This window is where the user interaction (i.e., selection of tract) takes place. The areas in white represent privately-owned tracts of land in the county while the areas shaded gray indicate federal or state lands that are not included as analysis units within BEST.

The third window, located at the bottom left of the desktop, is the map index window (Figure 3.2). This window depicts a smaller scale map of the county and is used to orient the user when navigating in the tract window. The crosshatched rectangle represents the area in view on the tract window. The rectangle will move and resize as the user pans

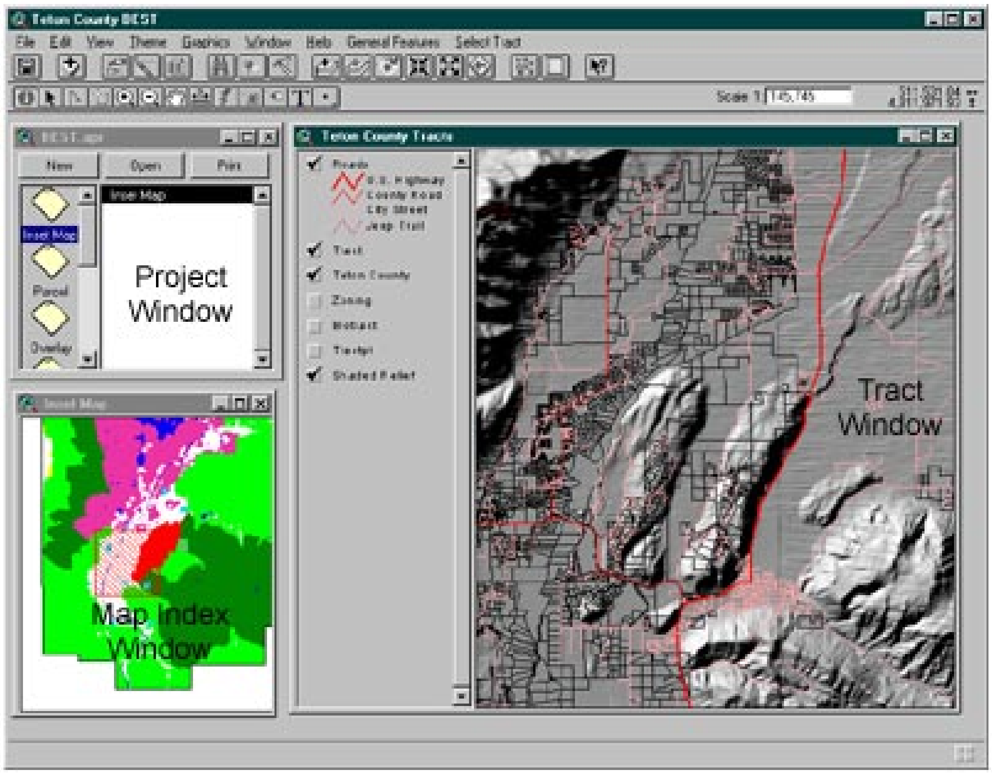


Figure 3.2. The tract window and map index window in BEST showing land parcels for Teton County.

and zooms around the tract window.

Tract Selection

BEST users begin by selecting tracts using the drop down menu at the upper right corner of the menu bar. Users may select tracts interactively using a mouse or by typing in a Parcel Identification Number (PIDN) which uniquely identifies every privately owned tract in the county. If the users select tracts with the mouse, the system will prompt them to point and click on individual tracts within the tract window. If the users select tracts using PIDN numbers, a menu will be displayed prompting them to type in a 20-digit numeric code for the desired tract. A default PIDN number is listed in the menu when first displayed and may be replaced with a user-defined PIDN.

Once the tract is selected either by mouse or PIDN, the tract window is refreshed and the selected tract on the map is highlighted in yellow. At this point, an information menu will appear showing the owner and address for the selected tract (Figure 3.3). This allows users to verify that the correct tract has been chosen. At the bottom of the

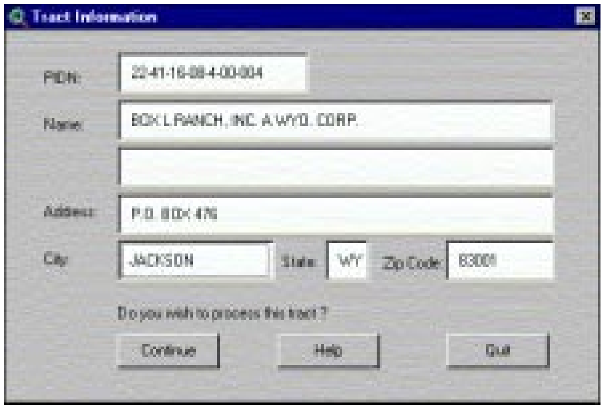


Figure 3.3. Menu showing owner information for selected tract in BEST

menu, users are asked if they would like to process this particular tract. If the users choose "No," the BEST routine will terminate. If "Yes" is chosen, users will be prompted to select an allowable land use for the tract.

Land Use Selection

The next menu in BEST prompts users to select an allowable land use for the previously selected tract (Figure 3.4). The allowable land uses for the tract are determined by the current land use zone displayed at the top of the menu. Once a land use is selected, the land cover alteration and the human presence conflict rankings are presented at the bottom of the menu. A rating of "N/A" means that there was not enough information available in the county land use plan to rank that particular land use.

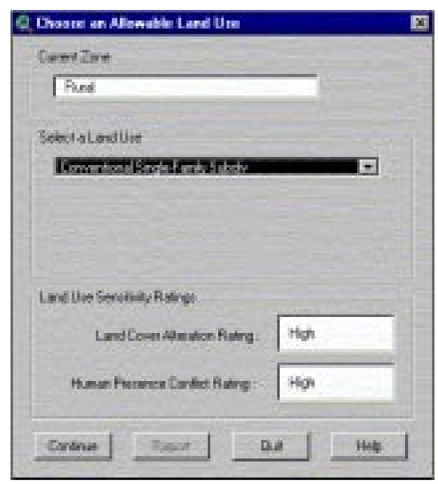


Figure 3.4. Land use selection menu in BEST.

Selection of Biotic Element for Analysis

With the tract and land use chosen in previous menus, users are now prompted to select the biotic elements for analysis (Figure 3.5). Users may choose to have BEST perform a land cover assessment or animal species assessment. If a land cover assessment is chosen, users are given the option to filter only land cover types of concern as identified by the WY-GAP project. If users choose an assessment of animal species (which is the default option), they may apply one of several filters as listed in Table 3.3.

Once the assessment type is selected, BEST will begin to search the WY-GAP databases for all species and land cover types predicted to be present on the tract. Upon completion of the search, a menu listing the results of the search will be displayed.

Results

The results of the biotic element assessment are presented in a menu with three distinct sections (Figure 3.6). The top section lists the PIDN and zone of the tract along with the land use that the user had previously selected.

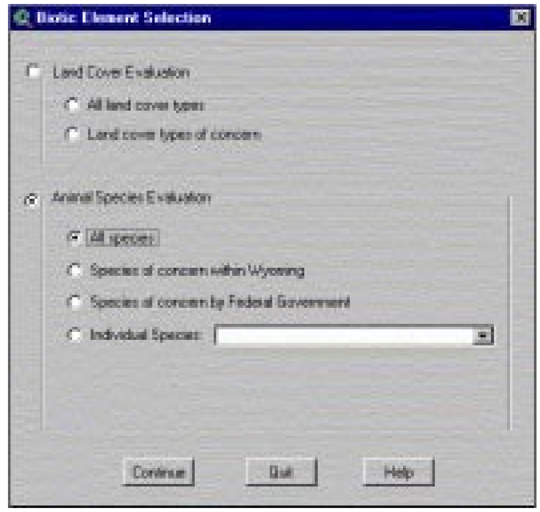


Figure 3.5. Biotic element selection menu in BEST.

The middle section of the menu displays the number of biotic elements predicted to occur on the tract. At this point users must select an individual element from the scrolling list to retrieve more information from BEST. Once an individual element is selected, BEST references a series of tables containing attributes about the element (e.g., federal and state rankings) and sensitivity ratings for each element. If the selected element is a species or land cover concern, the agency ranking would appear in the middle section of the menu next to the federal or state agency with which it is listed.

The bottom portion of the results menu lists the expected sensitivities of the element to the estimated impacts of the user-defined land use. These sensitivities are based on the biotic element databases described above.

Table 3.3. Filters that may be applied to the evaluation of animal species within BEST.

Filter	Selected Species
All Species	All species present within the county as modeled by the Wyoming Gap Analysis Project (Merrill et. al., 1996).
Species of Concern within Wyoming	Animal species that are listed as SSCI, SSC2, or SSC3 by the Wyoming Game and Fish Department (see Luce et. al., 1998 for definitions of codes)
Species of concern by Federal Gov't.	Species listed as candidate, threatened or endangered by the U.S. Fish and Wildlife Service or listed as "sensitive" by Region 4 of the U.S. Forest Service
Individual Species	User is given the option to select any one species predicted to be present within the county

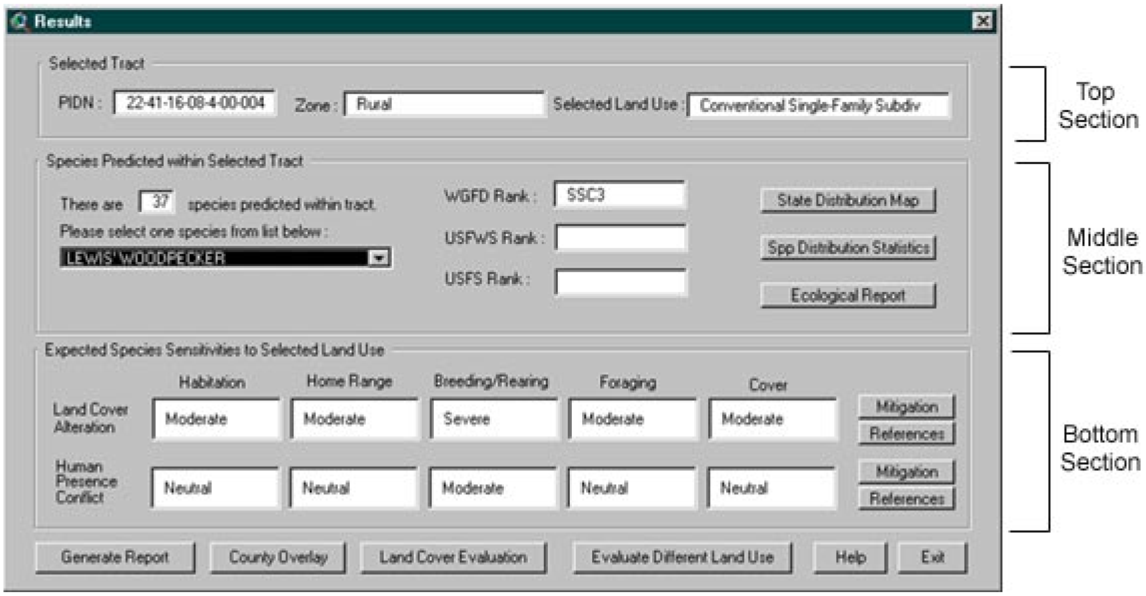


Figure 3.6. Menu presenting the results from the animal species evaluation in BEST.

To access additional information about the biotic element, users can select one of three buttons on the right side of the middle section. The information referenced by these buttons come directly from summaries of the WY-GAP project.

The first button, *State Distribution Map*, will open an image showing the statewide distribution of the biotic element (Figure 3.7). The areas in green and tan represent suitable habitat for the element that is within the species' predicted range. The map is intended to give users a different perspective on the distribution of the biotic element and help determine the county's role in the species conservation.

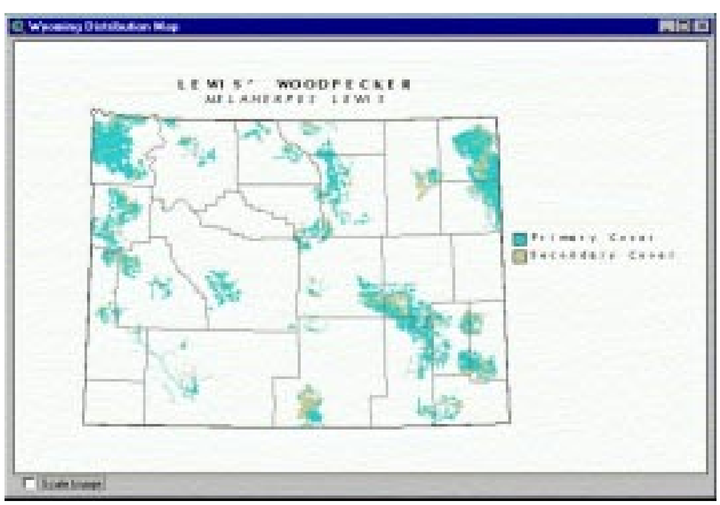


Figure 3.7. Example of a statewide species distribution map available in BEST.

The *Spp. Distribution Statistics* button will activate another menu containing pre-calculated statistics on the distribution of the element's habitat across

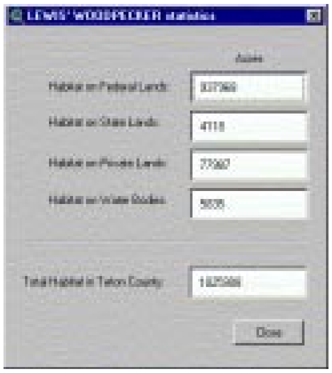


Figure 3.8. Species distribution statistics

federal, state, and private lands within the county (Figure 3.8). This tool helps determine who plays an important role in the conservation of the biotic element within the county.

The *Ecological Report* button opens a text file containing habitat affinities information for the element (Figure 3.9). The text file includes information on the elevation range, habitat associations, and mapping constraints that were encountered in modeling the distribution of the biotic element. This type of information will be helpful when verifying the presence and suitable habitat of the biotic element on the tract used in the analysis.

To the right of the sensitivity ratings are buttons labeled *References* and *Mitigation*. The *References* button opens a text box listing all the scientific literature used to establish the element's sensitivity ratings by the biologists. The *Mitigation* button opens a text box listing general mitigation suggestions on how to avoid human-related impacts (Figure 3.10).

County Overlay

The user may view the distribution of the biotic element in relation to the selected tract by choosing the *County Overlay* button from the bottom of the results menu. This button will create a new map view containing the element's distribution (in red and blue cross-hatching) overlaid with the selected tract highlighted in yellow (Figure 3.11). Reference themes such as roads, rivers, lakes, and elevation can quickly and easily be added to the map view from a pulldown menu from the menu bar. At this point, users have all the pan/zoom/query capability that ArcView provides and may at any time return to

Figure 3.9. An example of an ecological report for an animal species generated by BEST.

Figure 3.10. Mitigation suggestions on how to avoid human-related impacts.

the results menu to process another tract or biotic element.

Report Generation

Users may also choose to generate a summary report for all species by clicking the generate report button. This button will create a new text document listing all the biotic elements predicted to occur on the tract along with the expected level of impact the land use will have (Figure 3.12). This report is generated within a windows-based text editor and can be saved or printed at any time.

Upon completion of the biotic assessment, users may go back and run another assessment using a different biological filter or choose a different land use for evaluation.

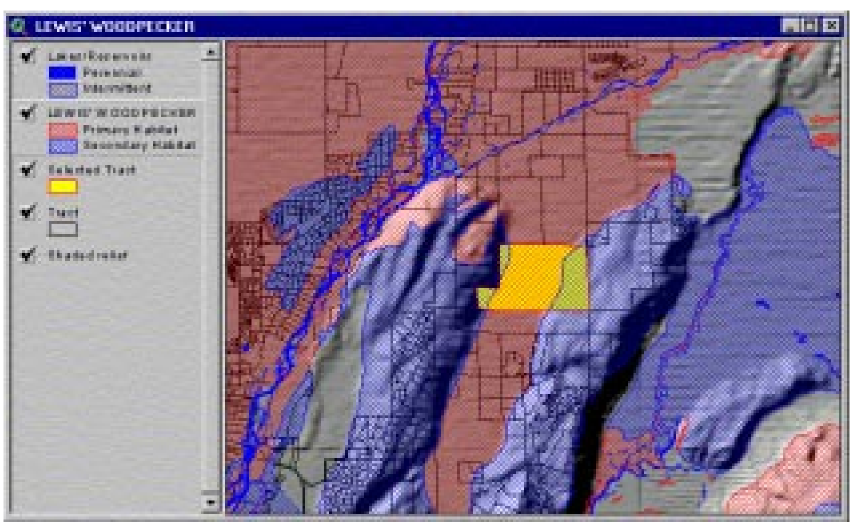
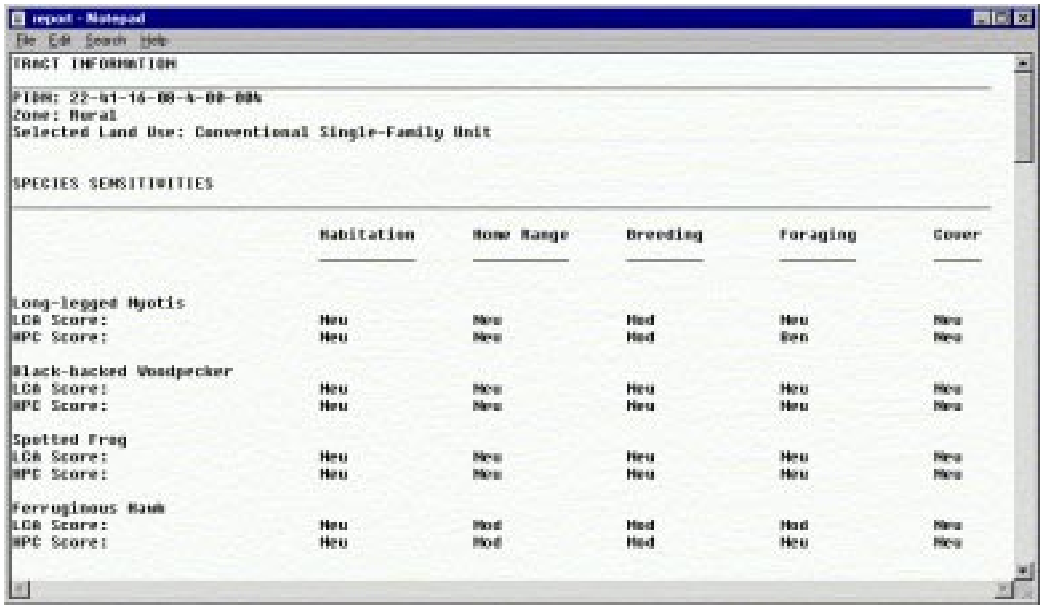


Figure 3.11. Graphic window in BEST showing the distribution of a biotic element overlaid with a previously selected tract.



report - Notepad

TRACT INFORMATION

PIDN: 22-41-16-00-4-00-006
Zone: Rural
Selected Land Use: Conventional Single-Family Unit

SPECIES SENSITIVITIES

	Habitation	Home Range	Breeding	Foraging	Cover
Long-legged Myotis					
LCA Score:	Neu	Neu	Mod	Neu	Neu
HPC Score:	Neu	Neu	Mod	Ben	Neu
Black-backed Woodpecker					
LCA Score:	Neu	Neu	Neu	Neu	Neu
HPC Score:	Neu	Neu	Neu	Neu	Neu
Spotted Frog					
LCA Score:	Neu	Neu	Neu	Neu	Neu
HPC Score:	Neu	Neu	Neu	Neu	Neu
Ferruginous Hawk					
LCA Score:	Neu	Mod	Mod	Mod	Neu
HPC Score:	Neu	Mod	Mod	Neu	Neu

Figure 3.12. Example of a species sensitivity report generated by BEST.

PLANNED FUTURE ENHANCEMENTS

It is important to understand that BEST was developed to demonstrate the potential integration of Gap Analysis and county land use data to support land use planning at a local level. There are many assumptions within BEST that need to be thoroughly tested and peer reviewed before the system can be implemented as a decision support tool. The goal over the next year is to garner support for BEST and seek funding to test these assumptions while continuing development of the BEST interface to improve functionality and make it more user-friendly. This prototype is only the beginning of a much more comprehensive decision support tool for land use planning and biological conservation.

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CHAPTER IV: BIOLOGICAL EXTENSION ACTIVITIES

BACKGROUND

A primary component of the WBN project's scope of work was to explore opportunities for establishment of a "bioinformation extension program" in Wyoming. At the time of the WBN's initiation, the National Gap Analysis Program had identified an immediate need for local extension activities beyond initial statewide Gap efforts the for purpose of continued in-state maintenance, archive, distribution, and use of data products for interagency conservation planning (Crist 1996). In the long-term, the National Gap Analysis Program sought to promote, "the institutionalization of a biological information extension program …supported at the state level to serve all constituencies in need of such information and services," (Crist 1996). As a result, establishing biological extension activities under the WBN initially focused on promoting the use and integration of WBN databases (including those generated by WY-GAP) into natural resource planning, management, and education programs across Wyoming. Additional emphasis was placed on demonstrating the value of adopting the standards developed by the National Biological Information Infrastructure (NBII) for data collection, classification, and documentation to ensure compatibility with the WBN.

WBN EXTENSION ACTIVITIES

The WBN project team initiated extension efforts through a series of meetings with the University of Wyoming Cooperative Extension Service (CES) in Fall 1996. While unable to allocate resources for a biological extension staff position, the CES expressed great interest in incorporating WBN data and tools into the 23 CES county offices around the state. This cooperative effort resulted in development of a technology transfer workshop for CES natural resource extension agents attending the 1998 CES Extension Professional Improvement Conference in Jackson, Wyoming. This eventemphasized increasing awareness among county extent agents of the WBN digital databases and their potential utility in resource management applications.

A similar technology transfer approach was taken with two WBNsponsored short courses for Wyoming Game and Fish biologists in November 1997 and February 1998. In this case, given a two-day format and access to a GIS training facility at the Spatial Data and Visualization Center (SDVC), the WBN project team was able to go beyond "awareness training" and focus more on integrating the WBN databases into a series of hands-on desktop GIS training exercises.

The WBN project team also participated in a number of forums identified as potential outlets for exchange of information about the WBN with a wide range of professionals. Examples included: the Wyoming Chapter of the Wildlife Society (Cody, Wyoming, 1996); Western Planners Conference (Red Lodge, Montana, 1997); Natural Resources Conservation Service GIS Awareness Training (Laramie, Wyoming, 1997); GIS for Managers, Engineers, and Environmental Scientists in Mining and Reclamation (Gillette, Wyoming, 1997), Greater Yellowstone Area National Spatial Data Infrastructure Initiative County GIS Implementation Workshop (Jackson, Wyoming, 1998); and the Greater Yellowstone Area Aurora Partnership (Grand Teton National Park, 1998).

WY-GAP CDROM PRODUCT

To help promote use of WBN data resources, a CD-ROM product was developed for use in extension activities targeting state, regional, and local natural resource management professionals. This two-volume CD-ROM set (currently in production) contains the three main GIS layers produced by WY-GAP (vegetation, land stewardship, and the vertebrate species distributions composed of 445 individual images) and a customized ArcView Interface for displaying and querying the data.

How to Order

The WY-GAP CD-ROM package will be distributed to interested parties at no charge or for a small fee to cover shipping costs. To order, contact the Spatial Data and Visualization Center at the University of Wyoming by writing P.O. Box 4008, University Station, Laramie, Wyoming 82071, faxing (307) 766-2744, or calling (307) 766-2532.

Customized ArcView Interface

This ArcView interface was developed to provide on-site technical and conceptual training in using the WY-GAP data. The interface is bundled with the three main Gap data sets, plus several additional datasets, such as rivers and water bodies, roads and cities, and elevation. The WY-GAP data that works with the interface has been modified in order to work with the interface. For instance, a JPEG image format was chosen for the individual species distributions because the original polygon coverages were much too large to write to CD-ROM and too complex to draw within a reasonable time. Converting the polygons to raster format cut down on the size and complexity. Other changes included separating the land ownership, management, and status elements of the land stewardship coverage into separate coverages to simplify their display and reformatting the species' hexagon ranges from a polygon coverage to an ARC/INFO "region" format to simplify species-hexagon queries.

The customized ArcView interface adds four additional menus to the standard graphical user interface (GUI): *Vertebrates*, *Vegetation*, *Stewardship*, and *General Features*.

The *Vertebrate* menu options are:

- Pick species from list to display. The user first selects from the four taxonomic groups: Amphibians, Reptiles, Mammals, and Birds. The next selection is based on a general species grouping (e.g., toads/frogs, lizards/reptiles, hares/rabbits, ungulates, game birds, and raptors). When the user selects one of these groups, a pick list of species is presented. Once an actual species is selected, a registered JPEG image of the species is displayed in ArcView in three colors (green = primary habitat, brown = secondary habitat, white = no habitat).
- Enter a species name to display. The user can type in all or part of a scientific or common name and then pick a species to display from the resulting list of matching species.
- Display species habitat types. A list of the species' associated habitat is displayed in table format. Functionality is not yet available to display the land cover types for the species distribution because the tool lacks the Spatial Analyst extension.
- Display species land stewardship types. A list of all ownership types and management units that the species is predicted to occur within is displayed. (Functionality is not yet available to display the land cover types for the species distribution because of the tool lacks ArcView's Spatial Analyst extension)
- Display species hexagon range. This information is also included for each of the 445 species because it contains additional information not available from the final distribution map. Hexagons are

color-coded by occurrence (e.g., confirmed, probable, possible) for the species' range.

- Display species range by degree block. This is included because the best source of distribution information for birds in Wyoming is by degree block, which includes color-coded information about breeding and non-breeding status that is not available in either the hexagon database or the final predicted distributions.
- Display species richness predictions. Options to display calculated species richness (total number of species by area) for all 445 species, or by taxonomic group.
- Clear all species distributions, and clear all hexagon/degreeblock ranges. This is included so that the user can immediately remove all the current information from the display and start fresh.

The *Vegetation* menu includes options to display the primary land cover, secondary land cover, percent primary land cover, percent secondary land cover, percent crown closure, and boundaries of the Landscape Thematic Mapper (TM) scenes used to interpret and digitize the land cover polygons.

The *Land Stewardship* menu includes options to display the major land ownership categories, management areas (e.g., national and state parks, wildlife refuges), management (biodiversity) status categories, and national forests.

The *General Features* menu includes options to display Wyoming counties, roads, major streams, lakes/reservoirs, cities/towns, 30x60 minute quadrangles, 7.5-minute quadrangles, townships and ranges, and shaded relief (in BIL image format).

Each of these options on the menus is designed to automatically load the appropriate legends when they are selected for display. All the menus except the *Vertebrate* menu will remove a particular option completely from the display if the users select it again while it is already displayed. This is so the user does not have to learn how to add or delete themes from the view, or how to set up the legends using the legend editor and color/symbol palette.

In addition to these menu options, the *Species Area Query* and the *Hexagon Source Identity* tools were added to the interface's standard tool bar.

<u>Species Area Query</u>

This tool allows the user to draw a polygon of any size or shape, anywhere in the state. Once the user finishes the polygon shape by double-clicking the mouse, the interface generates a table of all the species predicted to occur (based on the hexagon database) within the selected area. Figure 4.1 shows a shaded area defined by the user in the northwestern portion of Wyoming. The results of this query show the number of mammal species predicted to occur within the area. After the user clicks “Okay”, the interface returns a listing of the selected species and related information about them such as their ranking, sensitivity, range, habitat, references, and issues encountered in modeling the species’ distribution. Users can specify whether they want to view all species or a particular taxonomic group (mammals in this example), all species or federally listed species, species of concern to the state, or Gap species. Options also exist for selecting species based on their occurrence ranking (confirmed, probable, and possible) for the selected area.

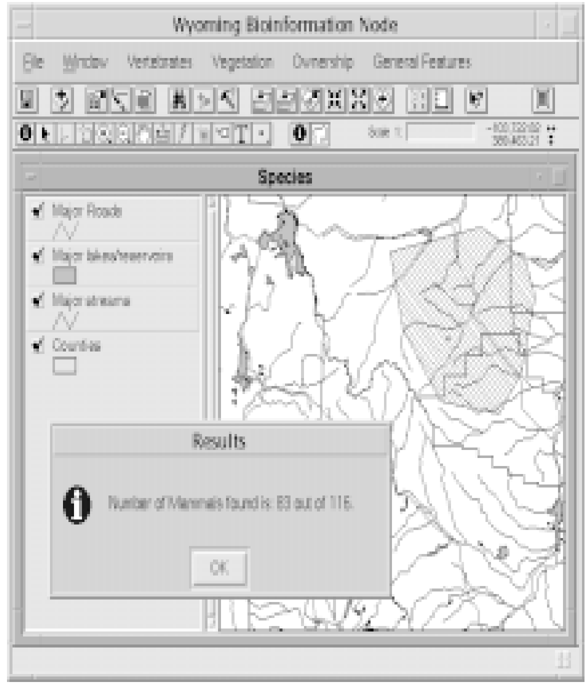

Figure 4.1 The species area query.

Hexagon Source Identify

Similar to the standard *Identify* tool, this tool works specifically with the hexagon database. For any species’ hexagon distribution currently displayed, the tool will report back the source of the ranking associated with any hexagon the user clicks on. Because of the number of hexagons in the state (438), there would be too many labels to be legible if each hexagon was individually labeled with its source, therefore, this tool was developed to help identify this important information.

Future Functionality

Additional functions were identified as possible additions to the interface in the future. One very important function to be added is a method to update the Gap data on a regular basis, including the land cover data, but even more importantly, the vertebrate species data. Another tool needs to be developed to facilitate the transfer of species location records, whether collected by Global Positioning System (GPS) receiver or by the more traditional township/range/section/quarter descriptions, into one centralized database instead of separate databases maintained by different organizations and research projects. Functionality could be added to this database to upload either coordinates or descriptive records into the existing species' locality database (originally compiled for the WY-GAP project in 1996). Programming such functionality is trivial compared to the amount of work it would require to make such a system available to all potential data collectors and then to coordinate updates from multiple sources across the state. It is possible that an Internet-based application, which has the advantage of centralized data storage and access, would be the most efficient manner of implementing such a system in the future.

The advent of the Spatial Analyst extension to ArcView opens up a whole new range of raster-based analysis functions previously limited to ARC/INFO software. The interface could be designed to do "overlays" of different data sources, for instance overlaying species distributions or vegetative cover types with a selected parcel of ownership or a particular zoning within a county. In a limited sense, this functionality is already available via the Wyoming Internet Map Server, in which Internet users can choose to display any of the 445 species distributions along with any other source of information within the continually expanding database, including some county-level information. Because of the benefits associated with making GIS data and functionality available over the web, such as removing the obstacles of distribution and redistribution of updates, there is the possibility that traditional development of applications will not continue alongside the new Internet application development.

FUTURE DIRECTION OF WBN EXTENSION

While application tools such as the WY-GAP ArcView CD-ROM will continue to be extremely beneficial in educating potential users and promoting the WBN's value as a management resource, increased emphasis must be placed on outreach to constituencies in the state not traditionally involved with biodiversity planning. A key factor in pursuing such activities will be to move beyond the original WY-GAP coordinators such as the Wyoming Game and Fish, Bureau of Land Management, and Natural Resources Conservation Service, to engage both counties and communities as well as commodity groups involved in agriculture and extractive industries in Wyoming. While the project team did attempt to cooperate with such statewide efforts as the Wyoming Association of Conservation District's watershed planning program and the Wyoming Open Space initiative, future success will require institutional backing from such groups as the Governor's Natural Resources Sub-Cabinet and the Wyoming Business Council, as well as integration with ongoing statewide information technology implementations by the Wyoming Office of GIS (OGIS) and the Wyoming Geographic Information Advisory Council (WGIAC).

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CHAPTER V: CONCLUSION

The Wyoming BioInformation Node (WBN) project remains an ongoing attempt to advance coordinated sharing and utilization of state-level biological resource information in Wyoming. In reviewing the objectives and tasks of the original WBN proposal, it is evident that this state/federal partnership has, to a large degree, been successful in achieving its goals.

Resulting from a recognized need to extend and expand upon on the valuable results of the Wyoming Gap Analysis Project (WY-GAP), the WBN's initial products and experiences not only demonstrated a design framework for successful implementation of the National Biological Information Infrastructure (NBII), but also laid the technical and institutional groundwork for future full-fledged Gap "implementation" and cross-jurisdictional biodiversity planning in Wyoming.

With regard to the WBN web resources and data clearinghouse, the project's efforts continue to be very successful, adhering not only to NBII standards, and protocols, but also complimenting the overall goals of the U.S. Geological Survey, Biological Resource Division's (USGS/BRD) geospatial technology strategy (D'Erchia et al. 1997) and the National Spatial Data Infrastructure. Much of this success is due to the WBN's position within the Spatial Data and Visualization Center's (SDVC) larger data clearinghouse and Internet map server data distribution structure. A comparison to the Hollander et al. (1994) conceptual biodiversity database model reveals the technological progress made over the last five years and affirms the need to combine biological resource data with other base reference information and physical and cultural attributes (Davis 1995). Despite ongoing technical debates on the merits of "store-and-serve" versus "store-and-send" architectures (NBII 1998), a future is envisioned in which the SDVC clearinghouse will accommodate gateways for biologists and land developers alike, while continuing to support biodiversity-specific networks such as the Natural Heritage Programs and the Association for Biodiversity Information (www. abi.org).

The WBN's Biological Expert Systems Tool (BEST), developed in coordination with the National Gap Analysis Program, demonstrates the application of Gap concepts at the local planning level and exemplifies the potential for biodiversity decision support systems (Crist 1998). BEST technology has already been adapted beyond the WBN's initial scope to a demonstration of Gap-based decision support for National Wildlife Refuge planning (Herdendorf and Crist 1998).

While the WBN biological extension activities fell short in achieving establishment of a state biological resources extension agent, the project was successful in undertaking significant information- and technology-transfer activities through presentations, workshops, and application developments. While outreach will continue to benefit from enhancements to the SDVC's Wyoming Internet Map Server and the Center's collaboration with educational efforts like the University of Wyoming's Earth System Science Internet Project (nasc.uwyo.edu/essip), the WBN's biggest challenge in achieving results from its extension efforts will continue to be the need for cooperator 'buy-in" and participation.

Finally, creation of the WBN has demonstrated that the long-term success of a state-based biological resource information network will be dependent upon statewide institutional support. Looking to the future, it is worthwhile to note a growing commitment to understanding and managing the nation's biological resources. In advocating the creation of NBII-2, a second-generation National Biological Information Infrastructure, the President's Committee of Advisors on Science and Technology (PCAST) emphasized that, "the economic prosperity and, indeed, the fate of human societies are linked to the natural world. Because of this, information about biodiversity and ecosystems is vital to a wide range of scientific, educational, commercial and government uses" (PCAST 1998). As the Wyoming BioInformation Node moves toward its own WBN-2, it will be critical to engage communities, constituencies, and stakeholders alike in advancing this connection between biological resource data and biodiversity policy, and the potential for its positive impact on our quality of life and sustained existence on the planet.

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