INTEGRATED SCIENCE FOR ENVIRONMENTAL DECISION-MAKING: THE CHALLENGE FOR BIODIVERSITY AND ECOSYSTEM INFORMATICS

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ABSTRACT

Information concerning biodiversity and ecosystems is critical to a wide range of scientific, educational, and government uses; however, much of this information is not easily accessible. This paper presents the core concepts underlying the National Biological Information Infrastructure (NBII) <www.nbii.gov>, a Web-based system coordinated by the U.S. Geological Survey that provides data and information on U.S. biological resources and, through a variety of partnerships, biological resources in many other nations. This paper will highlight NBII development, implementation, technological innovation, and successful user applications at two regional nodes: the NBII Southern Appalachian Information Node and the NBII Central Southwest/Gulf Coast Node.

Keywords: Environmental decision-making, Information retrieval, Information resources management, Biodiversity informatics, Biological networks

1   INTRODUCTION

Information concerning biodiversity and ecosystems is critical to a wide range of scientific, educational, and government uses; however, much of this information is not easily accessible (Paul, 2000). The National Biological Information Infrastructure (NBII) <www.nbii.gov> was created to provide a comprehensive framework that allows this information to be readily accessed and effectively used by a variety of audiences.

Numerous challenges are intrinsic to this undertaking. Biodiversity data are collected by many organizations within the United States for scientific understanding and natural resource management. Scientific inquiry includes studies that are carried out by educational institutions, museums, zoos, non-government organizations, and the private sector (for instance, consulting firms, corporate environmental programs, and so forth). In addition to institutionally owned biodiversity data, similar data are collected under the sponsorship of national, state, and local governmental agencies. The scope and scale of these data vary, but often they are targeted to local issues such as land use planning, the management of invasive or endangered species, or the management of economically important species (especially recreational species). In addition, there are numerous data collection efforts at regional and national levels with little or no adherence to national and/or international guidelines or standards (Cotter, Lahr, & Hill, 2002). Data may exist in disparate forms, at varying scales, on servers that may not be accessible to, or even known of, by others; or, the data may not even be stored digitally. Wasteful duplication of effort, loss of time, and a loss of collaborative opportunities are just three of the potential implications of not collecting such data using common protocols/reporting standards or of not making data available.

The NBII was created to help remedy this situation. Its successes have been ongoing, as have its challenges. This paper looks at the Program's history, innovations, and a sampling of its node activities. In so doing, it augurs a future rippling with possibilities for enhanced biodiversity and ecosystem informatics capabilities and improved environmental decision-making.

2   PROGRAM OVERVIEW

The NBII Program is a broad, collaborative undertaking to provide increased access to data and information on the nation's biological resources. Coordinated by the U.S. Geological Survey (USGS), the NBII is a digital, interactive system for accessing integrated biodiversity and ecosystem information. This user-friendly, Web-based, distributed system provides the public with natural science data and information that are scientifically reliable.

The reliability of the scientific data offered by the NBII is a result of scrutiny rooted in a number of measures. First, NBII node teams made up of dedicated scientists and researchers as well as information professionals review all information sources before they are included in the NBII node Web sites. Sites are reviewed for their scientific credibility, the consistent and long-term availability of their information, and the site's overall content and purpose as it relates to the NBII mission. In addition, the Program asks that data and information provided within the NBII federation be documented with detailed metadata descriptions that are intended to allow NBII users to make informed decisions as to whether the level of quality of a particular data set meets their specific requirements.

Supplying such data and information is an outgrowth of the Program's mission, which is to provide the nation with a mechanism for accessing the vast amount of existing biological and natural resources data, information products, and analytical tools that support and enhance science-based decision-making. It is the cornerstone for the gathering and efficient transfer of biological information (i.e. research and monitoring, publications, museum collections, raw data, and so forth) from all sectors of the global biological community to those who make decisions regarding the care, use, and conservation of natural resources.

The NBII is available at no charge 24 hours day, seven days a week. Meeting the needs of the wide range of NBII users is, of course, the core focus of all Program efforts. NBII end users are anyone who manages, studies, uses, or simply enjoys biological resources. Typically, these users come from both the public and private sectors — scientists; planners; decision-makers in industry as well as federal, state, and local government agencies; international entities; teachers and students; and other private citizens.
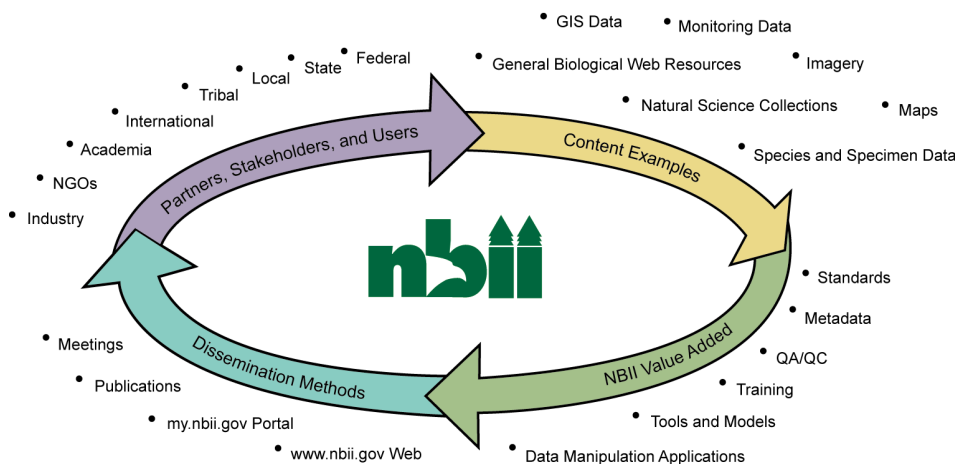
Figure 1. The NBII makes it possible to collect and organize biological information from partners, add value, and provide products and services back to these partners and others to meet their needs.

NBII end users come to the Program with a variety of information needs.

- *Scientists* need access to data of a range of levels of quality to help design and direct their research.
- *Planners and decision-makers* need timely, credible data to make knowledgeable determinations about managing the nation's natural resources.
- *The private sector* needs better information to understand such things as the impacts of metropolitan growth on ecological resources.
- *Educators* need the most relevant and stimulating materials to enlighten their students or support research.
- *Private citizens* need unbiased information, for instance, to take advantage of recreational uses of natural resources, such as watching wildlife.

Here are a few statistics that offer a representative sense of Web site activity:

- More people are coming to the NBII now than ever before -- from September 2002 through August 2003: we received 25 325 201 hits, with 16 917 497 from <www.nbii.gov>, and 8 407 704 from the NBII network of nodes throughout the country.
- The top five searches and/or topics of interest in a typical month are: West Nile Virus, Biology News, Teacher Resources, Biodiversity, and Frog.
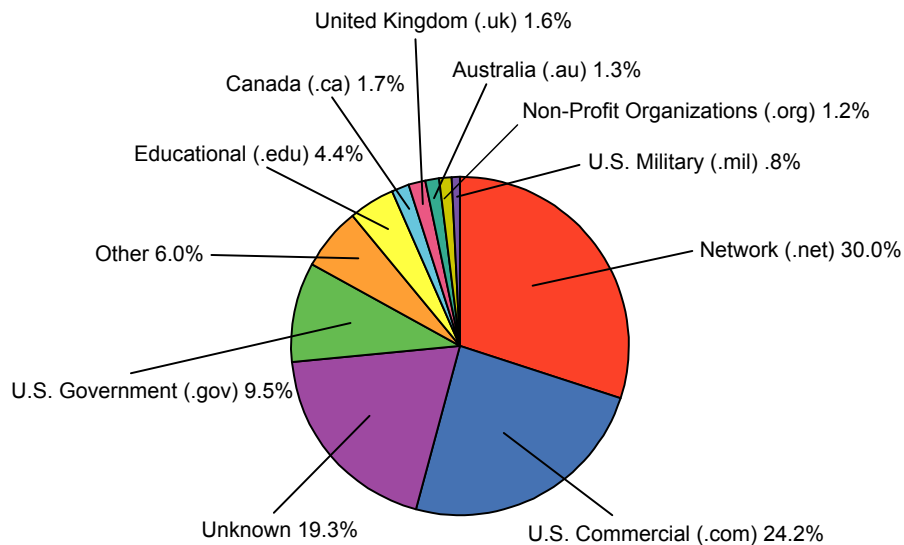

Figure 2. Usage by organizations and countries, with all values as best estimates (government users may be from .net and other categories).

NBII success has sprung in part from the rich tapestry of partners that have joined the effort. In accordance with the President's Management Agenda, they represent all sectors, and together, are leading a paradigm shift toward public-private partnerships (Sepic & Kase, 2002). In fact, the Program's motto "Building Knowledge Through Partnerships" reflects its goal of uniting the intellectual capital of the private sector with the government's commitment to meeting the information needs of the country's natural resource managers and stewards. Data and information provided by and to these groups include diverse, high-quality biological databases, information products and services, and a variety of analytical tools. NBII partners

and collaborators also work on new standards, tools, and technologies that make it easier for NBII customers to find, integrate, and apply biological resources information.

The NBII's partnership structure leverages the resources of the 200+ member federation against actual NBII expenditures. Currently, the NBII leverages contributions from partners at a ratio of 1:3 (one NBII dollar leveraged by the monetary or in-kind equivalent of three contributed dollars from partners). Given this leveraging ratio, the quantitative benefit of the NBII was equal to the leveraged value of partner contributions, or $18.0 million in fiscal year 2003.

Leveraging estimates for each NBII node are based on a process that addresses: criteria for identifying in-kind contributions, procedures for documenting contributions, elements/contributions eligible for consideration, and a process for estimating values for in-kind services. This process is based on guidance from the U.S. Office of Management and Budget and, in particular, circulars A-87 (U.S. Office of Management and Budget, 1997a), A-102 (U.S. Office of Management and Budget, 1997b), A-110 (U.S. Office of Management and Budget, 1999), and A-122 (U.S. Office of Management and Budget, 1998).

In addition, the Program's emphasis on partnership provides such qualitative benefits as:

- Cost avoidance -- Leverages other federal and private resources and provides controls for the efficient, coordinated collection and dissemination of biological data,
- Stakeholder benefits -- Development costs are shared among stakeholders, which results in spreading costs for development and providing a framework through the use of a project-wide enterprise architecture, tools and models, and
- Customer benefits -- Many NBII customers are also stakeholders, but these additional benefits apply even when the customer is not a partner involved in NBII development; users of NBII data and information can access a "one-stop-shop" for all biological data and information; and products are produced in a timely fashion through shared responsibility among partners.

3   BRIEF HISTORY OF THE NBII

The NBII grew out of a set of related policy statements and management recommendations that provided the foundation for this cooperative undertaking.

As early as 1990, a federal report issued by the Office of Technology Assessment recognized that continuous information technology advancements are critical to the continued growth of the body of scientific knowledge. "Scientific and technical advancements are information-intensive, and those who know how to obtain and use [scientific and technical information] will have a competitive edge -- whether the competition is over market share or over intellectual leadership on global issues." Although, it acknowledges, critical scientific and technical information is created by all sectors, the report supports development of a federal framework in which to lead information management efforts. "In the U.S. Government, the long-term objective is to develop a " 'virtual' interagency information system... " 'Virtual' means that the information system will be a family of decentralized data centers" (U.S. Congress Office of Technology Assessment, 1990).

In 1993, a National Research Council (NRC) report said that "There is wide agreement on the urgent need to organize existing biological information and make it more readily available and to coordinate future data collection and exchange" (National Research Council, 1993). This report recommended that the Department of the Interior oversee the development of a National Biotic Resource Information System. The system, the report recommended, should be a distributed federation of databases designed to make existing information more accessible. It should also develop new ways to collect and distribute data and information, as well as lead in promoting standards that aid these activities. The system should support continuing state efforts to develop regional and statewide environmental databases and work closely with and support database development in museums, universities, and similar organizations. Finally, it should

participate in interagency initiatives to coordinate the collection and management of biodiversity data by the federal government.

The President of the United States signed Executive Order 12906 (The White House, 1994). This order requires federal agencies, in cooperation with state, local, and tribal governments, and the private sector, to help implement the National Spatial Data Infrastructure (NSDI). The NSDI deals with the acquisition, processing, storage, and distribution of geospatial (geographically referenced) data. The responsibility for carrying out the Executive Order was given to the Federal Geographic Data Committee (FGDC). In parallel with this Executive Order, the national biotic resource information system officially became the National Biological Information Infrastructure (NBII). The NBII Program works with the FGDC to increase access and dissemination of biological geospatial data through the NBII and the NSDI.

Circular A-130 (U.S. Office of Management and Budget, 1996) is the cornerstone of federal information resources management policy. A-130 was authorized through the Paperwork Reduction Act, which established a broad mandate for agencies to perform their information management activities in an efficient, effective, and economical manner. A-130 requires federal agencies to take the initiative to disseminate information, to maximize the usefulness of information to the government and to the public, and to assist the public in locating government information. The NBII Program works in accordance with these requirements to broaden the dissemination of biological information produced by federal government programs to the public.

February 1997 marked the release of the report that included a series of recommendations to improve the effectiveness of federal programs through information technology (National Performance Review and Government Information Technology Services Board, 1997). The report noted the need for an NBII. One of its recommended actions was the establishment of a federal interagency working group to coordinate the continued development of the NBII.

While much progress had been made on the NBII thus far, there was still much work left to do. In 1998, additional suggestions came on how to proceed (President's Committee of Advisers on Science, 1998). This report, written by a team of internationally renowned scientists including a Nobel Prize winner, recommended that the federal government push forward to the "next generation NBII" or NBII-2. The Committee clearly saw the need for applying information technology to the management of science information, stating: "The economic prosperity and, indeed, the fate of human societies are inextricably linked to the natural world. Because of this, information about biodiversity and ecosystems is vital to a wide range of scientific, educational, commercial, and governmental uses. Unfortunately, most of this information exists in forms that are not easily used… There exists no comprehensive technological or organizational framework that allows this information to be readily accessed or used effectively by scientists, resource managers, policy makers, or other potential client communities."

The panel recognized that NBII-2 would greatly enhance current NBII capabilities, taking advantage of newly emerged technologies to automatically integrate and synthesize many different databases, to analyze information in new ways, and to answer questions and present results that could be readily used by resource managers, policy makers, and educators. But meaningful integration and synthesis of data from diverse sources would only be possible through the application of robust standards governing the way data and information are described, managed, stored, and shared, and through the provision of common tool suites designed to effectively interact with the data and information.

One of the key components of NBII-2 was a "node"-based structure that is being developed to ensure broad partnerships and information from all sectors of society. The nodes are interconnected NBII entry points that, taken together, are forming the Program. The establishment of these nodes is helping the NBII provide a vast community of users with rapid access to data and information on biological resources as well as national -- and increasingly, international -- coverage on a range of major biodiversity and environmental issues. NBII nodes (focal points through which key elements for providing the information and services envisioned by the NBII are made available) comprise computer equipment and software, human resources, data and information, catalogs and tools, seamless access to biological data catalogs, and other capabilities that let users locate, manipulate, and use data from diverse sources.

In the waning days of fiscal year 2000, Capitol Hill lawmakers allocated funds for the promotion and development of this system of NBII nodes.

3.1   A Closer Look at NBII Nodes

NBII nodes are of three types:

- *Regional* -- Have a geographic orientation. By taking a regional approach, local data issues, data collectors, and owners are involved in the process. They also allow people closer to the issues and the partner groups to form active coalitions in addressing biological issues within their regions.
- *Thematic* -- Focus on a particular biological issue, such as avian bird conservation, providing the support and infrastructure to help address these issues. Such issues often cut across multiple geographic areas and have national significance.
- *Infrastructure* – Are responsible for common standards, data interoperability, and tools, as well as the integration of content.

In addition, NBII nodes operate against well-defined objectives and outcomes, with scalable milestones that allow flexibility to accommodate funding changes and shifting priorities due to the urgency associated with emerging biological issues, such as chronic wasting disease.

This approach received another endorsement in a publication that looked across the USGS and provided advice on its future goals and challenges (National Research Council, 2001). The NRC program evaluation found that biological information is produced and maintained by diverse federal, state, and local agencies and private organizations. Collectively, this is a vast effort, and no organization or central facility could effectively compile, maintain, and distribute all relevant information. In order to reduce redundancy, the NRC concluded that a realistic goal is to link existing and new biological databases into a distributed federation of NBII databases. They concluded that the linkage must occur both physically over networks and logically through the use of appropriate software and data standards. The NRC identified the necessity of both regional-specific as well as program-specific database directories in which to store and retrieve biological data.

In addition, since multi-sector partnerships allow each node team to take advantage of the strengths in each sector, a federated approach has proven cost-effective. As examples of sector strengths, universities often can provide graduate student labor for a fraction of the cost of the same labor in the private sector, or even in government positions. Likewise, a government partner may be able to provide the node team with the advantage of steeply discounted rates per seat for software licenses.

Today, as work on the NBII nodes continues, the Program's community of users gains access to increasingly rich and varied information on the nation's plants and animals. NBII regional nodes are aimed at meeting a variety of biological resources data and information needs in regions around the nation, including:

- Addressing the biodiversity aspects of sustainable development issues within the Central Southwest and Gulf Coast through research into the applications of new spatial digital data analysis and visualization technologies,
- Developing regionally-oriented information content and a global thematic focus on invasive species in Tennessee, the Pacific Rim, and the Southeast Region,
- Offering information to evaluate strategies and practices associated with helping to stem the decline of salmon in the Pacific Northwest as well as the management of the region's forest ecosystems, and
- Supporting information systems addressing interagency biodiversity and watershed assessments in California, the Pacific Coast, and southwestern desert ecosystems (remote sensing, database, and Internet technology developed by the node will strengthen national/international information exchanges).

NBII thematic nodes address such issues as:

- Helping to implement the North American Bird Conservation Act as well as provide a location for the coordination, management, and dissemination of data and information related to North American bird fauna, and
- Offering fisheries information in a single location that can include everything from the latest published research ... to real-time stream flow data ... to fishing statistics and species profiles.

Pilot NBII nodes are attuned to such topics as:

- Invasive Species – Invasive species are the number one environmental challenge of the twenty-first century and also represent a significant economic challenge to our nation. This node will provide access through a single Web portal to a vast array of information on invasive species throughout the nation. This information can then be used for the management of invasive species and habitat vulnerability.
- Wildlife Disease – Disease has long been recognized as one of the limiting factors on wildlife populations. Now, the rapid spread of established diseases; the emergence of new diseases in humans, domestic livestock, and wildlife; and the threats of bioterrorist attacks have attracted considerable attention. This node will provide information and links to information on wildlife health and wildlife-human-domestic animal disease interactions.
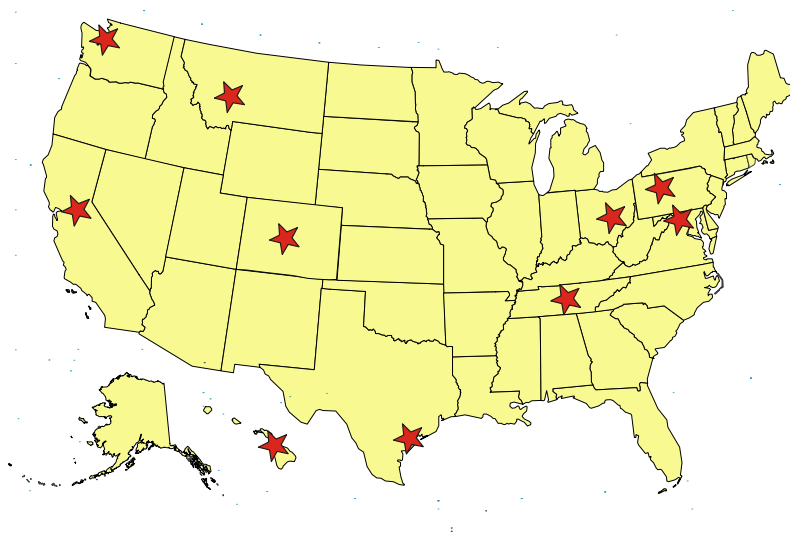

Figure 3. Current NBII regional, thematic, and infrastructure nodes throughout the United States.

The interaction between NBII regional, thematic, and infrastructure nodes is a complex but well constructed relationship. Since NBII thematic nodes provide national coverage related to a thematic area of interest, they are often jointly working with the NBII infrastructure nodes as they relate to developing the necessary standards, tools, and capabilities that facilitate seamless access to all NBII information. NBII thematic nodes are often thought of as a "virtual" node, in that they may contain data and information from a number of NBII regional nodes and/or national data providers, while the content exists and is maintained locally by those data providers. The NBII infrastructure nodes serve as the "glue" that supports the development of the necessary standards, common services, and tools to manage the interactions between NBII regional nodes, thematic nodes, and other members in the NBII network. A perfect example of this complex interaction is centered around addressing the growing

concerns of invasive species (i.e., species non-native to a region or ecosystem). The NBII Invasive Species Information Node, a thematic node, spends a considerable amount of time and effort in developing the necessary national data sets, standards, and capabilities that allow for the integration of data and information being produced from other regional nodes -- such as the NBII Pacific Basin Information Node, the NBII California Information Node, and the NBII Southern Appalachian Information Node -- which are also developing invasive related applications and tools that are more specific to their region or local issues. By deploying common standards, and by sharing methodologies and approaches, the NBII effectively leverages its resources throughout the network.

To ensure the NBII is moving in directions that will continue to serve its public -- i.e., its many and diverse users -- NBII National Program Office staff, key representatives from the NBII nodes, and NBII friends from the broader community who have an interest in the Program attend annual national meetings to hear speakers examine the NBII's current status, its successes, as well as a variety of new developments. These meetings afford an opportunity for all parties to raise issues of concern and to suggest new Program goals and strategies.

The NBII has also commissioned a Science Committee to serve in a guidance and advisory capacity. This group is made up of nationally and internationally known experts from the fields of biology and other natural sciences, information science, and computer science.

Input on virtually any issue of concern is also available through ongoing feedback from users through the Web site. Customer input is provided to the National Program Office in Reston, Virginia, USA, by way of a general Web feedback as well as the NBII "User Survey," which is available via a mouse click on a button on the left-hand side of the home page.

3.2   Selected International Developments

Internationally, the United States has made commitments to participate in a number of biodiversity network initiatives that seek to facilitate the exchange of biological data and information among partners worldwide. These initiatives include the Global Biodiversity Information Facility (GBIF) (Russo, 1999), the Inter-American Biodiversity Information Network (IABIN), the North American Biodiversity Information Network, and the Clearing-house Mechanism (CHM) of the Convention on Biological Diversity, among others. The NBII represents the U.S. contribution to these initiatives, and the NBII Program Office at USGS has been officially designated as the U.S. focal point for GBIF, IABIN, and CHM.

In October 2002, the NBII gained additional international responsibilities when it was evaluated by the International Counsel of Scientific Unions and designated as the World Data Center (WDC) for Biodiversity. The NBII is the first and only biology/ecology data center of the approximately 50 WDCs worldwide, 14 of which are in the United States. Three are operated by the USGS.

The Program has also achieved international prominence through the Information Management Committee (IMC) of the NATO Research and Technology Agency, which began developing the Science, Technology, and Research Network (STARNET) in 2002. The purpose of this network is to facilitate access to information elements already existing within NATO agencies and NATO member countries in science, technology, and overall research. The STARNET will serve as a virtual library for these information elements. It will provide a "one-stop" information resource for policy makers, program managers, scientists, engineers, and researchers within the NATO community. The NBII has been crucial to development of the STARNET through its leadership within the IMC and by contributing its technical and thematic expertise. Initial incorporation of Web-based information resources began in late 2002. The STARNET debuted in October 2003 at a ribbon-cutting ceremony during the IMC's fall meeting.

4   TECHNICAL INNOVATION

One of the major strengths of the NBII is its growing and increasingly valuable collection of data and information on the nation's biological resources. Today, the NBII has to continue to build on this content while providing additional user capabilities. This presents a host of challenges to NBII developers, data producers, and users. A brief sampling follows of some of the new capabilities being designed and prototyped. The functionalities are organized into the Services, Tools, Content, and Infrastructure components that will be required for the dramatic expansion and development of the NBII as it is envisioned.
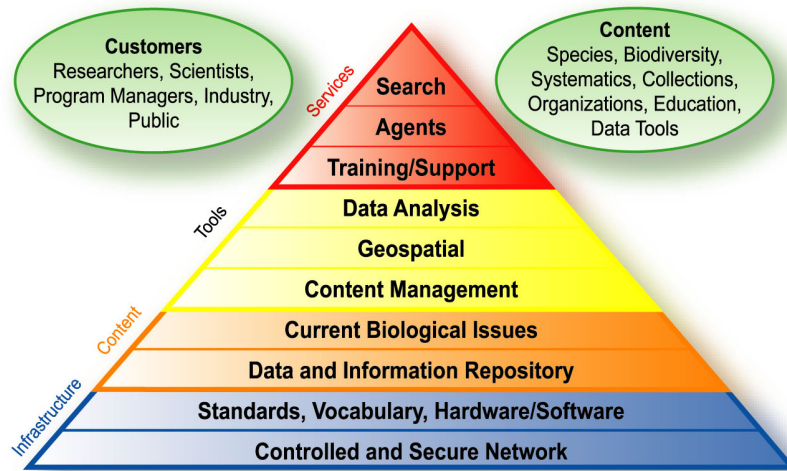

Figure 4. The NBII technical evolution and conceptual framework ensures inclusion of all the functions and capabilities needed to provide the nation with access to existing biological and natural resources data.

The pyramid (see Figure 4) illustrates the technical evolution the NBII is undergoing. The pyramid is arranged hierarchically to demonstrate the evolutionary phases the NBII must go through to achieve its ultimate goal of being the world's premier biological information network. As described below, considerable progress is already being made with prototype projects, identifying partner organizations, and defining the NBII functionality required to meet the nation's ever growing biological needs.

4.1　Controlled and Secure Network

The capabilities to limit access to certain data sets and information for a period of time, and to provide a secure and encrypted network to ensure data integrity, are important components of the system. In cases where data and information are considered sensitive, and may be available only to specific and limited audiences, the NBII architecture facilitates secured access to that data. The NBII Portal <my.nbii.gov> is a key infrastructure building block, providing both secure access to biological information, and delivering customized information to NBII customers, stakeholders, and users (Stevens, 2002; Vaas, 2002).

4.2　Standards, Vocabulary, Hardware/Software

The underlying foundation for the NBII includes: standards, controlled vocabulary, and hardware/software. Established standards and a flexible controlled vocabulary enable effective and efficient exchange of information, facilitate the discovery of information, and significantly enhance information management. Several ongoing initiatives for enhancing resource cataloging and retrieval include the National Vegetation Classification standard, the NBII Vocabulary project (Cotter, Frame, Sepic, & Zolly, 2000), cataloging of Web resources via the Dublin Core standard for metadata, and the FGDC-compatible NBII Metadata standard (metadata are data about data; searchable, structured information about the content and character

of a data collection). The latter is known as the NBII Biological Data Profile (Federal Geographic Data Committee, 1999). It encompasses biological data that are geographically referenced, as well as data that are not specific to a geographic area, such as taxonomic data, research reports, field notes, or specimen collections. Metadata created according to the Biological Data Profile can be added to the NBII Metadata Clearinghouse (NBII Metadata Clearinghouse, 1997), one of the most important NBII components. This is where NBII users can search the online card catalog of metadata from many different agencies and organizations to find a particular item of interest.

4.3   Data and Information Repository

The core focus for the NBII is to provide ready and easy access to metadata, data sets, tools, and information products. From the distributed environment of the Web – and the NBII network – arise data and information from myriad sites, in various formats, with multiple owners. The NBII must harvest these resources and provide a seamless interface to them for data and information discovery, regardless of source and format. Several activities that support this goal include the Z39.50 Biology Implementers Group <http://raptor.kbs.ukans.edu/zbig>, which has evolved into the DiGIR distributed data querying tools (2003), the Oak Ridge National Laboratory Mercury Distributed Retrieval system (2000), the implementation of Hiawatha Island Software Co. (2000) LLC software product, TagGen and Policy/Accessibility tools, and the USGS Center for Biological Informatics prototype Uniform Resource Locator Registration and Categorization system (1999). On the horizon is the NBII goal of providing easy access to museum collections information throughout the United States. In partnership with the Natural Science Collections Alliance, the NBII is actively working to deploy data provider and portal tools to support this effort. The ultimate goal of providing seamless access to biological resources information, no matter type or location, is becoming a reality with developments currently underway by the NBII Program.

4.4   Current Biological Issues

Biological information is of growing importance to the general public, land managers, policy makers, and others, and the role of the NBII in facilitating access to that information is a critical one. Various tools and delivery mechanisms are vital if these users are to interact with data and information related to invasive species, wildlife disease, and other current biological issues. NBII node architecture supports the establishment of thematic nodes to provide seamless access to data and information addressing these important national issues. Current NBII thematic nodes include the Bird Conservation Node as (Koneff, 2002), the Fisheries and Aquatic Resources Node as (Beard, 2003), and the Invasive Species Information Node.

4.5   Content Management Tools

A key responsibility for the NBII is to create and continue to enhance content management tools and practices that support the creation of metadata, the identification of important electronic resources, and the timely delivery of biological data and information that are relevant to user needs. Paramount to the NBII's success is the ability to make tools available to biological data providers that can help them provide high-quality data and information to the NBII network. The NBII Program partners with private sector organizations to implement commercial, off-the-shelf products to support this effort, or develops the process in-house when no solution exists. A suite of tools has been provided to support NBII content management requirements. For example, specific tools to create NBII/FGDC compliant metadata are licensed from a commercial vendor and provided by the NBII National Program Office in Reston, VA, to data producers and partners within the network. Another set of tools, developed in-house, assists partners in cataloging their biological data and information, facilitating faster and more relevant discovery of information resources by NBII users. The Program Office also successfully partnered with a private-sector vendor to develop and license a suite of metadata content tools that enforce content standards for information, monitor compliance with those standards, and assist NBII partners in resolving instances of non-compliance. Further metadata efforts are ongoing with the NBII Program's creation and deployment of the Web Resources Catalog tool. The asp.net based Web input tool utilizes the Dublin Core standard for

metadata to easily allow NBII content managers to catalog and store relevant resources. Resources are then seamlessly shared and accessed via NBII partner sites through the NBII network of nodes.

4.6   Geospatial Applications

The NBII, through its establishment of the NBII Geospatial Working Group, has taken a leadership role within the geospatial community in the implementation and adoption of Open Geospatial Information Standards (OGIS). These standards underpin the NBII's ability to provide critically needed geospatial tools to scientists, resource managers, and other users to access biological data and information. When NBII data and information are properly geo-referenced using OGIS, the entire NBII network and user community can access and use various types of distributed data, tools, and services, regardless of their physical location, platform, or format. All resources, information, and data within the NBII network, when spatially relevant, will be georeferenced and easily retrievable. This further extends the NBII's capability of providing geography as key criteria for data discovery. The vision for a Geospatial NBII application has three components: data discovery, data visualization, and data interoperability. The NBII Program is working in all of these areas with its network of partners to ensure the realization of this vision.

4.7   Data Analysis Tools

The capability to download and manipulate data sets accessed through the NBII is a necessity for researchers, policy makers, and educators to model, forecast, and understand current and potential conditions. Traditional search and retrieval mechanisms for the Web will most likely be replaced by distributed queries across databases, as well as tools to further manipulate the resulting data set on the user's local workstation or server. Within the NBII network, several regional nodes are co-located at super-computing facilities whose capacities are shared across the NBII network. Providing easy access to these facilities enables NBII modeling, analysis, and data synthesis tools to process data supporting their calculations in one-tenth the time it would traditionally take.

4.8   Training and Support

The NBII Program Office believes that creating the basic infrastructure to support the data, models, tools, and applications developed by the NBII Program is the key to overall network performance. Further, the NBII Program is investing in establishing bioinformatics curricula at several universities to support future biological data and information management requirements. The Program has also established working groups within the NBII network to share applications, learn from one another, and provide expert support for basic questions. The NBII Program continues to actively provide metadata training for implementation of the NBII/FGDC biological data profile.

4.9   Intelligent Agents

Intelligent agents and push technologies provide a much-needed capability to profile various user communities and establish baseline information needs. As a result, hundreds of thousands of records, projects, and resources can be filtered so that researchers or program managers only see those materials that are relevant. The NBII BioBot tool (Daukantas, 2000) and NBII Portal Publications allow users and researchers to automatically be notified and presented with information from a variety of sources, and also provide a single search interface from which users can locate and access multiple, distributed biological information. As software tools develop over the next several years, intelligent agents will play a key role in delivering timely, customized information to NBII users.

4.10   Search and Retrieval Services

One basic function of the NBII is to provide users with the capability to query multiple, distributed data sources from a single user interface. NBII users do not and will not necessarily know all of the biological

information resources available on the Web. The NBII's most important service is to provide a seamless interface to the various biological repositories in existence. The NBII search engine, BioBot, is designed to provide search services for all NBII pages, data sets, tools, and applications within the NBII network. Users can search not only the NBII network, but also partner sites, regardless of where they physically reside. The NBII search service provides a single point of access to network holdings, including data and information, as well as those of other federal agencies. A multi-lingual version of BioBot is also being deployed to support NBII international efforts with organizations such as the IABIN network. Another important consideration in providing a search service for biological information is to ensure included resources are of the highest quality possible, are permanently available to users, and are maintained for currency. The NBII accomplishes these goals by dedicating staff resources to review content, develop tools to aid in the identification and management of relevant data and information, and implement state-of-the-art technologies to support the discovery and retrieval of biological information.

5 ACTIVITIES AT TWO REGIONAL NODES

No examination of the NBII's role in biodiversity and ecosystem informatics can be complete without looking at characteristic node activities. It must be remembered that node success is rooted in one of the primary guiding principles of the NBII Program; namely, that the effort to create and implement an NBII information node, and to provide the resource support it requires, is a joint responsibility. The contributions of NBII partners are critical. Those contributions include:

- Salaries of partners working directly on Program projects,
- New technologies, models, and applications,
- Metadata records prepared for legacy or new data,
- Real property, space, equipment, and software,
- Educational materials,
- Computational tools and capabilities, and
- Newly digitized data and newly created databases.

5.1 Southern Appalachian Information Node

The NBII Southern Appalachian Information Node (SAIN) provides data and information about the biology and ecosystems of the southern Appalachians and similar or related regions. The node focuses on one of the most biologically rich areas in the nation and serves as a natural laboratory for understanding our nation's biological resources as well as developing new approaches to better manage sensitive ecosystems for public use. Using numerous Internet media and techniques, SAIN partners with many providers to make knowledge of biota and ecosystems more accessible and more understandable. SAIN also partners with users to help them translate and interpret data into meaningful information -- and into knowledge upon which they can act.

SAIN provides support to local managers and resource management agencies including a wide range of public and private decision makers, local to federal. Support to local municipalities has resulted in new or revised ordinances in Walden and Pittman Center, Tennessee, USA, and Macon County, North Carolina, USA. SAIN has worked with regional planning agencies, development districts, and councils of government throughout the region. SAIN is working with the Tennessee Wildlife Resources Agency to update its databases, with the Organization of Fish and Wildlife Information Managers (OFWIM) to coordinate support to a number of states, and with the USGS Gap Analysis Program (GAP) and the southeastern states to facilitate sharing and practical use of GAP data by resource managers.

SAIN works with numerous federal agencies on supporting various inventory, monitoring, and resource management projects, issues, and needs. The Southern Appalachian Man and the Biosphere (SAMAB) Cooperative of federal and state agencies has designated SAIN as the partner to serve as its "information arm." SAIN is working with land conservancies and trusts such as the Tennessee River Gorge Trust, Little

Tennessee Land Trust, and The Nature Conservancy on local and regional land/resource management/conservation issues. Finally, SAIN is working with many citizen and community organizations around the region to assist with their information needs for managing private and public lands.

More detailed information on selected SAIN activities follows.

5.1.1 12 Year Data Set Rescued

SAIN recently partnered with SAMAB, the Tennessee Valley Authority (TVA), and the Little Tennessee Watershed Association to rescue 12 years of time-series data on the biological health of aquatic systems in the upper Little Tennessee River watershed. These data had been collected by Dr. Bill McLarney of Franklin, North Carolina, USA, along with over 1,500 volunteers, under TVA funding. McLarney believes the upper Little Tennessee is the only Blue Ridge waterway that still contains its full complement of pre-European biota (Norwood, 2003).

The data contain many interesting trends and stories, and McLarney had extracted pieces for various scientific and local decision-making support purposes. Except in several hard-copy annual reports and on McLarney's PC hard drive, however, these valuable data were inaccessible -- and in danger of being lost. With McLarney's assistance, SAIN combined multiple spreadsheets of data into a database, quality assured the data (going back to McLarney many times to get errors and inconsistencies resolved), and made the data and map summaries of the data available on the Web. SAMAB and SAIN are now using McLarney's methods and results as a prototype for other citizen monitoring efforts of aquatic-system health around the region. SAIN is also exploring with researchers at the Coweeta Long-term Ecological Research site how these data may be used in their research on generalizing results from intensive research sites to the broader landscape.

5.1.2 SAIN Wins ESRI Award

In 2002, SAIN was awarded Environmental Systems Research Institute's (ESRI) "Special Applications in GIS" award. The reason? NBII partners at the University of Tennessee at Chattanooga (UTC) Geographic Information Systems (GIS) Research Laboratory, working with wildlife control officers from the Great Smoky Mountains National Park (GSMNP), began using GIS to examine records of 26 years of park service efforts to control an invasive species, the exotic European wild boar. Current control efforts removed approximately 300 wild boars annually. Nevertheless, wild boars in the GSMNP continued to be a major management problem.

Properly ascertaining equitable distribution of parkwide hog control efforts required the display of successful hog removal graphically in a spatially referenced format. Work began at UTC in January 2002 on GSMNP records from 1976 forward. It was felt that if hog control efforts were not uniformly distributed throughout the park, these efforts might actually encourage population growth. The newly created hog map showed that control activities had, in fact, been uneven.

ESRI was so impressed with the graphic that SAIN won the award for a special application of GIS software. The project is an example of how SAIN and the NBII can assist public land managers in protecting and preserving natural communities while bringing new and valuable information to a broader audience.
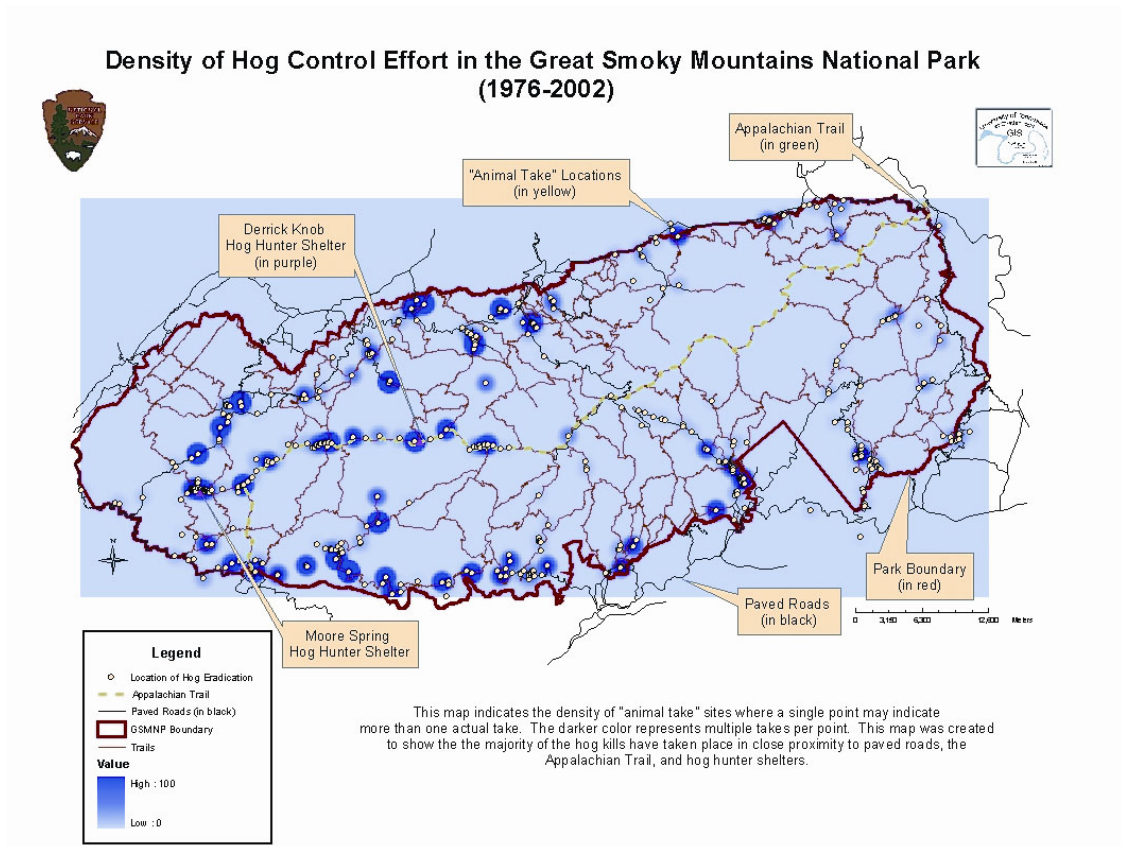
Figure 5. ESRI showcased UTC's hog map in the opening ceremony of the ESRI 2002 annual conference, which was held in San Diego, California, USA.

5.1.3   Bringing Virtual Appalachia to the World

SAIN has developed several examples of the use of immersive 360-degree photography for visualizing key regional environments, and providing a virtual tour of the habitats, biota, and forces influencing those places. Links from the 360-degree "bubbles" provide detailed photographs, sounds, natural history, and numerous other kinds of information. The node has also explored ideas for using this technology for mountaintop-to-seacoast visualization of habitats and biota, virtual trail hiking and monitoring, and incorporation with 3-D modeling of habitat change. These visualization tools enable resource managers and others to show effectively the beauty of the region as well as scientific relationships in an engaging and entertaining way of learning. The SAIN's first prototype of these immersive technology tools, The Appalachian Ecosystem, can be observed in action online (SAIN, 2003). By Spring 2003, the SAIN had completed the following views: the Tennessee River Gorge, the Little Tennessee River, and the Hemlock View at Albright Grove in the GSMNP (part of the Hemlock Woolly Adelgid Project).

5.2   Central Southwest Gulf Coast Information Node

The NBII Central Southwest Gulf Coast Information Node (CSWGCIN) is developing a digital, standardized (with metadata), integrated, archived, managed, updated, and Web-accessible collection of high-quality biological data and information of its region (Arkansas, Louisiana, Oklahoma, Texas, and the Gulf of Mexico). CSWGCIN is also designated as the NBII national lead for developing, acquiring,

assessing, implementing, transferring, and coordinating state-of-the-science geospatial technologies (e.g., GIS, remote sensing, digital field data collection, and verification technology).

CSWGCIN with works closely with its partners, other NBII regions, and the national NBII Program to assess and integrate new and emerging information technologies that help address national biological science and resource management objectives. The node is particularly focused on geospatial technologies, with an emphasis on Web-based mapping, digital field data collection systems and methodologies, and 3-D visualization. The node continues to assess, acquire, develop, and deploy Open-GIS compatible (AGIS/WMS) Web-based mapping tools and applications. The node is also developing the custom ArcIMS HTML template that includes options for data extraction and exchange for users accessing applications via standard Internet browsers or handheld computers (Palm-type devices for Pocket PCs). Digital field-based mapping and data collection systems are being fully documented through a user manual and associated help files so that the technologies can be used by partners and other NBII Regions/nodes. CSWGCIN also supports Toolkit and standards development, which includes support of the NBII Bird Conservation Node. Further, CSWGCIN works with the NBII Program to improve collaboration among existing and proposed NBII nodes.

Brief descriptions of representative CSWGCIN projects follow.

5.2.1   Fort Hood

Established in 1942, the Fort Hood Military Reservation is the nation's foremost training facility for tank warfare. At the same time, this 340-square-mile tract of land in central Texas is richly endowed with habitat for a variety of wildlife including the black-capped vireo (*Vireo atricapillus*), an endangered species. Given these two truths, the Fort's military planners are committed to striking a balance between the need to produce battle-ready tank crews with the mandate to maintain the base's ecological integrity. To address the second requirement, the Fort enlisted the help of The Nature Conservancy of Texas. The Conservancy's Texas Office funded the acquisition of high resolution LIDAR data for a 10-square-mile portion of Ft. Hood. CSWGCIN is working closely with Conservancy Fort Hood project staff to use the LIDAR data and associated ground control data to determine the potential to map threatened and endangered (T&E) bird habitats, focusing initially on the black-capped vireo. Initial results are highly encouraging with the Conservancy acquiring extensive field verification data. CSWGCIN is assisting in this process by helping design the ecological field sampling protocol, and in developing custom ArcPad field data collection applications and a secure Web site (with an OpenGIS compliant ArcIMS map server application) to facilitate the exchange of geospatial and related data and information on the project. CSWGCIN also trained and continues to support the Conservancy in metadata construction. Based on the results of this project, the Construction Engineering Research Laboratory of the U.S. Army Corps of Engineers is funding a multi-year follow-on project to further develop the methodology, develop habitat change/condition detection capabilities, and assess the potential to apply these findings to assess additional T&E habitats on other military installations.

5.2.2   Big Bend National Park

The National Park Service's Big Bend National Park covers over 801,000 acres in west Texas, in the area where the Rio Grande makes a sharp turn (the "Big Bend"). Situated as it is on the border with Mexico, Big Bend is a place where countries and cultures meet as well as a place that merges natural environments, from deserts to mountains. CSWGCIN has established a partnership with Big Bend National Park. As part of this project, CSWGCIN staff are customizing and operationally implementing the following technologies: ArcPad digital field data collection and verification of biological and associated data and OGIS/Web Mapping. The node has also sponsored a seasonal employee (approximately 6 months) to conduct the following tasks: 1) organization and digitization (as appropriate) of all information on T&E species in the park (T&E data from the Texas Park and Wildlife Department (TPWD) have also been digitized by node staff for eventual incorporation into the Park's GIS), and 2) archival research assessment and digital field data verification (ArcPad) of threatened and endangered species information compiled by

the Park. CSWGCIN staff are also going to acquire Landsat satellite imagery to create a time series of erosion on a highly erodible soil in the Park. These data will be integrated and analyzed with historical land use practices (i.e., grazing) and incorporated in the conservation management plan for the Park.

5.2.3 NAFTA Highway (I69) Environmental Permit (NEPA)

Running from Mexico to Canada, straight through America's heartland, the NAFTA Highway will cross more than 1,000 miles of Texas from Brownsville to Texarkana. The project is named after the North American Free Trade Agreement (NAFTA), and like any large highway project the environmental review process is daunting. The highway is an enormous undertaking, both geographically and financially; it will cover more than 400 USGS quad maps. Like virtually all highway construction projects, environmental review is a critical part of the project, and quality data is a prerequisite for project success. Numerous contractors will provide environmental review, and they all must use consistent data. TPWD has the best wildlife-related data in the state and, most importantly, TPWD holds vital data on T&E species locations. The data are mostly, if not entirely, on paper maps. The conversion of the TPWD Biological Conservation Database (BCD) (which includes T&E species data as element of occurrence [point], transect, and polygon information) from paper to digital format has been a requirement for years. TPWD had earlier converted the element of occurrence data to digital format. CSWGCIN agreed to work cooperatively with TPWD to complete conversion of transect and polygon data within the NAFTA Highway corridor, establishing and implementing a methodology (including technical oversight and labor) to digitize these data. Now that the digital BCD data for the NAFTA corridor are completed, the TPWD would like to jointly work with CSWGCIN to complete the data set for the entire state. TPWD is providing the Quality Control for the digitization process. TPWD has also requested that CSWGCIN participate (with the U.S. Fish and Wildlife Service [USFWS]) in the integration of the BCD data into the predictive habitat modeling effort (associated with the environmental permit process of the NAFTA Highway) using state-of-the-science models developed by the Environmental Protection Agency/USFWS and The Nature Conservancy. This project will contribute to the streamlining of the NEPA permit process associated with the NAFTA Highway.

6   CONCLUSION

America has been endowed with a rich variety of biological resources, as have many other nations around the globe. Since they vary by structure, content, and focus, the data and information that describe these resources can meet a wide variety of needs. The NBII is dedicated to helping us better understand and preserve our nation's living resources by unleashing the enormous power of the data and information resources that describe them. More specifically, the NBII is committed to ensuring biodiversity data are organized, accessible, and available to those who make decisions regarding the care, use, and conservation of natural resources. We have attempted to demonstrate that the technical and organizational challenges inherent in this undertaking are being overcome. The implementation of the infrastructure is proceeding, and the direction of the development of the NBII is being guided by the expressed requirements of the communities it serves.

As technology changes, so too will the NBII's approaches to solving this important, ongoing challenge. But while the preceding pages detail selected NBII successes, the Program's focus is on the future (Committee on Environment and Natural Resources Subcommittee on Ecological Systems, 2001). We invite all interested parties from around the nation and the world to join us in helping to make the NBII an even more effective tool to facilitate environmental decision-making.

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APPENDIX – NBII PROGRAM PRODUCTS AND SERVICES

The following provides an inventory NBII products and services. In addition, it offers a sampling of products available from the NBII nodes. As these nodes are being established, the various partners in each node contribute – or are in the process of developing – additional data sets, tools, and other information resources and services that enrich the NBII. Any listing such as this can become dated quickly, so please check online at <www.nbii.gov> for the latest developments.

CLEARINGHOUSES (OF WEB SITES)

Biodiversity   www.nbii.gov/issues/biodiversity/
   includes genetic, species, ecological or ecosystem diversity, geopolitical perspectives
Biology in the News   www.nbii.gov/issues/bionews/
International Resources   www.nbii.gov/geographic/international/
   biological organizations by country
Online References and Electronic Journals   www.nbii.gov/datainfo/onlineref/
   includes dictionaries, glossaries, textbooks
Organizations and Associations   www.nbii.gov/datainfo/orgs/
Systematics and Scientific Names   www.nbii.gov/disciplines/systematics.html
U.S. Node of the Inter-American Biodiversity   www.iabin-us.org/information_links/index.html
   Information Network
U.S. Programs and Activities   www.nbii.gov/geographic/us/
   resources by state and federal resources

DATA/DATA APPLICATIONS

IABIN European Collections of New World Vertebrates   www.iabin-us.org/information_links/eu_inventory.html
IABIN Invasives Species Information Network (in development) www.iabin-us.org/projects/i3n/i3n_project.html
Land Use History of North America   biology.usgs.gov/luhna/
Land Use History of the Colorado Plateau   www.cpluhna.nau.edu/
National GAP Analysis Program   www.gap.uidaho.edu/
   GAP Data Sets (ftp or CD-ROM)   www.gap.uidaho.edu/Projects/data.asp
     Each state data set includes land cover maps and documentation, stewardship maps, vertebrates distribution maps, ancillary data, analysis summary of the protection status, final project report, pdf versions of all maps, metadata.
     Completed states: *Arizona, Arkansas, California, Louisiana, Maine, Montana, Nevada, New Mexico, New York, Oregon, Utah, Washington, West Virginia, Wyoming.*
   GAP Land Cover Mapping Protocols   www.calmit.unl.edu/gapmap/
     synthesis/analysis of GAP protocols used by states
   GAPServe (ArcIMS application)   (in development)
   Handbook for Conducting GAP Analysis   www.gap.uidaho.edu/handbook/
     methodology and standard
   Aquatic GAP   www.gap.uidaho.edu/projects/aquatic/default.htm
   Southwest Regional GAP Analysis Project   leopold.nmsu.edu/fwscoop/swregap/
USGS-NPS Vegetation Mapping Program   biology.usgs.gov/npsveg/index.html
   Nat. Vegetation Classification Standard   biology.usgs.gov/npsveg/standards.html
   Vegetation Mapping Data Sets   biology.usgs.gov/npsveg/products/parkname.html
     Each park data set includes aerial photography, spatial database of vegetation communities, field vegetation database, vegetation communities descriptions, dichotomous field key of vegetation communities, accuracy assessment of spatial data, procedure reports, photos of vegetation classes, metadata.
     Complete data sets:
     Agate Fossil Beds National Monument   biology.usgs.gov/npsveg/agfo/index.html
     Congaree Swamp National Monument   biology.usgs.gov/npsveg/cosw/index.html
     Devils Tower National Monument   biology.usgs.gov/npsveg/deto/index.html
     Fort Laramie National Historic Site   biology.usgs.gov/npsveg/fola/index.html
     Isle Royal National Park   biology.usgs.gov/npsveg/isro/index.html
     Jewel Cave National Monument   biology.usgs.gov/npsveg/jeca/index.html

Mount Rushmore National Memorial	biology.usgs.gov/npsveg/mporu/index.html
Scotts Bluff National Monument	biology.usgs.gov/npsveg/scbl/index.html
Tuzigoot National Monument	biology.usgs.gov/npsveg/tuzi/index.html
Wind Cave National Park	biology.usgs.gov/npsveg/wica/index.html

Parks in progress: *Acadia National Park, Badlands National Park, Black Canyon of the Gunnison National Park, Curecanti National Recreation Area, Fire Island National Seashore, Glacier National Park, Great Smoky Mountains National Park, Joshua Tree National Park, Point Reyes National Seashore, Rock Creek Park (Washington, DC), Sequoia & Kings Canyon National Park, Sunset Crater Volcano National Monument, Theodore Roosevelt National Park, Valley Forge National Historical Park, Voyageurs National Park, Walnut Canyon National Monument, Wupatki National Monument, Yosemite National Park, Zion National Park*

Vegetation Mapping ArcIMS application (in development)

DIRECTORIES

Dir. of Research Systematics Collections	www.nbii.gov/datainfo/syscollect/drsc/
Ecological Information Network	ein.nbii.gov/

ecological experts who have volunteered to answer questions or provide input on various scientific issues

GAP International www.gap.uidaho.edu/International/default.asp

biodiversity inventory, monitoring, assessment, and conservation projects by country

Taxonomic Resources and Expertise Dir. www.nbii.gov/tred/

INDEXES
Biocomplexity Collection (in development)

in partnership with Cambridge Scientific Abstracts

INFRASTRUCTURE

BioBot Search Engine	search.nbii.gov:9999/nbii/search.html
Biocomplexity Thesaurus	(in development)

in partnership with Cambridge Scientific Abstracts

IABIN Invasive Species Information

www.iabinus.org/projects/i3n/i3n_tools/cataloguer_concept.html

Network Cataloger (in development)

Integrated Taxonomic Information System www.itis.usda.gov

Metadata Training Program

www.nbii.gov/datainfo/metadata/training/index.html

includes training-the-trainer, workshops, training materials, tools, standards development

NBII Metadata Clearinghouse metadata.nbii.gov

Includes metadata from:

Australian Institute of Marine Science

BIOSIS UK

California Department of Agriculture

Connecticut Invasive Plant Working Group

U.S. Army Corps of Engineers

National Park Service

U.S. EPA, Chesapeake Bay Water Quality Monitoring Program

Long-Term Ecological Research Program (LTER)

National Oceanographic and Atmospheric Administration

Pacific States Marine Fisheries Commission

Smithsonian Environmental Research Center

Texas A&M University, Department of Marine Biology

USDA Plant Genome Project

Agricultural Research Service

Forest Service

USGS-NPS Vegetation mapping program

USGS Biological Resources Division

NBII Portal my.nbii.gov

METADATA GATEWAY

BRD Bibliographic Metadata Node
Columbia Environmental Research Center's Metadata Node
Eastern Sierra Geospatial Data Clearinghouse
EMAN Data Set Library (Environment Canada Server)
Forest Aquatic and Rangeland Ecosystems in the Western USA
National Gap Analysis Program Metadata Node
National Wetlands Research Center (NWRC) Spatial Data and Metadata Server
New Mexico Resource Geographic Information System Clearinghouse
New Mexico USGS Partnership Clearinghouse
Clearinghouse for the Olympic Peninsula
Southwest Region Road Map of Natural Resource Data and Information
Texas/Mexico Transboundary Metadata Clearinghouse
Texas Natural Resources Information Systems (TNRIS)
Virginia Natural Resources Geospatial Clearinghouse
Washington State Geospatial Clearinghouse Node
Wyoming Natural Resources Data Clearinghouse

WEB SITES
Botany   www.nbii.gov/disciplines/botany/
   includes plant biology, gardening, plant species, bryophytes and fungi, collections, botany for kids
FrogWeb   www.frogweb.gov/
   includes frog and amphibian declines and deformities information, species information, resources for kids
Teacher Resources
www.nbii.gov/education/index.html
   includes curricula, state activities, biodiversity and environment, various biota and discipline sections
Trilateral Committee for Wildlife and Ecosystem Conservation and Management www.trilat.org/
U.S. Node of the Inter-American Biodiversity Information Network   www.iabin-us.org/index.html
West Nile Virus   westnilevirus.nbii.gov/
   includes latest news, human health issues, state and regional sections

WEB SITES HOSTED
FGDC Biological Data Working Group
FGDC Metadata
FGDC Vegetation Subcommittee
Hawaiian Ecosystems at Risk Project
Hyperspectral Imaging DOI-NASA Technical Transfer Project
Inter-American Biodiversity Information Network
US-Ecosystems.org
USGS Biological Resources Division
USGS BRD Geospatial Technology
USGS Central Regional Office
USGS Cooperative Research Units
USGS Global Change Research Program
USGS Northern Rocky Mountain Science Center
USGS Pacific Island Ecosystems Research Center
USGS Science Information System
USGS Western Fisheries Research Center
USGS Western Regional Office

SAMPLING OF NBII NODE PRODUCTS AND SERVICES
Bird Conservation Node   birdcon.nbii.gov
Breeding Bird Survey Abundance Map   www.mbr-pwrc.usgs.gov/geotech/bbsmaps3.html
Migratory Bird Data Center   birddata.fws.gov/
   warehouses and serves the databases from Breeding Bird Survey, Waterbird Monitoring Database,
   the Waterfowl Breeding Population and Habitat Survey, and the Mid-winter Waterfowl Survey

Online mapping application for querying Migratory Bird Data   rockys20.cr.usgs.gov/nbii/
Patuxent Bird Identification InfoCenter   www.mbr-pwrc.usgs.gov/Infocenter/infocenter.html
photographs, songs, videos, identification tips, maps, and life history information for North American birds

California Information Node   cain.nbii.gov/
Calflora *(California Plants)*   www.calflora.org/calflora/
CalWeed *(California Noxious Weed*   endeavor.des.ucdavis.edu/weeds/
   Control Project Inventory)
Invasive Species Management Thesaurus   cain.nbii.gov/2002/01/thesauri/ISMT.shtml
Invasive Species Search Engine   cain.nbii.gov/searchform.shtml
Metadata Tool   cain.nbii.gov/IMTdoc.shtml

Central Southwest/Gulf Coast Information Node cswgcin.nbii.gov/
Bayou Information Center   mapserver.harc.edu/website/bpaweb1/viewer.htm
Habitat Prediction for Texas Trailing Phlox   cswgcin.nbii.gov/dm/Phlox/p120.htm
Seagrass Information   www.tpwd.state.tx.us/texaswater/coastal/seagrass/index.htm
Taxonomic Inventory of the Flower   www.flowergarden.nos.noaa.gov/about/taxonomy.html
   Garden Banks National Marine Sanctuary

Fisheries and Aquatics Resources Node   far.nbii.gov
National Fish Strain Registry   159.189.37.201
   includes Web mapping application for viewing data on trout, catfish, perch, and sturgeon
Pennsylvania Fisheries Explorer   pasdaims.erri.psu.edu/website/NBII2/viewer.htm
   Web mapping application
Fishing Resources by State   far.nbii.gov/fishinfo.shtml
Fishing Conditions by State   far.nbii.gov/condinfo.shtml

Northern Rockies Information Node   nrin.nbii.gov/
Greater Yellowstone GIS Datasets   nrin.nbii.gov/gis/
Trumpeter Swan Information and Models   nrin.nbii.gov/swan/

Pacific Basin Information Node   pbin.nbii.gov/
Avian Conservations   pbin.nbii.gov/avianconservation.asp
Hawaiin Ecosystem at Risk Project   www.hear.org/
Plants and Animals of the Pacific Basin   pbin.nbii.gov/plantsanimals.asp

Pacific Northwest Information Node   pnwin.nbii.gov/
Bottomline Density Management Study   axe.nacse.org:8080/ims/bline/viewer.htm
Epiphytes and Forest Management   ucs.orst.edu/~mccuneb/epiphytes.htm
Forest Mycology and Mycorrhiza   mgd.nacse.org/fsl/
Oregon Coalition of Interdisciplinary Databases www.nacse.org/ocid/
Pacific Northwest Lichen and Air Quality   www.nacse.org/lichenair/
Plants and Fungi of the Oregon Research Forest mgd.nacse.org/hyperSQL/mcfors/

Southern Appalachian Information Node   sain.nbii.gov/
Nature Guides and Tools   sain.nbii.gov/tools.shtml
Mercury Web Collection search engine   sain.nbii.gov/search.shtml

Nodes In Development
Invasive Species
Southwest Information Node
Wildlife Disease