SCIENCE
BIODIVERSITY and
SUSTAINABLE
FORESTRY

A FINDINGS REPORT OF THE

NATIONAL COMMISSION ON SCIENCE FOR SUSTAINABLE FORESTRY

The mission of the National Commission on Science for Sustainable Forestry (NCSSF or Commission) is to improve the scientific basis for developing, implementing, and evaluating sustainable forestry in the United States.

The Commission is an independent, non-advocacy, multi-stakeholder body that plans and oversees the NCSSF program. It includes 16 leading scientists and forest management professionals from government, industry, academia, and environmental organizations—all respected opinion leaders in diverse fields with broad perspectives. Members serve as individuals rather than as official representatives of their organizations. The Commission convenes at least twice a year to plan and oversee the program. Members' names and affiliations are listed on page 2.

The primary goal of the NCSSF program is to build a better scientific underpinning for assessing and improving sustainable forest management practices. The program strives to produce information and tools of the highest technical quality and greatest relevancy to improving forest policy, management, and practice.

The initial five-year phase of the program focuses on the relationship between biodiversity and sustainable forest management. The program addresses information needs for managed forestlands, both industrial and non-industrial, in the continental United States. Syntheses and surveys, research and assessments, tool development, and communication and outreach activities all contribute to the program's goals.

The Commission does not promote specific policy positions, promulgate management practices, or endorse any particular sustainable forest management certification systems. However, the results of the NCSSF program provide a stronger scientific basis for evaluating forest practices and certification systems, comparing them more objectively, effectively assessing their progress, and developing more innovative approaches to forest management.

Applications of the Commission's work include:
- informing forest management decisions, conservation plans, and governmental and private sector policies
- providing a sound ecological framework for long term economic management of forests
- refining and evaluating certification systems such as the Forest Stewardship Council (FSC), American Tree Farm System (ATFS), Green Tag, and Sustainable Forestry Initiative (SFI).

More information on the NCSSF program and results of specific projects are available on our web site at: **www.ncssf.org**.

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A Program Conducted by the

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Improving the scientific basis for environmental decisionmaking

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OVERVIEW

The National Commission on Science for Sustainable Forestry (NCSSF or Commission) includes leading scientists and forest management professionals from government, industry, academia, and environmental organizations who collaboratively plan and oversee the NCSSF program. This independent, multi-stakeholder character enables the Commission to serve as an "honest broker" who can address controversial issues more objectively. The Commission has completed about half of its initial five-year program to advance the science and practice of biodiversity conservation in sustainable forestry.

The Commission has found that appropriate forest policies and practices can be beneficial to biodiversity. While gaps in knowledge remain, the Commission's findings will help forestry practitioners working in the field, forest managers, and policy makers do a better job of conserving biodiversity within the context of sustainable forestry. These groups are the primary audience for this report because they can use NCSSF's findings to develop and apply policies and practices that will conserve biodiversity more effectively. NCSSF also produces technical reports for use by researchers.

The Commission identified the major obstacles that practitioners, managers and policy makers face in applying sustainable forestry policies and practices through a nationwide survey and users' workshops conducted in partnership with the National Forest Foundation (NFF). The users identified four major barriers to sustainable forestry, in priority order they are: (1) lack of data

and information, (2) polarization within the field, (3) misperceptions and lack of public awareness, and (4) lack of financial resources. The NCSSF program addresses the first three of these, which comprise more than three-fourths of the users' identified barriers.

The Commission has synthesized existing information into useable knowledge, sponsored projects to fill key research gaps, developed tools for practical applications, and reached agreement on important issues related to biodiversity and sustainable forestry. The findings presented here are based on the results of NCSSF-funded projects, the Commissioners' expertise, and three years of dialogue among themselves, as well as discussions with a wide range of experts and stakeholders. The NCSSF findings are an especially valuable resource for the broad forestry community because a wide range of sources have been reviewed, assessed and synthesized into consensus judgments by a credible independent body of diverse experts and representative stakeholders.

The greatest threat to forest sustainability and biodiversity lies in conversion of forestlands to other uses. This often results when markets undervalue natural systems and populations. With demands on forests increasing, not all forests can sustain the same benefits at all times. Forest reserves are necessary but insufficient for biodiversity conservation. In that context, NCSSF offers initial findings in four areas.

Area 1: The effectiveness of biodiversity conservation is largely determined by interactions between stand- and landscape-level patterns.
- **Finding 1A.** Biodiversity conservation requires knowledge and policies that cross landscape levels.
- **Finding 1B.** Stand-level diversity is heavily influenced by disturbance legacies.
- **Finding 1C.** Biodiversity correlates to spatial variability in forest management.
- **Finding 1D.** Forest fragments support reduced levels of biodiversity.

Implications: Landscape-level information is necessary to the full use of science in conservation efforts everywhere. The problem with a top-down, "how should the world look proportionally?" view of scientific findings is that a single management organization generally can't change the mix of ownerships and management practices. Most landowners can't control or influence both policy and ownership-level activities in combination. A further complication is that the specifics of many landscape-level management strategies can't be generalized.

Area 2: Sustaining disturbance dynamics within appropriate ranges sustains biodiversity and ecosystem services.
- **Finding 2A.** The historical range of variation (HRV) is a useful but limited concept for managing biodiversity.
- **Finding 2B.** Fire significantly influences patterns of biodiversity within and among forest ecosystems.

- **Finding 2C.** An interdisciplinary scientific approach is necessary to address invasive species.
- **Finding 2D.** Variations in disturbance dynamics are often connected to changes in climate, human land use and management.

Implications: Departures from the historical range of variation (HRV) will often have adverse consequences for native biodiversity. The HRV concept must be updated and adapted with new information, such as data about climate change, invasive species, and fragmentation, to create a "future range of variation" (FRV). Attempting to restore ecosystems to a single set of conditions that existed before European settlement of North America won't suffice because strategies must consider each site's historical legacies and composition as well as climate forecasts and other anticipated future changes. Management efforts should focus on sites with the highest biodiversity values.

Area 3: Biodiversity indicators must be matched to land-use objectives.
- **Finding 3A.** Biodiversity is too broad a concept and too variable across forest types to be represented by a universal set of indicators.
- **Finding 3B.** Clear objectives and processes are crucial to selecting appropriate sets of indicators.

- **Finding 3C.** A logically structured process is needed for selecting indicators.
- **Finding 3D.** An effective set of indicators includes three different types that cover five separate functions.

Implications: Indicators are a relatively few measures that provide information about the status of as many unmeasured biodiversity elements as possible. There is a need to rethink the role of indicators and how they are selected and used in certification systems or regulatory programs. NCSSF found that commonly measured and monitored features of forestry, that were described by practitioners as biodiversity indicators, are not always congruent with the indicators best suited for measuring biodiversity values. An NCSSF-sponsored tool (Project A8) provides a flexible system to select indicators tailored to sustaining specific biodiversity values.

Area 4: Sustainable forestry and biodiversity conservation require management that recognizes and adapts to new information, changing environments, and shifting social priorities.
- **Finding 4A.** Management practices must adapt to evolving knowledge.
- **Finding 4B.** Biodiversity conservation requires traditional forestry practices and more.
- **Finding 4C.** Forest management under different ownership types has implications for biodiversity.

- **Finding 4D.** The increasing interest in and gathering of non-timber forest products has both positive and negative implications for sustaining biodiversity.
- **Finding 4E.** Effective management is benefited by access to accurate relevant information and decision support tools.
- **Finding 4F.** Biodiversity conservation theories require adaptive management to assess their validity.

Implications: Developing and applying cost-effective conservation strategies and practices can enhance biodiversity, but biodiversity conservation efforts are constrained by tract size and history, ownership patterns, and overall management goals. Uncertainties about complex interactions highlight the growing importance of using adaptive management approaches that bring scientists, managers, and stakeholders together to collaboratively analyze and assess policies, plans, and practices.

Over the next two years, NCSSF's ongoing work will yield additional useful findings. Equally important, we will generate additional practical tools—based on science and tested for their utility—to enable practitioners to achieve more progress where it counts: across America's diverse forest landscapes. The gaps that are revealed along the way will highlight areas where new research is most needed for further progress on the ground in the future.

1 INTRODUCTION

The Commission's Role

The National Commission on Science for Sustainable Forestry (NCSSF or Commission) is working to improve the scientific basis of sustainable forestry practice, management, and policy. NCSSF is funded by a consortium of foundations whose leaders recognize the need for better science to support sustainable forestry and biodiversity decisions. These sponsors include the Doris Duke Charitable Foundation, the Surdna Foundation, the Packard Foundation, and the National Forest Foundation.

NCSSF is unique in using a diverse group of stakeholders and experts to collaboratively plan and oversee a science program designed to yield results relevant to sustainable forestry applications. To ensure that the program includes both the best science and the most useful applications, about half of the Commission's 16 members are "producers" of information (researchers/educators) and the other half are "users" of that information (practitioners/decision makers). All of the members are leading professionals drawn from diverse sectors, including government, industry, academia, and environmental organizations.

BUREAU OF LAND MANAGEMENT

As an independent, multi-stakeholder body, the Commission works to develop consensus on the science and its implications, as well as finding and filling gaps in understanding and developing the tools needed to implement and evaluate sustainable forestry in the United States.

The Commission and its sponsors agreed that NCSSF would focus the program's first five-year phase on the critical intersection of biodiversity and sustainable forestry, an area with major gaps in understanding and lack of available tools. The potential benefits to society of forests on any geographic scale ultimately depends on the mix of plants and animals that comprise the forest. Better scientific understanding of biodiversity will provide a context for addressing the social, ecological, and economic aspects of sustainable forestry.

Through ongoing discussions among themselves and with stakeholders, the Commissioners:
- identify users' information needs
- define specific projects to meet users' needs
- integrate and interpret the program's results
- communicate the results and findings.

Priority needs identified by the Commission become requests for proposals (RFPs). To encourage the best qualified investigators and organizations to compete for the work, the RFPs are issued publicly on the NCSSF web site, advertised in journals, and sent by e-mail to thousands of potential applicants. External review panels, composed of practitioners as well as scientists, evaluate submitted proposals to select those that are both of the highest technical quality and most relevant to users' needs. NCSSF also conducts projects and communication activities led by Commission members and other recognized leaders, as well as program staff.

Commission members remain actively engaged through the life of each project, serving as project stewards who oversee the research by tracking progress from inception to final product. This also provides a first level of critical review and establishes a relationship between researchers and the Commissioners. During its first three years, the Commission provided an average of more than

Figure 1
NCSSF Role Linking Science and Management Needs

$1 million in project funding annually. This is less than 1% of total U.S. forestry research funding, so NCSSF has focused its efforts on filling the science gaps most crucial to advancing biodiversity conservation in the context of sustainable forestry.

In planning and implementing the program, the Commission uses adaptive management techniques, conducting research and outreach activities and then applying what has been learned to the next annual round of activities. The Commission regularly invites users to define their information needs by using surveys, public meetings, and workshops that bring producers and users together for mutual learning.

As the NCSSF program produces new tools and information, the Commission holds applications workshops to provide small groups with hands-on experience using NCSSF-funded products. This experience helps users understand the project results and provides feedback to the producers on how to improve their products to make them more effective for practical applications.

Through a nationwide survey and workshops jointly conducted by NCSSF and the National Forest Foundation (NFF), NCSSF's target audience of information users identified the lack of data and information (Figure 2) as the most common barrier to sustainable forest management (SFM). The NCSSF program directly addresses this gap as its top priority, sponsoring projects to improve the information and tools available to implement and evaluate SFM approaches.

NCSSF's multi-stakeholder, consensus-building approach to identifying research needs and interpreting research results is intended to reduce polarization, the second most common barrier. The Commission's program and outreach activities help improve general awareness of technical issues and provide objective information to address public misperceptions, the third barrier.

The NCSSF Program

The NCSSF program is science-based and results-oriented, with an emphasis on developing knowledge and tools that are most directly relevant to improving sustainable forestry over the next five to ten years. NCSSF addresses users' priority needs through four program areas:

- **Synthesis and Surveys:** Projects to evaluate and document the existing knowledge base, data, and models. Synthesizing and effectively communicating existing information is at least as important as developing new information and protocols that support biodiversity goals.

- **Research and Assessments:** Projects to develop relevant new knowledge and to assess the significance of current scientific understanding for improving sustainable forestry and biodiversity conservation.

- **Tool Development:** Projects to develop new tools to assess biodiversity trends, forest health, ecosystem functions, and decision support systems (DSSs) to provide scientific understanding in usable forms to help improve decision making.

- **Communication and Outreach:** Proactive efforts that involve stakeholders in the program to enhance the relevancy and acceptance of the results. Program results are widely communicated and disseminated through the NCSSF web site, workshops, symposia, briefings, reports, peer-reviewed journal articles, and popular publications.

Table A-I in the Appendix (pg. 46) lists NCSSF's projects and major activities to date, and Table A-II (pg. 49) shows the general timeline for the first five years of the NCSSF program.

Report Purpose and Organization

The Commission has reached agreement on many important issues related to biodiversity and sustainable forestry. The findings presented in this report have value to the broad forestry community because this independent body of diverse stakeholders and experts has served as an "honest broker" as it reviewed and assessed a wide range of resources and synthesized them into consensus judgments.

Figure 2
Obstacles to Sustainable Forestry

- 23% Polarization within the field
- 19% Public awareness/misperceptions
- 39% Lack of data and information
- 19% Lack of financial resources
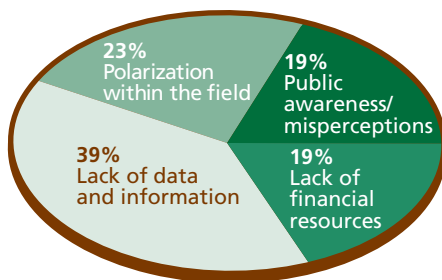
Source:
NCSSF–NFF Users' Needs Workshops 2003

This report presents the Commission's findings to date about sustainable forestry and biodiversity conservation, based on the results to date of NCSSF-funded projects and the Commissioners' deliberations over the last three years. This Findings Report is intended primarily for readers who will use the information to make decisions—working foresters in the field, forest managers, and policy makers. NCSSF also produces technical reports and scientific journal publications to inform the research community.

- **Section 1**, "Introduction," provides an overview of the Commission's role and how the Commission defined the emphasis of the first five years of program activity.
- **Section 2**, "Context," outlines the Commission's consensus on major issues in biodiversity and sustainable forestry, developed through three years of dialogue among Commissioners and with stakeholders, and which guides priorities for the NCSSF program.
- **Section 3**, "Findings and Implications," provides the major findings of the Commission to date and discusses the implications of those findings for sustainable forestry and biodiversity.
- **Section 4**, "Work in Progress," outlines NCSSF projects currently underway, including work that expands upon new knowledge generated through the earliest NCSSF research efforts.

Defining Terms Used in the Report

Sustainable forestry is the suite of forest policies, plans, and practices that seek to sustain a specified array of forest benefits in a particular place. Sustainability is a process and a goal, not a single end-point condition. The suite of benefits may include various values, uses, products, functions, and services from forests, including but not limited to wood, recreation, water quality, biodiversity, and atmospheric processes. This definition of sustainable forestry recognizes that not all forests can be expected to—or are capable of—sustaining the same suite of benefits at all times. The place can range from as small as a single tract of forest to an area the size of watersheds, states, regions, nations, or the world. As the defined place increases to the scale of a state or nation, the suite of forest benefits to be sustained increases to approach all possible values. The length of time over which the array of benefits is to be sustained in a particular place varies, but is commonly thought of in terms of decades or centuries rather than years, and it may be influenced over time by changes in demand for forest products and services, new information and technologies, changing environments and shifting social and economic values.

Biological diversity refers to the variety and abundance of all life forms in a place—plants, animals and other living organisms—and the processes, functions, and structures that sustain that variety and allow it to adapt to changing circumstances. This includes the complexity of gene pools, species, communities, and ecosystems at spatial scales from local to regional to global. It is also known simply as "biodiversity" or natural heritage, and commonly includes all of the plants, animals, and other organisms native or indigenous to a place. Biodiversity is the first of seven Montreal Process Criteria and Indicators (C&I), developed after the 1992 United Nations Conference on Environment and Development to assist countries to inventory the elements of sustainable forestry.

The following terms are used frequently throughout this report:

- **Forest structure** is the physical distribution of components of a forest including height, diameter, crown layer, and stems of trees, shrubs, non-woody understory plants, snags (standing dead trees), and downed woody debris.
- A **watershed** is an area drained by a single stream, river, or drainage network.
- **Landscape** is a general term that may imply scales from small watersheds to regions.
- A **stand** is a distinguishable, contiguous area of trees reasonably similar in age, composition, and structure.
- A **patch** is a relatively uniform area of vegetation that differs from its surroundings.

The NCSSF website at **www.ncssf.org** contains more detailed information, including: summaries of projects in plain English, technical project reports for completed NCSSF projects, and abstracts of ongoing projects. The web site also contains summaries of past NCSSF sponsored meetings and workshops, a calendar of events, and an online version of this report.

Advancing Science for Sustainable Forestry

When they began their work, the Commission members found an abundance of scientifically sound research on biodiversity and sustainable forestry. Thousands of individual studies by government, academic, industrial, and environmental organization researchers yield a constant flow of bits and pieces of information.

The problem is that no well established institutional processes exist to assemble this diverse information into a coherent picture and translate the results into useful knowledge and tools for practitioners, managers, and policy makers. The Commission addresses this problem by establishing consensus on the science and its implications as a credible independent group of respected individuals with a broad range of expertise and stakeholder perspectives.

BUREAU OF LAND MANAGEMENT

The Commission's approach is first to synthesize and draw upon the extensive research that has already been done. Then they work together to identify gaps in the collective results of that work and collaboratively define research and other activities to fill the most important ones with new knowledge that will improve the scientific basis for practice, management, and policy. The Commission has summarized what it has learned in this report and is using other communication channels to share the consensus that its members have developed.

Forests in Context

The area of the earth's surface covered by forest—defined as 10% or greater land cover in trees—was estimated to be about 9.6 billion acres in 2000 (UN FAO 2003). Over time, forestland has been lost principally through the conversion of forests to agricultural, residential, commercial, and industrial land uses that came with human population and economic growth. Net forest loss appears to have stopped in developed nations, mostly in the temperate zones, while it continues in developing, mostly tropical countries.

In developed nations, forest management and harvesting of trees for various wood products are well into a major transition similar to the changes that agriculture has experienced over the past several centuries. Until the late twentieth century, most industrial wood came either from forests that were being harvested for the first time or ones that had naturally grown back following earlier harvesting or fires. The world now gets approximately 33% of its industrial wood from planted forests and is expected to obtain around 80% or more of its wood from such forests by 2050 (Sedjo and Botkin 1997, Victor and Ausubel 2000, World Wildlife Fund 2001). It appears that planted forests can meet future wood demand.

The transition from obtaining forest products from extensive natural forests to producing them from smaller, intensively managed planted forests will have significant implications for sustainable forestry and biodiversity conservation.

U.S. forests now cover roughly the same amount of land as they did in 1920—749 million acres, or about one-third of the nation's land area. Most North American forestlands have been impacted by human activity for thousands of years. Native Americans cleared agricultural plots and burned forests to provide openings and wildlife habitat. European settlers cleared large forested areas, for agriculture in the seventeenth to nineteenth centuries, but as U.S. agriculture moved westward, abandoned farm lands in the Northeast were widely reforested in the twentieth century.

Past land uses have greatly influenced current forest conditions, and some have left long-lasting impacts on the landscape. Over the past 400 years, U.S. forests have declined in area by at least one-third, and the ecological quality of what remains has often changed. As with global forests, most of these losses resulted from forest conversion to agricultural, urban, suburban, and industrial uses. Most of the conversion occurred between 1860 and 1920 (Williams 1989, Perlin 1991, MacCleery 1992, FAO 2002, USDA Forest Service 2003). The total forested area of the United States has been relatively stable since 1920, although changes are still occurring in individual states.

U.S. public and private lands are often intermixed in a patchwork of ownerships and different land uses. Most publicly owned forestland is in the West, while most privately owned forestland is in the East (Figure 3). Approximately 10 million non-industrial private landowners hold about 58% of the nation's forestland. These privately owned lands not only are the largest area of forest ownership in the United States; they also comprise the nation's largest area of the most biologically productive forestland (USDA Forest Service 2004).

Figure 3
U.S. Forest Ownership

Millions of Acres
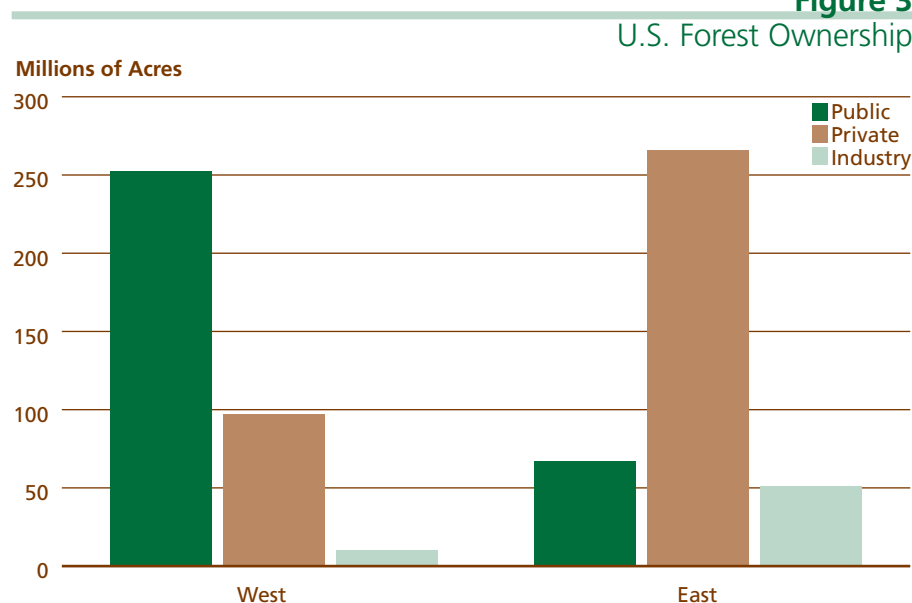
Source:
USDA Forest Service 2004

About two-thirds of the forested land in the U.S., or 504 million acres, is classified as commercial forestland, or timberland. Repeated growing and harvesting of trees for wood or wood-based products is economically feasible on commercial forestlands. About 72% of these commercial forest-lands are in the East. Some 52 million acres of U.S. forests are reserved or dedicated for non-timber uses as parks, refuges, or wilderness areas managed by a variety of public agencies. The U.S. Department of Agriculture (USDA) Forest Service manages 19% of the nation's forestland, the forest industry owns 13%, and other public agencies own 10% (USDA Forest Service 2001).

Growing demand for wood and the economics of wood production are encouraging more intensive management of the most produc-tive forestlands. As noted earlier, individuals own about 58% of U.S. forests and private forest industry owns another 13%. Together, those forests provide most of the wood that the nation uses and exports, and they are now almost entirely second-, third- or fourth-growth forests, some reconverted from agriculture. This creates opportunities and challenges for integrating biodiversity conservation into sustainable forestry. There are opportunities to enhance bio-diversity in intensively managed forests, e.g., by incorporating small reserves and other conserva-tion measures, and to de-empha-size wood production on lands that are better suited for other purposes. The challenge is to achieve sustainable *mixtures* of forest uses and management incentives at scales ranging from a single ownership to a large region.

As the demand for wood has grown, so has the demand for virtually every other forest benefit, primarily water. Forests in the United States are commonly the headwaters for major river systems. High water quality and normal flow patterns have been reasons for protecting forests in the United States since the late 1800s (Adirondack Forest Preserve 1885, Organic Administration Act of 1897). More recently, recre-ational uses of forests, the role of forests in storing atmospheric carbon, and the conservation of biodiversity have become highly valued forest benefits.

The Forest Continuum

Forests provide benefits that are based on the management goals for each forest as well as its natural potential. The role of biodiversity in sustainable forests and the con-tribution of each kind of forest to overall biodiversity conservation vary across a broad continuum of forest purposes.

At one end of this continuum are traditional *reserves*—often large contiguous areas protected from development and focused on preserving native species, "wild" ecosystems, and natural processes. Reserved forestlands, including state and federal parks and wilder-ness areas, have doubled since 1953 and now comprise 7% of all U.S. forests. However, some regions don't have appropriate lands and/or conditions for large reserves, and the scientific and conservation communities now recognize that reserves are neces-sary but not sufficient to maintain biodiversity in its fullest dimen-sions. For example, entire eco-regions—very large geographic areas that usually cross ownerships

and include a diversity of habitat components—have been shown to have an important role in sustaining certain wildlife and fish such as grizzly bears and salmon.

At the other end of the contin-uum of forest purposes are *wood production forests*—plantations that are managed primarily for indus-trial wood. These forests tend to have a broad distribution of age classes, including significant early successional stages, which reflect planned disturbance by harvesting at regular intervals. Forest planta-tion biodiversity is often aug-mented by retaining biological legacies such as snags, large live trees, downed woody material, streamside management zones, and small, scattered conservation plots as miniature reserves.

Multi-resource forests where no single purpose dominates lie between the reserves and wood production forests. The majority of America's forests are multi-resource. *Urban forests* are a special and growing type of multi-resource forest. U.S. urban areas have doubled in size over the past 20 to 25 years, and 28% of the nation's forests are in counties with urban populations greater than 20,000. As urbanization spreads into less developed rural areas, a growing percentage of the nation's natural resources will become part of urban forest ecosystems (Dwyer et al, 2000). Multi-resource forests, including urban forests, are the next frontier in overall biodiversity conserva-tion.

Fortunately, the existence of forests across this continuum tends to increase biodiversity of all plants and animals. Conditions within specific parts of it are very favorable for some species, and the survival of some species might be

threatened without the entire continuum. This biodiversity is reflected at the landscape level but not necessarily at the individual forest level.

Changing Forest Ownerships

According to the 2002 USDA Forest Service National Woodland Owner Survey, more than 10 million people own 276 million acres of forestland in the United States for non-industrial purposes. About 4 million of those owners hold less than 10 acres that are essentially extended home sites. Another 4 million of those owners hold 220 million acres in parcels of 10 to 1,000 acres.

The average tenure of family forest ownerships is 10 to 15 years. Trends suggest over the next two decades, the number of family forest owners will increase to 12 million, but the total amount of forest acreage will remain the same. This large-scale turnover of forest ownership is leading to increasing conversion of forests at the urban-rural interface to other uses and increasing fragmentation of the remaining forests.

At the same time, economic forces are triggering change in the forest products industry. Pension funds, investment trusts, and timber investment management organizations (TIMOs) are buying large amounts of industrial timberland. Some of this forest-land is being converted to other uses, such as large home sites. In general, each transaction further fragments ownership.

Some large private forests are being identified and managed to protect their significant cultural and biodiversity values. Large easements, such as 170,000 acres in New Hampshire acquired in 2003 from International Paper Company, have explicit biodiversity goals. While similar opportunities still exist, resources are not always available to acquire and establish additional conservation easements at this scale.

America's mix of forestland ownerships requires us to achieve biodiversity across diverse landscapes rather than relying solely on large public reserves. Comprehensive biodiversity conservation must appeal to private-sector forestland managers. They aren't likely to dedicate large parts of their ownerships specifically to biodiversity, but they may be willing to incorporate small reserves and some biodiversity values into their overall goals.

The conversion and fragmentation of private forests will continue to challenge policy makers and forest managers who are working to maintain biodiversity. This is especially important in regions where private lands dominate, such as the eastern United States.

Forestry and Sustainability

The greatest threat to forest sustainability and biodiversity is conversion of forests to other land uses, which often results when markets undervalue natural systems and populations. Traditional forest management, often called sustained-yield forestry, has sought to provide forest values, uses, products, and services such as wood, water, and wildlife for society and landowners. It has focused on large plants and animals and on recreation—trees for wood products, birds and mammals for hunting, fish for catching, and woods for hiking and camping.

The Value of Biodiversity

Conserving and sustaining biodiversity is important for many reasons, including but not limited to:

1. Biodiversity supports the functioning of the ecological systems upon which humans depend, provides genetic material for new agricultural and silvicultural crops, and provides resilience necessary for ecosystems to withstand climatic changes, disease and pest out-breaks, and other environmental stresses (Keystone Center 1991).

2. Nearly half the world's medicines are derived from living plants or animals, and the potential exists to develop additional pharmaceutical products as new species are screened (Keystone Center 1991).

3. Biodiversity conservation makes good economic sense. Humans are dependent on natural resources for both commodities such as forage for livestock and lumber for homes and for ecological services such as flood control, waste detoxification, and creation of soil (Brussard 1994).

4. Many people assign intrinsic value to biodiversity because of ethical concerns or personal interests and affections. Through actions such as contributions to conservation organizations and ecotourism, these concerns, interests and affections translate directly to economic value.

People increasingly understand that forest values extend beyond these traditional resources and they expect more. Forest managers in turn seek policies, plans, and practices to sustain a more diverse array of forest benefits.

Sustainability has three essential, interacting components: (1) economic, (2) environmental, and (3) social. The typical definition of sustainable forestry—meeting the needs of today's people without compromising the needs of future generations—is derived from a set of non-binding "forest principles" developed at the 1992 United Nations Conference on Environment and Development (UNCED).

Over the past 10 to 15 years, a more comprehensive approach to biodiversity has been integrated into sustainable forestry. Central features of this approach include:

- identifying forest values to be sustained in the place(s) under consideration
- specifying indicators for the biological and ecological values to be sustained at various scales in the place(s)[1]
- exploring the effects on biodiversity of natural processes such as wildfire, invasive species, insects, diseases, and climate change in sustaining habitat diversity, productivity, and resilience; these effects ideally would be assessed through the selected indicators
- addressing the effects of human uses on biodiversity, i.e., native species, forest structure, and composition at the stand, watershed, and/or landscape scales, also assessed through the selected indicators
- managing forests to maintain and enhance the biodiversity values identified above, including establishing "reserves" at appropriate geographic scales for species that can't be accommodated without such special provisions
- monitoring and evaluating indicators and making appropriate adjustments in management.

This broader concept of sustainability needs a broader foundation of science and practice than the one that has supported sustained-yield forestry since the 1950s.

Efforts to maintain biodiversity and sustainability are driven by such things as federal water and endangered species laws, state forest practice acts and regulations, forester licensing and certification, and forest policies. Sustainable forest management certification encourages, documents, and recognizes landowner commitments to sustaining biodiversity and other forest values. Major U.S. forest certification programs include the Sustainable Forestry Initiative, the Forest Stewardship Council, and the American Tree Farm System.

Biodiversity Indicators

The biodiversity of any forest is very complex. Many aspects of this complexity are hidden and can't feasibly be observed, let alone understood. Thus it is essential to use indicators—a relatively few measures that provide information about the status of as many unmeasured biodiversity elements as possible—to represent major biodiversity values in a particular area.

Many Federal and state agencies in the United States have used the Montreal Process Criteria and Indicators (C&I), an international guide for evaluating progress in achieving sustainable forests at state and national scales. The C&Is are applicable to large regions, across multi-owner landscapes of Federal, state and private lands, but they are poorly suited to single ownerships or smaller geographic scales. An objective of NCSSF is to provide tools for developing criteria and indicators at multiple scales.

One challenge in implementing sustainable forestry across ownerships and regions is that there is no national definition or standard approach, and the forest certification and C&I systems do not mesh well as one goes from one geographic scale or ownership to another.

Indicators represent what biodiversity means for any forest, and they tell managers and others what is to be sustained in those forests. Because forests exist over a continuum of capabilities, conditions, and management purposes, forest biodiversity indicators will also be a continuum, with no single set appropriate to all forests in all places.

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[1]Indicators are also needed for other forest values to be sustained but those are beyond the scope of NCSSF Phase 1 work.

3 FINDINGS AND IMPLICATIONS

N CSSF is at the midpoint of its initial five-year time frame. Although more than half of NCSSF initiatives are still in progress, some important patterns already are emerging. After almost three years of Commission deliberations informed by research results, we think it is important to share the most salient findings about sustainable forestry and biodiversity conservation in this interim report. (*The summaries and detailed reports for completed NCSSF-funded projects are available at:* **www.ncssf.org**.)

Given the broad audience for this Findings Report, some readers may find that individual findings challenge their conventional wisdom, while other readers may regard the same findings as common knowledge. The findings presented here represent key areas of Commission consensus at this stage. They are not comprehensive. Rather, they are focused on defining a baseline of current knowledge on management issues where science is most needed by decision makers.

The NCSSF findings include four areas of sustainable forestry and biodiversity conservation:
• Stand-level and landscape patterns
• Disturbance dynamics
• Biodiversity indicators
• Adaptive management

NOTE: *The reference codes used in this document (i.e. NCSSF A3, NCSSF B1.2.) are keyed to Table A-I (pg. 46) in the Appendix which lists all the NCSSF projects and reports.*

BUREAU OF LAND MANAGEMENT

The effectiveness of biodiversity conservation is largely determined by interactions between stand- and landscape-level patterns.

Finding 1A
Biodiversity conservation requires knowledge and policies that cross landscape levels.

Landscapes are the mix of land-cover types resulting from human activities together with natural conditions and disturbance patterns. "Landscape" is a general term that may imply scales from small watersheds to regions. Working at a landscape scale often means integrating actions across jurisdictional boundaries, requiring community collaboration. The character of a landscape—size, context, connectivity and contrast among habitat patches or stands—both influences and is influenced by the elements of biodiversity within each individual patch or stand.

NCSSF Results: Landscape-level examinations across ownerships are necessary to assess the effects of forest management decisions on biodiversity. Patterns of forest structure arising from differing management objectives and approaches across the broader landscape are a significant determinant of biodiversity and of the success of conservation efforts. (NCSSF A5W: *Assessment of the Scientific Basis for Standards/Practices at the Stand, Management Unit, and Landscape Levels in the Western United States*).

Reserves—areas set aside from extractive and intensive uses such as mining and residential development—are necessary but insufficient for biodiversity conservation. Efficient and effective conservation decisions require a landscape view, accurate landscape-level information, and knowledge about how landscape patterns influence biodiversity and ecosystem functions. The shapes, sizes, and arrangements of stands on a landscape are important. Work on defining these relationships has just begun, but NCSSF project findings address several related considerations, including the following:

- The conservation goals that can be achieved on a given landscape depend upon its specific biological and physical characteristics.
- Interactions among natural events and the cumulative actions and effects of many decision makers determine regional landscape patterns. One or many decision makers may determine patterns across smaller landscapes, depending upon the landscape in question and the size of ownerships.

NATIONAL PARKS SERVICE

- There are methods to quantify relationships between measures of forest structure and indicators of biodiversity (Finding Area 3) to substitute for unmeasured or unknown biodiversity elements.

Landscape patterns within relatively small areas may influence some aspects of biodiversity. In the Southeast, local patterns in forest type (areas 0.5 miles in radius or smaller) are good predictors of bird species diversity. Patterns at that scale can be measured by remote imagery, which means that bird diversity can be predicted without detailed stand-level information (NCSSF A5E: *Assessment of the Scientific Basis for Standards/ Practices at the Stand, Management Unit, and Landscape Levels in the Eastern United States*). This may not be true for less mobile organisms.

Where spatial analysis can be used to identify portions of the landscape that are crucial to conserving high-priority aspects of biodiversity, it can reduce the cost of achieving biodiversity objectives (NCSSF A5W). ■

Legacies are conditions that link past and future systems. Many land management practices ranging from timber harvest to agricultural plowing have impacts that often are still apparent years after the activity has ceased. These "legacies" of past management may be beneficial or detrimental to long-term forest management and biodiversity goals. Such legacies sometimes play a crucial role in ecosystem resilience—the ability to recover from disturbance without long-term loss of diversity and functional integrity. Legacies at the stand scale include trees, logs, plant species that sprout from roots, and both living and nonliving components of soil. An important aspect of sustainable forestry practice is identifying and managing forest legacies.

NCSSF Results: Retention of large, mature trees on all forestlands (public and private) has a significant positive effect on the regional abundance of several species associated primarily with late-successional forests in the Pacific Northwest. On the other hand, management for early-successional stages is appropriate where species of biodiversity concern (e.g. Kirtland's warbler) decline due to a lack of early successional forests (NCSSF A5W).

Disturbances—conversion to agriculture, intensive utilization of wood, loss of topsoil— that destroy or significantly alter natural legacies can change the path of landscape succession and limit potential ecosystem restoration. For example, some modelers predict that management to maintain late-successional forests on public lands and to reduce some early-successional stands on private lands could cause a decline in the proportion of mid-successional forests in the Pacific Northwest that could affect biodiversity (NCSSF A5W).

Historical changes in land use in New England, particularly since European settlement, have affected the region's biodiversity significantly. Most of the affected landscapes can be functionally restored—made to accommodate species that were present at the time of settlement. But precise ecological conditions can't be recreated with any assurance because of uncertainty about historical conditions as well as irreversible changes such as soil loss, invasive species, climate change, and urbanization. (NCSSF B1.1).

It is important to note that:
- Legacies vary with disturbance type, intensity, and frequency, resulting in varying biodiversity responses.
- Variations in the timing and nature of disturbance generate significant biodiversity across landscapes.
- Spatial variability of disturbance and variation in post-disturbance patterns may also contribute to biodiversity at the stand level. ■

Finding 1C
Biodiversity correlates to spatial variability in forest management.

Many structural features that are important to diversity are influenced by common forestry practices, such as thinning. Various stand conditions favor different groups of species. Landscapes with a diversity of stand ages and types are likely to have a diversity of animals, plants, and microbes. However, because different species require different amounts of habitat, successful conservation requires quantifying the relationship between landscape patterns and the diversity of different species groups.

NCSSF Results: In the Southeast, bird species richness was positively associated with diversity of habitats at many spatial scales. By some measures, pine forests were richest in species, but some species and guilds were associated with hardwood forests. Because birds are highly mobile, their responses to patterns in forest types across landscapes may not be good predictors of how less mobile species, such as amphibians, will respond. (NCSSF A5E *Assessment of the Scientific Basis for Standards/Practices at the Stand, Management Unit, and Landscape Levels in the Eastern United States***).**

NCSSF A5E found that species richness within virtually every bird guild—a group of bird species with similar ecological requirements—that was examined correlated positively with one or more measures of local habitat diversity. Researchers found that species that nest in the canopy or in cavities and year-round resident birds were strongly associated with hardwood forests. Species richness within each of these groups correlated negatively with the extent of forests less than 4 years old in the immediate proximity (100 yards), but was positively influenced by the presence of some young forests when a larger (0.6 miles) spatial scale was considered.

Short-distance migrants and species that prefer early successional habitat were associated with pine forests, and birds within these groups were relatively insensitive to forest age. However, in some cases the number of species within one or both of these guilds declined as the amount of forest older than 80 years increased within the local landscape.

More amphibian and reptile species were found in hardwood forests than in pine or pine-hardwood forests, but hardwood forests often were on moist sites or closer to water than other forest types. Stand age diversity at relatively small scales (within 275 yards) was positively associated with greater richness for both amphibians and reptiles. Stands with high basal area—a measure of tree density—supported more amphibian species, while stands with low basal area supported more reptile species.

Overall, in habitat quality models, the relationship between richness of bird guilds and measures of landscape patterns addressing landscape scale is not well understood. Additional NCSSF research is furthering insights about multi-scale management across ownerships. ■

Finding 1D
Forest fragmentation generally reduces biodiversity.

Forest fragmentation occurs when parts of a contiguous forest are altered or removed so that the parts that remain are increasingly isolated from each other. Forests can become fragmented when land is converted to other uses such as agriculture, urban, residential, and commercial development, or tracts that are simply too small to manage, causing the most severe impacts on adjoining forest areas.

NCSSF Results: Fragmentation increases the effects of deforestation to the extent that a patchwork of forest remnants has less habitat value than one large patch of equal area. However, over the last decade, the view of how fragmentation alters forest biodiversity has shifted toward recognizing that a wide range of habitat quality changes take place in all components of the fragmented landscape. The new understanding moves away from viewing forest remnants as discrete habitat "islands" surrounded by inhospitable areas and toward the view that there are different degrees of fragmentation and that what is suitable habitat for some species is inhospitable for others. (NCSSF A7: *Identification of Biodiversity Research Needs Related to Forest Fragmentation***).**

Forests can be temporarily fragmented into smaller units by harvesting that changes the age classes and species composition of the next forest. Visual considerations and some wildlife habitat goals have led to smaller, more numerous openings in forests that may actually contribute to forest fragmentation.

Effects of forest fragmentation on biodiversity are often difficult to distinguish from the effects of habitat loss and forest succession. Moreover, fragmentation effects vary among landscape types and depend on the mix of species, spatial scales, and ecological processes. Landscape-scale measurements of fragmentation, such as edge density and the distance between patches, have value as general indicators of forest patterns but are often poor predictors of species richness and other measures of biodiversity in forest remnants. Specifically, habitat quality and thus biodiversity are affected not only by forest area but also by the arrangement of the forest and fragmenting factors such as non-forested areas and roads (NCSSF A7).

Although the effects of forest fragmentation are difficult to measure, they are well established in ecological theory and documented in many field studies. Larger patches of forest habitat generally support more species than smaller patches of the same forest type. Populations in smaller patches are at greater risk of extinction due to variability in environmental conditions and population levels. As remnant patches of forest become smaller and more isolated, adverse impacts of fragmentation increase and are likely to be greatest for species with limited dispersal ability (NCSSF A7). However, short-lived patches in a dynamic landscape that is continuously forested but with age classes moving spatially over time do not function in the same way as isolated islands surrounded by water. Also, isolated forest fragments have some biodiversity values that would disappear if they were converted to non-forest uses.

Local populations in remnant patches of forest in fragmented landscapes are strongly affected by the characteristics of surrounding areas. It is important to study and understand how fragmentation alters flows of energy, matter, and species—including dispersal and spread of non-native invasive species and diseases—across the modified landscape and thus affects forest succession, sediment movement, nutrient cycling, carbon sequestration, and other key community and ecosystem processes (NCSSF A7). ∎

Implications of Area 1 Findings for Sustainable Forestry

Landscape-level information is necessary to use science fully in conservation efforts everywhere. Landscape patterns in forest structure result from interaction between management practices on individual ownerships and natural disturbances. Management practices on individual lands within a region can affect regional biodiversity significantly, either directly by producing or retaining habitats or indirectly by influencing the spread and severity of natural disturbances. Human land use and other agents of change have significantly influenced diversity on many landscapes, and many new elements also have significant biodiversity value.

Changes in land use history influence biodiversity change. Consider the land-use history of a given site and how historical land use patterns constrain biodiversity goals. Aerial photographs made in the early 1940s of many parts of the country provide a useful starting point. For example, a former agricultural field on a steep slope may indicate low soil productivity because 90% of the topsoil is gone, whereas consistent forest cover can indicate a favorable site for endangered species (NCSSF B1.2).

Government agencies and nongovernmental conservation organizations often have databases on indicator species—species that can provide insight into the overall health of an ecosystem—that can inform decision making. Participating in conservation planning efforts at local and higher levels can help landowners understand relevant priority issues and conservation strategies for their areas. Collaborating with adjoining landowners or others can provide mutual benefits to landowners and other parties within a given landscape.

The problem with a top-down, "how should the world look proportionally?" view of scientific findings is that a single management organization generally can't change the pattern of forest landscapes. Most landowners can't control or even influence both policy and ownership-level activities. A further complication is that the specifics of many landscape-level management strategies can't be generalized—what works in one area may not in another. Social, policy, and land-management mechanisms for meeting landscape-level goals are generally not established, although the Minnesota Sustainable Forest Resources Act of 1995, with a Landscape Planning Component, is a notable exception.

NCSSF is currently funding several projects to help both land managers and policy makers address this problem. Renewals of Projects A5E and A5W are examining new approaches to managing forests at the landscape scale and across ownerships. A new project, NCSSF C2: *Existing and Potential Incentives for Practicing Sustainable Forestry on Non-Industrial Private Forestlands*, focuses on non-industrial private forests, an important segment of forestland ownership. Project C2 is determining what incentives—cost-sharing for stewardship practices, preferential tax-assessments, market incentives, etc.—would encourage private landowners to practice sustainable forestry, which is necessary for biodiversity conservation to succeed at the landscape level. Another new project, NCSSF C3: *The Conservation Context of Forestry*, addresses non-industrial private forestlands in the context of state conservation plan impacts.

Sustaining disturbance dynamics within appropriate ranges sustains biodiversity and ecosystem services.

Finding 2A
The historical range of variation is a useful but limited concept for managing biodiversity.

For every landscape, natural disturbance processes have measurable patterns of frequency, intensity, and spatial scale. The pattern of variability over time constitutes the historical range of variation (HRV)—fluctuations in ecosystem behavior resulting from influences such as climate, fire, or flood. When humans alter ecosystems beyond the historical range of variation, they risk fundamental change that can threaten biodiversity. As Pickett et al (1992) noted, "Nature has a range of ways to be, but there is a limit to those ways, and therefore human changes must be within those limits."

NCSSF Results: Many components of biodiversity are affected by the complexity of forest structure and landscape diversity in relation to the disturbance regimes and history of a particular area (NCSSF A7). Management that sustains this complexity within its historical bounds may also sustain historical biodiversity; however, pre-settlement conditions are often not a realistic management goal because the landscape condition has been changed by human-caused disturbance. Attempting to restore earlier landscapes may not lead to resilience in the face of new forces, such as climate change, mega fires, exotic species invasions, or pollution (NCSSF B1.3).

Because HRV has sustained biodiversity over time, it is sometimes recommended that managers emulate those fluctuations and avoid exceeding historical extremes. A more productive approach is to understand how historical behavior shaped ecosystems and to try to project that behavior beyond any recent alteration into the future as a management target based on lessons of history, not a re-creation of history. A natural disturbance regime for an area comprises all of the various disturbances that affect it as well as their intensities and frequencies. When natural disturbance regimes are absent or altered, restoration and management approaches that integrate concepts of ecosystem responses to natural disturbances may achieve biodiversity goals. (NCSSF A6: *Evaluation of the Role of Ecosystem Restoration on Biodiversity*)

Managing within HRV is relatively simple in systems that have not been fundamentally altered by changes in land use, disturbance frequency, or species composition, human imposed infrastructure such as highways and dams, or climate change. Where extinctions, species introductions, or altered disturbance regimes have fundamentally changed the system, management-induced or natural disturbances may produce

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novel and undesirable effects such as uncharacteristically severe fire or species invasions. Sustaining historical dynamics into the future can be further complicated by climate change and invasive species.

At regional scales, changes have been profound and pervasive nearly everywhere, and managing ecosystems to function within their historical bounds is neither possible nor desirable. Still, lessons of history, such as the importance of maintaining forest complexity, can be applied to maintain biodiversity. For example, in one NCSSF-sponsored project, thinning younger conifer stands in the Pacific Northwest benefited at least one bird species (NCSSF A5W).

Managers can adhere too strictly to the HRV without considering significant changes that result from climate change, species invasions, and other pressures. The lessons of history should be combined with knowledge of expected ecosystem behavior under likely future scenarios to identify a "future range of variation" (FRV) that will sustain biodiversity in the face of ongoing environmental change. ■

Finding 2B
Fire significantly influences patterns of biodiversity within and among forest ecosystems.

A fire regime comprises the characteristics of fire in a given ecosystem, such as the frequency, predictability, intensity, and seasonality of fire. Several factors have altered fire regimes in forested ecosystems over the past century, including land-use history, landscape fragmentation, fire suppression, and changes in human access and ignition sources. The size and severity of recent fires in the dry forests of the U.S. West were historically unprecedented, a result of 50 years of effective fire suppression, high fuel amounts, and a warming climate.

NCSSF Results: Failure to reduce the risk of extreme fire behavior outside the historical range of variation can significantly affect biodiversity through changes in landscape patterns and other ecological processes (NCSSF R3: *Fire, Forest Health and Biodiversity— Second Annual NCSSF Symposium*).

Modeling by Perry et al (2004) showed that susceptibility to crown fires in dry forests of central Oregon varied widely at the landscape level. In most modeled cases, controlled underburns, or a combination of controlled underburns with light to moderate thinning of smaller trees, could significantly reduce risk. Field research done in Central Oregon by Fitzgerald (2003) indicates that moderate to heavy thinning of understory trees and reduction in surface fuels is required to change fire behavior significantly. However, human development in high-risk areas has greatly diminished fire management options. Air-quality standards can severely limit the number of days per year in which prescribed fire can be used, reducing the opportunity for risk-reduction fires and artificially constraining replication of historic fire levels.

The impacts of changes in fire patterns depend on the past frequency and intensity of fire behavior in a given ecosystem. Eliminating fire in areas that experience frequent, low-intensity fires can result in in-growth of shade-tolerant shrubs and trees and a loss of herb cover and diversity. In other areas, absence of mixed-severity fires leads to uniform landscapes at intermediate spatial scales (up to 0.6 miles); the loss of fuel variability results in less variability in future fire behavior. Areas that typically experience high-severity fires or those with long return times suffer effects of fire exclusion mostly at very large spatial scale with changes in patch size, shape, density, and distribution.

The biodiversity consequences of altered fire regimes include less variability in landscapes, loss of fire-dependent species such as the Kirtland's Warbler and Red Cockaded Woodpecker, and the introduction of invasive species. Without fire, the natural succession of vegetation in some areas ultimately eliminates conditions needed to sustain threatened or endangered species or, as in recent years, creates conditions for fire to operate well outside its natural regime for the forest where it occurs. Better scientific knowledge about the role of fire in maintaining biodiversity in forests and related ecosystems will be crucial to formulating appropriate policies. ■

Finding 2C
An interdisciplinary scientific approach is necessary to address invasive species.

Non-native invasive species play a significant role in redistributing species and altering ecosystems. For example, a non-native fungus introduced in the last century caused the chestnut blight that forever changed the Appalachian forest ecosystem by effectively eliminating its dominant tree species. Increasingly species invasions threaten sustainable forests and biodiversity in the United States and worldwide (Table 1). Non-native invasive species also are altering ecosystems by eliminating native vegetation or altering ecosystem function (e.g. the effects of salt cedar on hydrology in the Southwestern United States).
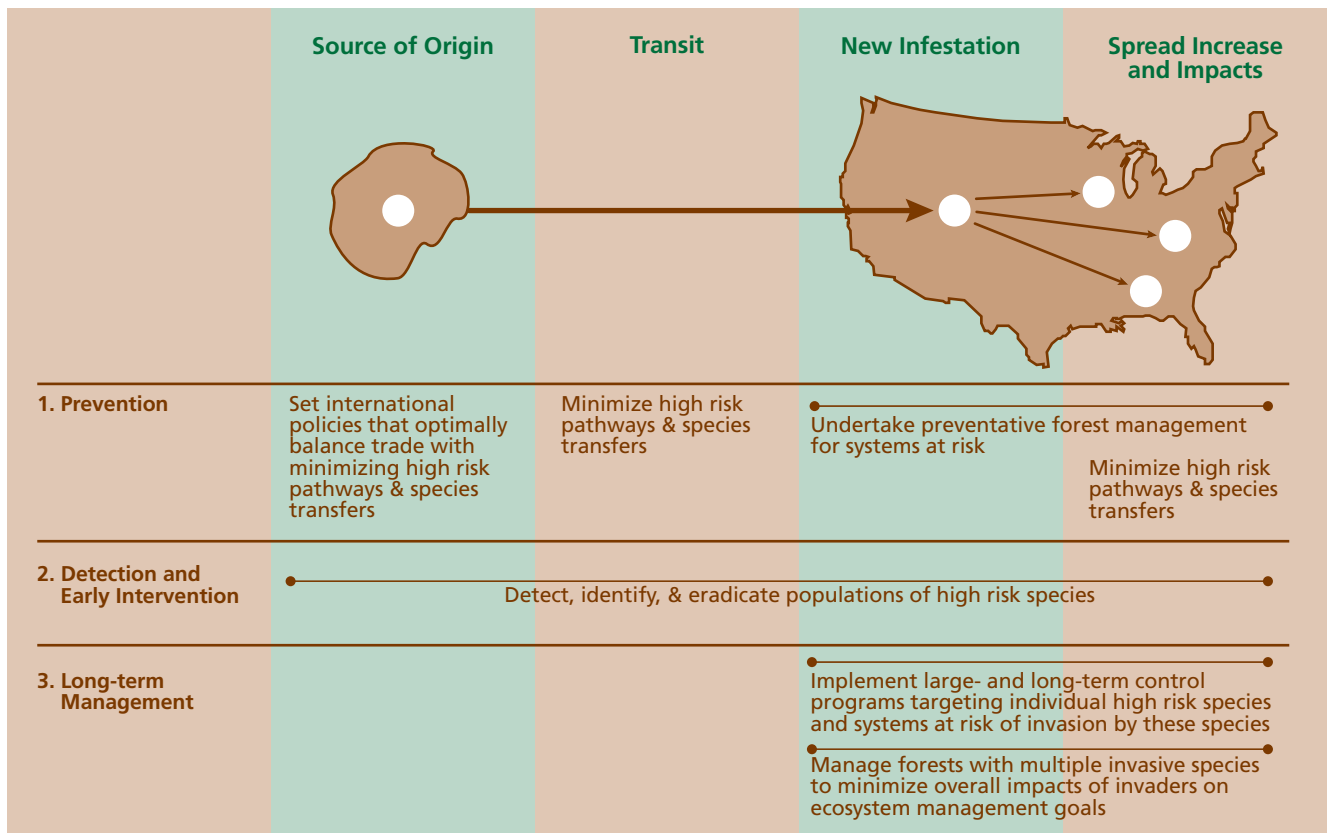
NCSSF Results: The effects of non-native species invasions in U.S. forests are lasting and cumulative, threatening to undermine the foundation of sustainability. Three complementary strategies are essential to counter invasives: (1) prevention; (2) detection and early intervention to eliminate invaders that elude prevention; and (3) long-term management of well-established invasive species. New scientific approaches and applications are needed to improve actions in each area (NCSSF A1: *Synthesis of the Existing Science Relating Forest Management Practices to the Spread of Forest Diseases and Exotic Invasive Weeds*).

Each strategy depends on the actions of individuals and institutions and the availability of appropriate knowledge and tools (Figure 4). NCSSF's priorities are to improve the underlying scientific concepts and technologies, addressing issues across sectors and at various geographic scales by identifying key science needs to reduce the threat of invasive species to sustainable forests.

By killing and damaging dominant tree species, invasive pathogens and insects cause cascading changes in the function and value of forest ecosystems. They also significantly modify forest ecosystem processes by altering fire and hydrological regimes and food-web dynamics.

Figure 4
Strategies for reducing invasive species impacts on sustainable forests (NCSSF A1)

	Source of Origin	Transit	New Infestation	Spread Increase and Impacts
1. Prevention	Set international policies that optimally balance trade with minimizing high risk pathways & species transfers	Minimize high risk pathways & species transfers	Undertake preventative forest management for systems at risk	Minimize high risk pathways & species transfers
2. Detection and Early Intervention	Detect, identify, & eradicate populations of high risk species			
3. Long-term Management			Implement large- and long-term control programs targeting individual high risk species and systems at risk of invasion by these species / Manage forests with multiple invasive species to minimize overall impacts of invaders on ecosystem management goals	

Table 1
Examples of Non-Native Invasive Species Significant to U.S. Forests

Species	First U.S. Detection	Ongoing and Possible Impacts
Nun moth (*Lymantria monacha*)[1, 2]	None	Could cause cumulative 20-year timber losses as high as $2.5 billion if established in 3 cities. Most damaging forest pest in Europe.
Sirex woodwasp (*Sirex noctilio*)[1]	None	Could cause cumulative 20-year timber losses of $760 million if established in 3 cities.
Emerald ash borer (*Agrilus planipennis*)	2002	In MI, OH, and MD. Could cause elimination of ash as a street, shade, and forest tree nationwide at an estimated cost of $282 billion.
Sudden Oak Death (*Phytophthora ramorum*)[7]	1994	In CA and OR and spreading rapidly. Has been detected in diseased nursery stock shipped from CA to 6 states. Could devastate oak forests nationwide.
Dutch elm disease (*Ophiostoma ulmi*)[1]	1930	Occurs in most states. Has killed more than 60% of elms in urban settings. A more virulent U.S. strain evolved and has caused significant impacts in Europe.
Hemlock woolly adelgid (Adelges tsugae)[2, 9]	1920's	Currently in more than 4 states. Contributing to decline of eastern and Carolina hemlocks. Alters bird communities where it kills eastern hemlock.
Balsam woolly adelgid (*Adelges piceae*)[2]	1908	Attacks true fir species. Caused dramatic declines in Fraser fir in Great Smoky Mountains National Park, resulting in understory and wildlife changes.
Chestnut blight (Dryphonectria parasitica)[1]	1904 or earlier	Eliminated American chestnut from eastern deciduous forests. Annual lost timber value for 3 states of $683.9 million (1999 dollars). Caused declines in chestnut-dependant wildlife and erosion where lost trees have not been replaced.
White pine blister rust (*Cronartium ribicola*)[3, 4, 5]	Late 1800's to early 1900's	Throughout range of eastern white pine and in 6 western states. Lost economic value. Killing pines in western high elevation ecosystems, eliminating wildlife forage; affecting soil stability, snowmelt regulation, and succession.
European gypsy moth (*Lymantria dispar*)[1]	1869	In 19 states, spot infests 12 more. Annually defoliates millions of northeastern and Midwestern forested acres; suppression costs tens of millions. Record losses in 1981: 13 million acres defoliated; $3.9 billion (1998 dollars) in losses.
Japanese honeysuckle (*Lonicera japonica*)[6, 8]	Early to mid-1800's	In 37 states. Invades forest edges and disturbed areas. Suppresses native plants, topples trees, alters songbird populations by changing forest structure.

References: [1]APHIS, 2000; [2]Campbell and Schlarbaum, 2002; [3]Ciesla and Coulston, 2002; [4]Krakowski et al., 2003; [5]Leibhold et al., 1995; [6]NRCS, undated; [7]PCA, undated; [8]TNC, undated; [9]Tingley et al., 2002

Monetary losses of U.S. forest products due to invasive species may be more than $2 billion annually. New invasions continue, spurred by changes in ecosystems and increased species mobility. The sudden oak death pathogen or emerald ash borer could have profound ecological and economic impacts; U.S. forests have experienced neither the full number of possible invasions nor the full effects of already established invaders. Economic globalization and increasing human access, fragmentation, disturbance, and climate change increase opportunities for invasive species to become established in U.S. forest ecosystems (NCSSF A1). ∎

Forest ecosystems are constantly changing. The speed and direction of that change have been and continue to be influenced by changes in human activities and variations in climate occurring over years, decades, centuries, and millennia. These patterns are further complicated by interactions among human actions and climate.

NCSSF Results: Climatic changes over the past 1400 years in Northern Arizona were inferred from tree rings. Researchers identified 58 distinct climatic periods—i.e., warm and dry versus cool and wet. These periods were often related to changes in human activities and land use that, together, influenced the species composition of forests. For example, the "Great Drought" from 1276-1299 was linked to regional-scale movements of prehistoric human populations. These migrations together with changes in climate influenced where and how forests were being used (NCSSF B1.3: *Land Use History Impacts on Biodiversity—Implications for Management Strategies in the Western U.S.*). ∎

Implications of Area 2 Findings for Sustainable Forestry

Departures from the historical range of variation (HRV) often have adverse consequences for biodiversity. HRV can be a useful guide for management, and it may even help build social acceptability when defining new biodiversity conservation goals. However, HRV isn't necessarily the appropriate goal in the face of changes in climate and species composition that change the nature of ecosystem behavior and response to disturbance. At the very least, there must be a mechanism to update and adapt the HRV concept with new information about such factors as climate change and invasive species to create a "future range of variation" concept or FRV.

Predicting the future range of variation (FRV) is difficult, but many possible forest futures can be accurately described. For example, most of the mixed-species forests of Northern New England include a narrow range of tree ages. Management can create a greater range of ages and thus more diverse forests. However, the upper limit of forest age will be dictated simply by the passage of time. This becomes a limit on the FRV.

In these forests, it will be a long time before there is a significant area of late successional or "old growth" forests. However, some structural characteristics of old growth can be accelerated. FRV can be manipulated by thinning forests to encourage the remaining trees to reach old growth size sooner. In this instance, the future can be both predicted and created. Similarly, the rate at which wind, fire, insects, disease or harvest create young forests will limit FRV on the other end of the age spectrum.

Forest fires outside the HRV will result from both human interventions, such as exclusion of fire from fire-dependent forests, and variations caused by combinations of natural and human influences such as changing climate conditions. Changing fire regimes will include more frequent extreme fires.

The effects of fuel reduction treatments on biodiversity are poorly understood, particularly in mixed-severity fire regimes. NCSSF is addressing this challenge by sponsoring a three-part project in fire-prone regions of the Western United States, NCSSF C4: *Biodiversity Implications of Post-Fire Recovery Strategies*. It will assess the impacts of post-fire treatments on immediate ecosystem recovery and the long-term impacts on subsequent fire severity by comparing post-fire treatments in areas that have recently been burned and areas that received some type of post-fire treatment after an older fire and then were burned again.

In a world where non-native, invasive species are jumping bio-geographic barriers, the usual approaches to ecosystem restoration won't work. We must move beyond the case-study approach to an interdisciplinary science, and emphasize pathways and prevention, combined with early detection and rapid eradication of emerging populations of invasives (Figure 5).

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A new project, NCSSF C7 *Understanding How Forest Management Practices Affect Species Invasions and Impacts*, will synthesize what has been learned from forest management for invasive species and highlight effective measures for combating harmful impacts of invasive species.
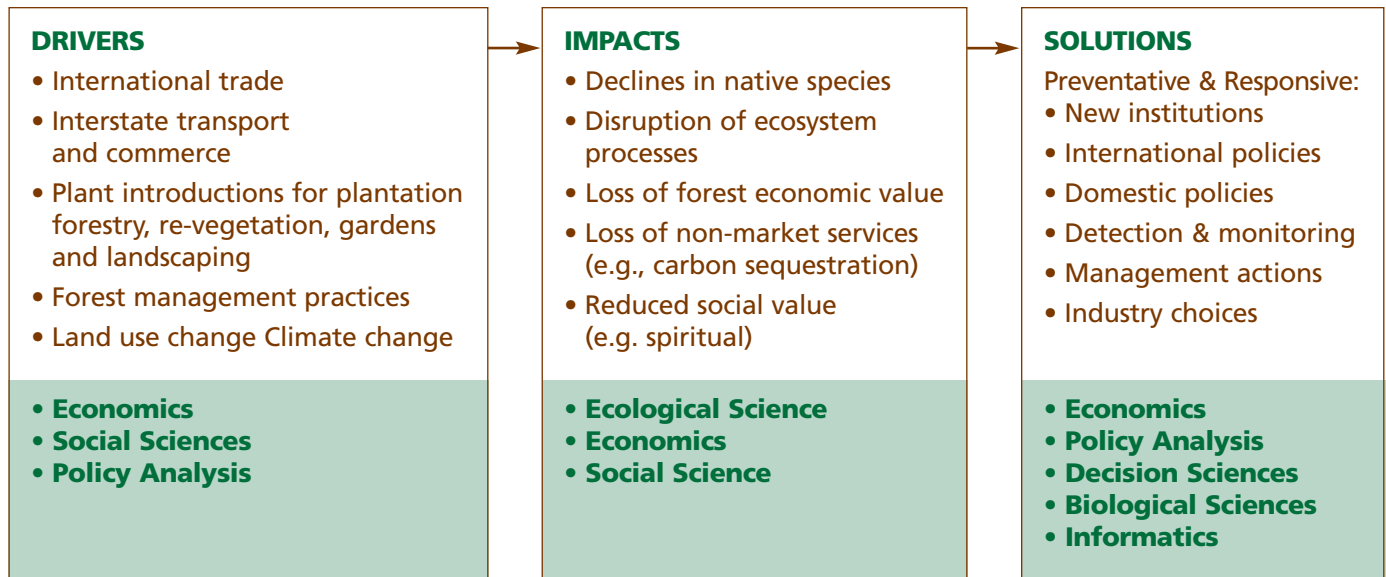
Specific relationships between land-use history and many elements of biodiversity are poorly understood in most regions, although ongoing NCSSF research is designed to increase knowledge of these areas. NCSSF-funded research has consistently shown the value of science of place—different systems are different in many ways. Constructing a frame of reference for a given site requires knowing the site's unique composition from its fire history, evidence from ecology, archeology, and other sources. For example,

thinning or shifting forest structure alone may not be enough to regenerate species richness; drought and arrested ecological processes will slow recovery. Future impacts on biodiversity of some land uses can't be predicted. Restoration goals and strategies must consider short- and long-term climate-change forecasts and anticipated outcomes. A key difference for biodiversity conservation in modern times is that some populations of plants and animals can no longer move in response to climate change because of man made physical barriers and other land uses. Given the uncertainties about these interactions, adaptive management will be critically important.

In the context of other goals, managing forests and woodlands for ecosystem resilience in the face

of pollution, invasive species, habitat loss and fragmentation, climate change, and other new threats can be more effective than attempting to return to past forest structure. Management practices that address ecosystem processes and composition in addition to structure will preserve and enhance resilience more effectively than those that address structure alone. Attempting to conserve biological soil crust integrity, native biodiversity, and endemic species, as well as a diverse pattern of habitats can strengthen resilience. Management plans that consider non-timber forest products, traditional use, and other forest products and values can help build a community of stewards and stakeholders who can foster more productive management partnerships (NCSSF B1.3).

Figure 5
The Need for Interdisciplinary Invasives Science (NCSSF A1)

DRIVERS	IMPACTS	SOLUTIONS
• International trade • Interstate transport and commerce • Plant introductions for plantation forestry, re-vegetation, gardens and landscaping • Forest management practices • Land use change Climate change	• Declines in native species • Disruption of ecosystem processes • Loss of forest economic value • Loss of non-market services (e.g., carbon sequestration) • Reduced social value (e.g. spiritual)	Preventative & Responsive: • New institutions • International policies • Domestic policies • Detection & monitoring • Management actions • Industry choices
• **Economics** • **Social Sciences** • **Policy Analysis**	• **Ecological Science** • **Economics** • **Social Science**	• **Economics** • **Policy Analysis** • **Decision Sciences** • **Biological Sciences** • **Informatics**

Biodiversity indicators must be matched to land-use objectives.

Finding 3A
Biodiversity is too broad a concept and too variable across forest types to be represented by a universal set of indicators.

No matter how far science advances understanding of sustainable forestry, the only way to monitor the status of biodiversity is through indicators—a relatively few measures that provide information about the status of as many unmeasured biodiversity elements as possible. We will never have the ability to track "life in all its forms."

NCSSF Results: Forest stakeholders and decision makers need to partition biodiversity into discrete components, such as aquatic/riparian values, late-successional values, early-successional values, game species values, snag and down wood values, or other specific components that are to be sustained. Only when this level of specificity is reached about values to be sustained by a specific forest or landscape can informative indicators be selected (NCSSF A8: *Identification of Biodiversity Indicators to Apply to Sustainable Forestry*).

In any forest type, at any scale, indicators are tools for assessing success or failure at maintaining biodiversity. Therefore, indicators must be chosen carefully. This hasn't always happened in sustainable forestry. But through the first and second phases of the A8 project, NCSSF has fostered the development and refinement of a tool to help select biodiversity indicators. ■

USDA FOREST SERVICE

Finding 3B
Clear objectives and processes are crucial to selecting appropriate sets of indicators.

Various policy initiatives have developed biodiversity indicator systems, beginning with the 1992 Montreal Process Criteria and Indicators. Since then, sustainable forest management certification systems such as—the Forest Stewardship Council, Sustainable Forestry Initiative, Canadian Standards Association, American Tree Farm System, Green Tag— have emerged with their own sets of biodiversity performance measures and indicators. In 2002, the Heinz Center for Science, Economics, and the Environment released the *State of the Nation's Ecosystems* report with a peer-reviewed, agreed upon small set of national-scale indicators that is updated periodically. NCSSF A8 identified more than 2,000 biodiversity indicators currently in use or proposed by scientists.

NCSSF Results: The bottleneck in effective selection and use of indicators is not a lack of good indicators or good science, but rather the lack of (1) clearly articulated management objectives for the values to be sustained and (2) a clear process for selecting indicators to reflect specific values and objectives. Therefore, although stakeholders may repeatedly select certain indicators for different situations (e.g., forest types, scales of application), a universal "core set" isn't useful (NCSSF A8).

NCSSF A8 research suggests that any tendency within laws, regulations, or certification systems to rely on only a few "core" indicators across large forests or landscapes can produce significant distortions or unintended consequences—the indicators may not be efficient or reflect the values or conditions to be sustained. Other NCSSF research shows that no single measure is adequate to measure biodiversity in sustainable forestry; multiple measures will be necessary (NCSSF A5W, A5E). ■

Finding 3C
A logically structured process is needed for selecting indicators.

Based on NCSSF survey research, decision makers said they were constrained in using indicators due to a lack of:
- existing data to calculate indicators
- information about how to select indicators
- information about how to use indicators
- credible indicators
- money (cost was listed first as the most constraining factor).

NCSSF Results: The reliability of identified measures is frequently questioned, at least in part because selection of indicators often has lacked transparency, social inclusiveness, and/or a logical structured process for selecting indicators that are locally appropriate and reflect values to be sustained (NCSSF A8).

Many forest managers and policy makers have been frustrated by the lack of a logical, stepwise, transparent process for selecting indicators. This frustration can be addressed by:
- subdividing biodiversity into more separate, workable units
- selecting indicators with a structured process so that their meaning can be interpreted by stakeholders and used by managers in forest decision making.

BUREAU OF LAND MANAGEMENT

Forest stakeholders must participate in the early stages of indicator selection to identify biodiversity values that interest and concern them. Scientists and forest managers can then help select indicators that track the societal values most cost-effectively. A follow-up project sponsored by NCSSF is developing and testing a new indicator selection process that meets these needs. Some key science priorities for biodiversity indicators are:

- testing the effectiveness of policy response indicators that measure the level of policy response being taken to reduce pressure on a biodiversity value
- improving species-habitat associations for "coarse-filter" indicators that measure broad indicators of ecosystem health
- extracting useful indicators from existing state, regional, and national databases
- conducting critical analysis to determine the most at-risk species, structures, and processes in individual forest systems

- identifying indicator thresholds (i.e., critical levels below which a biodiversity value is compromised).

A large gap remains between researchers who study forest biodiversity indicators and decision makers and users. This gap results from a lack of communication and information flow. Most decision makers face substantial information barriers in using biodiversity indicators. Researchers often are only weakly influenced by decision makers and are not meeting their information or applications needs (NCSSF A8). Most decision makers do not use peer-reviewed science journals as a primary source of information. Although researchers were key sources of forest biodiversity information for some decision makers, decision makers did not influence most researchers' selection of research topics. Conversely, researchers often feel their work is not understood and used effectively by decision makers. ∎

Finding 3D
An effective set of indicators includes three different types that cover five separate functions.

Based on a new framework of evaluation criteria, NCSSF-funded research identified many good biodiversity indicators for sustainable forestry—and many poor ones.

NCSSF Results: Informative biodiversity indicators for any single biodiversity value should measure (NCSSF A8):
- **current condition of the biodiversity value (a condition indicator)**
- **the level of one or more pressures affecting the value (a pressure indicator)**
- **the level of policy response being taken to reduce pressure (a policy response indicator).**

Each candidate indicator should be evaluated for:
- ecological breadth—number of other ecosystem components correlated to the indicator
- practicality—feasibility of measuring the indicator, including cost, time, and skill
- relevance—degree to which the indicator responds to the stress from a particular influence; e.g., timber harvesting as opposed to air pollution, or vice versa
- scientific merit—extent to which science supports the indicator
- usability— the ability of stakeholders to use the indicator to make decisions.

Table 2 lists indicators that exemplify these five characteristics. They can be used to thoroughly evaluate effective and informative indicators for use. Indicators of habitat quality are often surrogates for direct measures of biodiversity. Some indicators will be more generally applicable and will have direct links to biodiversity. Others will be less direct. For example, ongoing NCSSF research shows great promise for new, widely applicable indicators based on soil biology and chemistry.

In NCSSF's review of existing indicators, 47 received high scores for scientific merit, ecological breadth, and practicality. These included some commonly used indicators such as:
- the percent of forest in different forest types
- the percent of forest in different age classes (including late-successional and old-growth classes where they would naturally occur).

- various measures of standing and fallen dead wood, amount of forest, and age classes
- tree size
- harvest rate in managed forest settings.

These are predominantly condition indicators. Pressure and policy indicators would also be required to create an effective mix for even the broadest set of biodiversity objectives. ∎

Table 2
Examples of Effective Indicators Identified by Functional Category (NCSSF A8)

Top-Ranked Indicators for Scientific Merit (*Scientific basis and support for an indicator*)		Top-Ranked Indicators for Utility (*An indicator's level of usefulness for decision makers*)		Top-Ranked Indicators for Practicality (*Ease of measuring an indicator*)		Top-Ranked Indicators for Relevance (*Responsiveness to stressors in a decision making or policy area*)		Top-Ranked Indicators for Ecological Breadth (*Degree with which an indicator indicates something about the entire ecological system*)	
Water cycle	3	Forest age	2.4	Soil layers	2.67	Aquatic and riparian water quality forestry BMPs	3	Aquatic fine woody debris	3
Tree harvesting levels	2.87	Forest type composition	2.36	Epiphytes	2.6			Aquatic logs LWD	3
Hydrology	2.75	Aquatic and riparian water quality forestry BMPs	2.18	Late-successional species dominance	2.6	Biodiversity terrestrial forestry BMPs	3	Disturbance regimes indices	3
Logging road coverage	2.75			Bird indicator species	2.5			Ecosystem biomass	3
Disturbance-related bird species	2.62	Biodiversity terrestrial forestry BMPs	2.18	Bird indices of biotic integrity	2.5	Canopy structure	3	Habitat supply	3
Habitat supply	2.62	Habitat supply	2.18	Cavity nesting bird species	2.5	Cavity nesting bird species	3	Logging road coverage	3
Stand age distribution	2.62	Snags	2.18	Disturbance-related bird species	2.5	Disturbance regimes indices	3	Stream canopy cover	3
Forest age	2.57	Stand age distribution	2.18	Exotic plant species	2.5	Ecosystem biomass	3	Tree harvesting levels	3
Aquatic and riparian water quality forestry BMPs	2.5	Tree size/density	2.18	Forest bird species	2.5	Ecosystem respiration	3	Aquatic macro-invertebrates	2.75
		Ecosystem biomass	2.09			Exotic plant species	3	Cold-water Fish	2.75
Disturbance regimes indices	2.5	Forest soil BMPs	2.09	Lichen indices of biotic integrity	2.5	Foliage height diversity	3		
						Forest age	3		

1 = poor; 2 = fair; 3 = good

Implications of Area 3 Findings for Sustainable Forestry

Policy indicators establish overall directions and objectives. Condition and pressure indicators are expressed with units of measure (e.g., snags/acre, rotation length, etc.) and provide information on current conditions and trends. As a result, policy, condition, and pressure indicators all would be useful in making management decisions and in achieving biodiversity objectives in sustainable forestry (Table 3).

As forest certification systems and regulatory programs address the need to manage and protect certain aspects of biodiversity, policies and plans must address biodiversity indicators. Major certification systems and regulatory programs tend to emphasize *policy response* indicators, e.g., land area in reserves or the existence of a snag policy and management plan.

Some use *condition* indicators such as criteria for wildlife habitat to be retained, e.g., percent of land area in early successional vegetation, to a limited degree.

What is generally lacking is system flexibility and a process that forest managers can use to select condition and pressure indicators tailored to specific biodiversity values to be sustained in a specific forest or landscape. These indicators must be easy to measure and audit. This suggests the need to reassess the role of indicators and how they are selected and used in certification systems or regulatory programs.

For example, large-diameter snags are known to be important for biodiversity in many forest types. A sample condition indicator for large snags might be the density of large snags in the landscape. This metric tells us about the status, or condition, of the resource at present, and has units of measure (snags/acre). Research continues to improve understanding of relationships between condition indicators and biodiversity, such as that between snag density and the diversity and abundance of woodpecker species, or whether snags should be distributed evenly across the property or clustered in streamside zones and other small reserves.

A pressure indicator would tell something about where a resource is headed. A good pressure indicator might be harvest rotation length. If the present-day rotation length is too short to allow large diameter snags to develop, there will be fewer large-diameter snags in the future, regardless of the current density as indicated by the condition indicator.

In this respect, condition indicators alone can be misleading—evidence of change in a condition indicator may come too late, whereas pressure indicators can provide an early warning to future change in condition. Finally, a policy response indicator might be the presence of an internal policy for snag management. One of the easiest ways to identify policy response indicators is when there are no units of measure for the indicator (NCSSF A8).

Good indicators will have high scientific merit; i.e., a well-established scientific relationship between the indicator and the value(s) of concern. An indicator has good ecological breadth when it is correlated to a large number of other values that are not being measured. For example, large living-tree density, e.g., density of trees greater than 18 inches in diameter, can be a good indicator of mature forest epiphytes such as sensitive mosses and lichens, nesting habitat for raptors, and future large-diameter snag density.

Table 3
Types of Biodiversity Indicators (NCSSF A8)

Different types of indicators are designed to provide decision makers with different kinds of information. If indicators are chosen from each the three types listed, decision makers will be much better able to track performance for sustainability.

Type	Purpose
Condition	To indicate the level, or **condition**, of a specific value to be sustained (e.g., indicator: density of large-diameter snags).
Pressure	To indicate the **level of a stressor** affecting the **condition** of a value of interest (e.g., indicator: rotation length [a pressure that affects density of large-diameter snags]).
Policy Response	To indicate the level of **policy action** taken to maintain the **condition** or reduce the **pressure** (e.g., indicator: existence of a management strategy for maintaining large-diameter snags).

Practicality and utility are important to forest managers. Indicators are practical if they are not expensive to measure, do not require special skills (e.g., a plant taxonomist) to measure, and do not require complicated analysis. Utility refers to the forest manager's ability to use the indicator to make a decision. If the measured indicator metric does not guide the manager in making decisions, the indicator has low utility (Table 4). If indicators have been evaluated and have the above characteristics, they probably will be useful. They will inform decision makers and help them develop policies and objectives related to sustainable forestry. They will also be useful to independent auditors in assessing conformance with forest certification programs.

Using indicators to monitor results is an important way to determine if desired goals are being met. Effective monitoring can be based on a formal census of target species, or it may use informal tracking and recording of individual species or indicator occurrences encountered through other activities.

The Forest Biodiversity Indicators Selection Web Tool (NCSSF A8) helps forest managers, stakeholders, and policy makers to navigate the complex process of measuring biodiversity for sustainable forestry and pro-vides users with a list of relevant indicators. NCSSF is now funding a set of pilot activities (NCSSF A8 II) focused on refining its utility and effectiveness by field testing the indicator selection process with stakeholder groups in various regions. The project includes "train the trainers" workshops to create a nationwide pool of people who can help others use the web-based selection tool and conduct the workshop-based selection process.

Table 4
Biodiversity Indicator Evaluation Criteria (NCSSF A8)

Before specific indicators are selected for use in any sustainable forestry situation, each should be evaluated for each of 5 categories of evaluation criteria. Indicators that are not evaluated for these criteria are unlikely to serve decision makers or stakeholders well.

Evaluation Category	Description
Relevance	The degree to which the indicator responds to the stressor of concern; e.g. timber harvesting as opposed to air pollution.
Scientific merit	Extent to which the indicator is supported by science.
Ecological breadth	The number of other ecosystem components (species, structures, and/or processes that the indicator indicates.)
Practicality	The feasibility, including cost, time, and skill required, of measuring the indicator.
Utility	Ability of decision makers to make decisions with the indicator.

AREA 4

Sustainable forestry and biodiversity conservation require management that recognizes and adapts to new information, changing environments, and shifting social priorities.

Finding 4A
Management practices must adapt to evolving knowledge.

Forest landscapes are dynamic—forest uses and types will change. Policy and management must also be dynamic, able to effectively incorporate changing social values, new science, and improved practice. Because so much about how forests work is unknown or unknowable until the future reveals it, adaptive management is often advocated as the best way to advance knowledge while attempting to meet goals or solve problems. Adaptive management requires the full integration of science, management, and stakeholders in a process that treats policies and plans as if they were hypotheses and the forest practice or strategy is the experimental treatment (Holling 1978).

NCSSF Results: When NCSSF and NFF asked forest practitioners, managers, and policy makers what they needed to better address biodiversity and sustainable forestry issues, they identified three broad types of additional information as being of highest potential use. (NCSSF R4: *Users' Needs Survey and Workshops*)

- **Synthesized and highly accessible data** was the top concern for forest managers and forest policy makers, who saw a need to correlate different types and sources of data into an accessible "one-stop shopping" database, or a set of inter-related databases. This would include more common ecological classification systems to improve comparability and understanding, avoiding duplication of efforts.
- **Collaborative assessments**, involving all parties in monitoring and assessments, was a major concern for field practitioners. A more collaborative approach should also be used to make long-term predictions using all available information, with less time spent on legislative process. People also saw a need to include traditional ecological knowledge and recognize its worth.
- **Small-scale and site-specific information** especially on sites of significant value was most often mentioned in conjunction with the need for larger-scale analysis or collaborative work, making it important in the context of other broader types of data, information, tools, and approaches. Also important were better small-scale research on distribution of species and mixed-habitat ranges, and analysis at the micro-level (NCSSF R4).

BUREAU OF LAND MANAGEMENT

Finding 4B
Biodiversity conservation requires traditional forestry and more.

Adaptive management can work only if accompanied by aggressive, adequately funded monitoring programs based on clear working hypotheses that provide a steady flow of data for management decision making.

For example, NCSSF-funded research projects A1 and A4 respectively call for early detection systems for invasives and participatory monitoring and inventorying systems for non-timber forest products. But these systems will only be useful if interactive, up-to-date databases make this information easily accessible.

Thus far, the success of adaptive management has been limited by its inherent need for cultural change in both scientific and management communities (Stankey et al 2003) and the need for all involved to be willing to take risks through bold actions that may create errors or undesired outcomes (Wildavsky 1988). Table 5 indicates some key differences between scientists and policy makers in addressing issues. ■

NCSSF surveyed forestland owners and managers nationwide about their forest management and biodiversity practices, with an eye toward their selection and use of indicators for biodiversity conservation. Several interesting outcomes were identified. Most landowners and land managers surveyed believe the effects of their management on biodiversity are an important consideration. Practices aimed at protecting diversity are strongly influenced by other landowner objectives.

NCSSF Results: Nearly two-thirds of the landowners and land managers surveyed believed their biodiversity program to be successful and sixty percent of respondents felt their biodiversity program was mostly implemented (NCSSF A3). In contrast, the most commonly measured and monitored features of traditional forestry that respondents described as biodiversity indicators are NOT congruent with good indicators for biodiversity as found in the NCSSF A8 project results.

NCSSF researchers believe that to be successful, you need a broader suite of indicators (NCSSF A8).

This illustrates the new use of biodiversity indicators in forestry and the general lack of knowledge about effective selection and use of these indicators by forestry practitioners. Respondents most often considered timber inventory, tree species composition, age-class distribution, and stand structure to be important indicators for successful biodiversity programs, as well as ecosystem/habitat protection and protected areas provided by federal and state laws or regulations. Fragmentation wasn't considered to be important. Respondents who believed they had more successful programs tended to use more indicators. Figure 6 shows biodiversity indicators cited as "most important" by survey respondents.

As highlighted in Finding 3, good indicators address pressures and policies related to the resource, in addition to measurable conditions. Good indicators also must be based on composite ecological breadth, practicality, relevance, scientific merit, and usability characteristics. Table 2, "Important Indicators Identified by Functional Characteristics," offers a sampling of indicators across a range of characteristics. Finally, selecting effective indicators requires consideration of clearly stated, specific biodiversity conservation objectives. ■

Table 5
Contrasting Cultures of Scientists and Policy Makers
(after Bernabo, 1995)

Science	Policy
Incremental Progress	Deadlines and Crises
Objective Facts	Subjective Values
Proof	Beliefs
Measurements	Perceptions
Theory and Models	Applications and Results

Figure 6
Most Important Indicators Used
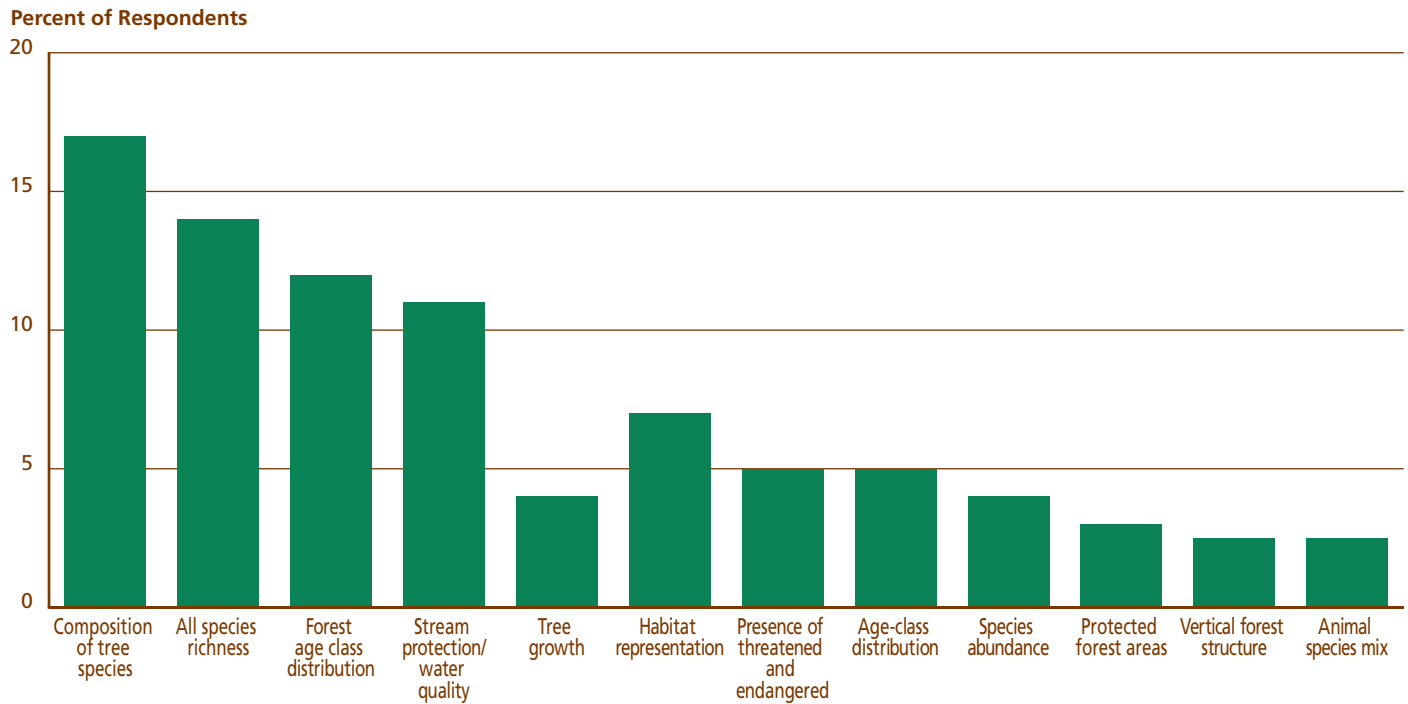
Percent of Respondents

Composition of tree species	~16.8
All species richness	~14
Forest age class distribution	~12
Stream protection/water quality	~11
Tree growth	~4
Habitat representation	~7
Presence of threatened and endangered	~5
Age-class distribution	~5
Species abundance	~4
Protected forest areas	~3
Vertical forest structure	~2.5
Animal species mix	~2.5

Finding 4C
Forest management under different ownership types has implications for biodiversity.

NCSSF research on land use in the Southeast has identified two different forest management approaches based on whether the owner is economically or conservation oriented.

NCSSF Results: Economically oriented private forest landowners in the South need strong incentives for reducing biodiversity impacts of harvesting and site preparation on more intensively managed stands, and for enhancing non-timber and non-game wildlife attributes of existing forests. Conversely, one of the biggest threats to the forests under conservation or recreation oriented-landowners is development, which is increasing land values and pressures to show economic return.

Regulatory policies that reduce the uncertainties and risks associated with endangered species protection, such as US FWS Safe Harbor, conservation programs that pay for "set-asides," such as the USDA Conservation Reserve Program, and conservation easements have been effective in encouraging retention of habitats for endangered species (NCSSF B1.2: *Land Use History Impact on Biodiversity: Implications for Management Strategies in the Southeastern US).*

Many economically oriented landowners in the South are actively managing to keep endangered species off their property. The Safe Harbor program provides a mechanism for maintaining habitat for the federally endangered red cockaded woodpecker while guaranteeing landowners use rights for their property. Many landowners in the Carolinas and Georgia participate in this program and view it as a positive response to many negative incentives for endangered species management by private landowners. There was more fear of endangered species among private landowners in Alabama, a state that does not participate in Safe Harbor, than in either Georgia or the Carolinas. For example, the growth of colonies of red cockaded woodpeckers in the Conecuh National Forest in South Alabama has caused many neighboring longleaf pine landowners to alter their

management to prevent the woodpeckers from establishing colonies on their land. The introduction of the Safe Harbor program in this area could help in the expansion of red cockaded woodpecker colonies onto private lands. (NCSSF B1.2).

Many conservation- and recreation-oriented landowners are concerned about the long-term sustainability of their efforts to conserve biodiversity. In the Southeast, the life cycle of longleaf pine forests is longer than the human life span. Many landowners who have invested a great deal of time, energy, and money in managing and restoring longleaf pine forests worry about what will happen when they die. Land ownership frequently passes down through several generations, resulting in management by many family members under a variety of arrangements. It almost always takes consensus on management to keep these forests intact. When development pressures build, that consensus is much more difficult to maintain unless a conservation easement is in place. Estate taxes and less conservation-minded heirs can undo decades of work to build and maintain a healthy, diverse forest (NCSSF B1.2).

Although current policies and programs can encourage private landowners to retain endangered species habitat and enhance biodiversity, these incentives do almost nothing to encourage creation of endangered species habitat on private land. ∎

Finding 4D
The increasing interest in and gathering of non-timber forest products has both positive and negative implications for sustaining biodiversity.

Non-timber forest products (NTFPs) are a significant part of forest biodiversity. They include thousands of wild or semi-wild forest species that occur throughout the United States on both public and private lands. Few forest managers are equipped to manage NTFPs effectively, as formal guidelines or inventory protocols are not generally available. Many NTFP harvesters have developed a keen awareness of life cycles, habitat, and availability of the products they collect, but this traditional knowledge is usually overlooked as a resource. Wider recognition of the credibility and value of this traditional ecologic knowledge could make it more useful in management strategies.

NCSSF Results: Limited research on the culture and ecology surrounding NTFPs and the general absence of inventory and monitoring programs on state and Federal land hinders conservation of non-timber forest product-related biodiversity. The impacts of removing fruits, cones, mushrooms, and medicinal plants is currently unknown, but could have a transforming effect—positive or negative—on forest biodiversity (NCSSF A4: *Assessment of Knowledge about Non-Timber Forest Products Management Impacts on Biodiversity).*

NTFP species and harvesting locations are declining as a result of development, road building, logging, grazing, and herbicide spraying. The impact of these forest management practices on NTFPs and the people who depend on them should be monitored and addressed. NTFP harvesting should no longer be ignored or considered a minor or special forest use. NTFP management needs more funding and increased staff responsibility and attention.

More research is needed to link the increasing use of NTFPs to forest biodiversity. Participatory inventory and monitoring programs for both direct biodiversity measures and indicators should be developed, implemented, and adequately funded, and the results should be used to determine if desired goals are being met. Effective monitoring may be based on a formal census of target species, or it may use informal tracking and recording of information collected in the course of other activities. In situations where NTFP harvesting adds value to a forest, encouragement of sustainable NTFP harvesting could also be an incentive to maintain working forest landscapes. ■

Finding 4E
Effective management requires access to accurate relevant information and decision support tools.

When NCSSF surveyed forest practitioners, managers, and decision makers, they identified the need for dynamic approaches and predictive tools to address biodiversity and sustainability issues.

Several participants identified the need to look at how forests are changing, and the impact that forest management alternatives, including no action, would have on such a dynamic system.

Both field practitioners and forest managers mentioned the need for predictive models and flexible approaches, such as virtual forest models that could simulate different management alternatives over time and models of relationships or responses of species to forest management.

Forest policy makers tended to mention improved scientific tools.

NCSSF Results: Many existing decision support systems (DSSs) can address components of forest biodiversity, but no DSS exists that is easily accessible and can be used to assess the probable impacts of alternative forest management options on biodiversity (NCSSF A10: *Evaluation of the Needs and Requirements for Decision Support Systems***).**

Decision support systems (DSSs) are computer-based tools that can help land managers and other stakeholders simulate, evaluate, and/or optimize management alternatives. NCSSF supported a project (A10) that compiled more than 100 DSSs into an on-line searchable database and compared 30 of them with demonstrated forest-biodiversity applications to a set of decision-making needs identified by a panel of forest biodiversity experts.

The lack of widely accepted problem definitions seriously restricts wider use of traditional DSSs in forest biodiversity decisions. However, this problem could be addressed by incorporating indicator frameworks into DSSs from the Montreal Process and other governmental efforts as well as non-governmental certification systems such as those of the Forest Stewardship Council (FSC) and the Sustainable Forestry Initiative (SFI).

Most existing DSSs focus either on forest conditions or on wildlife. Linking these two types could provide managers with a broad range of biodiversity indicator classes. However, integration of basic types of information (biophysical, social, and economic) by DSSs is still limited, and few DSS options exist for assessing the effects on biodiversity of climate, biological agents (pests, pathogens, invasives), or fire.

Biodiversity problems span a multitude of ownerships, reflecting the range of the species and ecosystems of interest, but relatively few regional institutions exist that can make decisions at these scales. DSSs could help coordinate decision making at various scales, but few have explicit capabilities to do this or provide options for small landowners. Most DSSs that are most suitable for use in sustainable forest management are still prototypes and aren't easily accessible by managers. ■

Finding 4F
Biodiversity conservation theories require adaptive management to assess their validity.

Although biodiversity conservation theories abound, no single theory serves all biodiversity purposes. NCSSF-funded researchers analyzed and organized theories into the following clusters:

- reserve- and matrix-based approaches, which allocate land to preservation through passive or active management
- "Diversity Begets Diversity" and "Using Nature's Template" models that either undertake a diversity of forest management regimes or mimic patterns created by natural disturbance regimes
- fine filter (focused on species), medium filter (ecosystem elements), coarse filter (ecosystems), and hotspots (areas of high species richness) approaches
- patchworks, networks, and gradients as models of landscape configuration.

NCSSF Results: Given the complexity of conservation strategies, variability in field applications and costs, and challenges in validation and calibration, adaptive management with effective monitoring and evaluation of implementation is the only feasible way to test the designs and applications of various conservation theories. (NCSSF B.2 *Calibration of Conservation Theory and Principles Applied at Various Geographic Scales*).

Each group of conservation theories has sound scientific foundations, and all are being used in the United States. However, few have been validated through field testing, as biodiversity is so complex and variable that it does not lend itself to traditional research methods (NCSSF B.2).

It is very important to evaluate the effectiveness of various theories and combinations of theories in terms of tradeoffs and costs. For example, a common approach to biodiversity conservation is to establish large reserves such as national parks and wilderness areas. But many of these reserves are in places without much biodiversity, some entail substantial tradeoffs to other resource values, all are costly, and it is unlikely that the area and location of such reserves will ever be sufficient to cover all biodiversity concerns. Less costly and more feasible ways to achieve biodiversity might include:

- "micro-reserves" of a few acres
- "meso-reserves" comprising medium-sized areas that provide appropriately managed buffers to protect landscape elements of extraordinary importance to native species and ecosystem processes such as aquatic features
- biological legacies that link past and future systems in working forest landscapes.

Because planning rules and processes and continued contention over federal land purposes impose serious constraints, investments in adaptive management are more likely to yield results on non-federal forestlands. In the meantime, funding a manager's guidebook to conserving biodiversity, incorporating biodiversity conservation into forest resource curricula, and most importantly, promoting adaptive management for outreach and demonstration can foster communication and understanding between conservation scientists and practitioners. Until successful adaptive management programs develop better knowledge about how well each theory works in practice and at what costs, it is also important to include clear descriptions of each theory's known efficacy and limitations for different biodiversity conservation purposes (NCSSF B.2). ∎

Implications of Area 4 Findings for Sustainable Forestry

Developing and implementing cost-effective conservation strategies and practices will enhance biodiversity. Biodiversity planning and implementation obviously are constrained by tract size and history, ownership patterns, and overall management goals, e.g., producing wood or maintaining a forest reserve. However, some general features apply across the range of considerations. Most biodiversity plans involve the following steps:

- Clearly articulate land-management objectives and determine what can be accomplished at various scales, e.g., legacies within stands, other aspects of stand structure, landscape, etc.
- Identify a set of relevant biodiversity indicators, using a tool such as the one developed in NCSSF A8. A combination of condition, pressure, and policy response indicators allows decision makers to track performance for sustainability more effectively. Conservation planning can then proceed by (1) delineating features that influence the suitability of a landscape for the indicators, and (2) managing for the features.
  - Identify, delineate, and protect rare plant communities and other areas of high conservation value such as bird nesting areas and colonies of protected species. State heritage programs and NatureServe are good sources of information. Gap analysis and eco-regional planning efforts are useful in identifying areas of high conservation value.
  - Protect landscape legacies and other system elements that maintain stability and resilience, allowing recovery from disturbance without long-term loss of diversity and functional integrity.
  - Protect "special places" such as waterfalls, cliffs, and caves that may harbor rare habitats and be subject to heavy recreational use.
  - Develop and implement streamside management and road construction practices consistent with best management plan (BMP) guidelines, best available science, and local knowledge.
- Determine the role of NTFPs, which can create economic return but may destroy biodiversity without careful management. Support of NTFP species can lead to increased variety in the landscape, and using them culturally can encourage stewardship of native biodiversity. Lack of data and guidelines on what to do or not to do makes NTFP management challenging.
- Use available tools. Great progress has been made in visualization, but few other features for communication and social negotiation have been integrated into DSSs. Such features would increase the usefulness of DSSs in multi-ownership, multi-stakeholder decision processes characterized by lack of agreement on either problems or solutions.
- Monitor results using indicators to determine if desired goals are being met. Effective monitoring may be based on a formal census of target species, or it may use informal tracking and recording of element occurrences encountered in the course of other activities. (An element occurrence is a natural feature of special ecological interest such as a bird rookery or a distinctive habitat such as a cave or sinkhole.)

Landowners and managers in the United States should become familiar with the important elements of biodiversity programs and the most useful options and strategies (NCSSF R2). This won't be easy to achieve. Current funding for research and technology to sustain biodiversity is inadequate. The number of foresters has also decreased in recent years, reducing family forest owners' access to professional advice.

However, several NCSSF projects were begun in 2004 to increase understanding of biodiversity conservation and what should be included in biodiversity management plans and to alert the scientific community to remaining gaps. NCSSF C5, *Assessment of Public Knowledge, Values, and Attitudes toward Biodiversity and Sustainable Forestry*, will emphasize

attitudes about biodiversity versus other forest values such as water quality, wood production, or recreation. NCSSF C4 is developing guidelines for participatory monitoring of sustainable forestry. NCSSF Project A4 (II) will create a professional and academic curriculum for NTFPs, as most current information about NTFPs comes from practitioners' knowledge rather than formal education. And NCSSF Project A10 (II) will develop plans for a state-of-the-art DSS that addresses current DSS weaknesses identified by NCSSF A10.

It is important to recognize that many family forest owners aren't managing their lands. As mentioned earlier, more than 10 million people own 276 million acres of forestland in the United States for non-industrial purposes. Four million people own almost 90% of that land in 10 to 5,000 acre parcels.

While well over half of the NCSSF Project A3 respondents listed nature protection as a reason for land ownership, fewer than 15% of those owners had improved any wildlife habitat in the five years prior to 2002 or planned any habitat improvement in the following five years. Less than half had sought professional advice of any kind.

Knowing everything there is to know about effective biodiversity conservation strategies won't matter if landowners don't see the value in using that knowledge in managing their forestlands. Many family forest owners simply aren't managing their lands for sustainability and biodiversity.

WORK IN PROGRESS

4
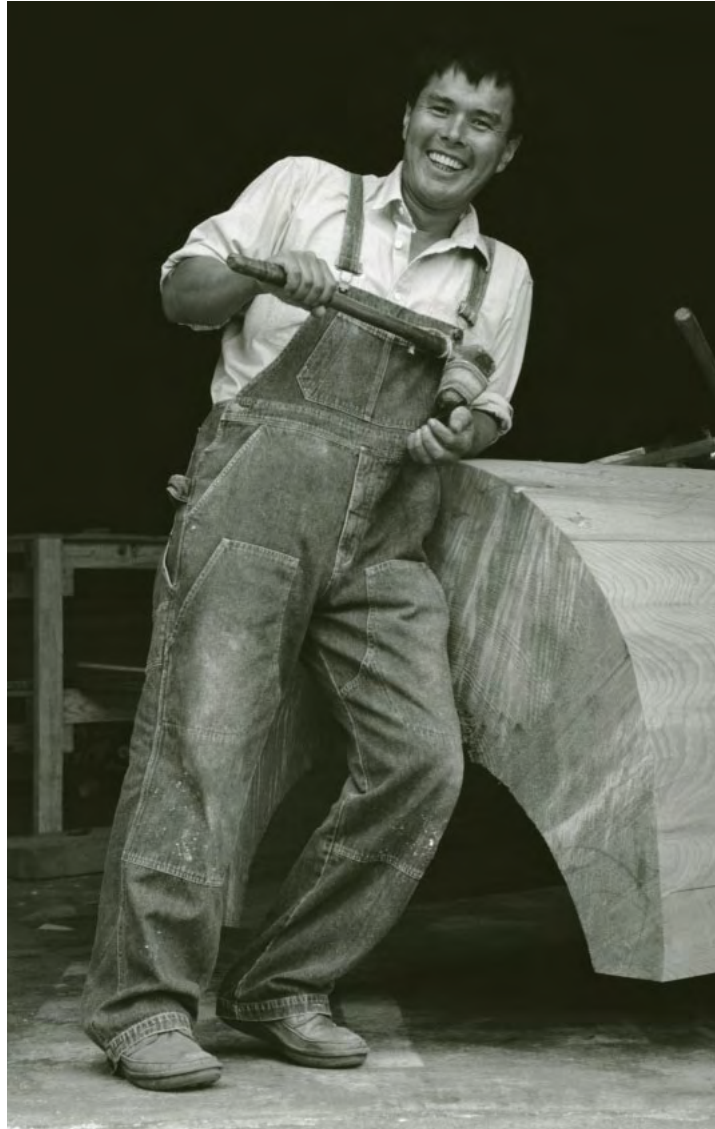
Adaptive Management of NCSSF

As the NCSSF program has advanced, the Commission has invited its broad target audiences to help interactively identify the most important work for improving the basis for sustainable forestry and biodiversity conservation. The initial NCSSF project selections were based primarily on the broad expertise of the diverse Commission members, but later projects emerged from extensive external input from a larger set of stakeholders as well as the Commission's deliberations over the earlier projects' results.

Stakeholders have repeatedly urged NCSSF not only to continue research and tool development but also to shed light on where consensus exists on major issues related to biodiversity and sustainable forestry (the goals of Sections II and III of this report). The Commission is viewed as a much needed impartial mediator who can address controversial issues more objectively because of its independent, multi-stakeholder character. This Findings Report attempts to do that by synthesizing the significance of the NCSSF project results into broader "findings" and providing the Commission's consensus on key issues. Feedback and responses to this report will be used to make future reports and materials published by the Commission even more effective in reaching our communication goals.

In response to the stakeholders' articulated needs, NCSSF also is addressing two major concerns by hosting meetings of key parties to identify consensus (as well as divergence) to help the broader stakeholder communities sort out these issues. These meetings will assess the role of globalization of forest products markets on biodiversity (C9) and develop a better definition of "old growth" from the practical aspects of sustainable forestry and conserving biodiversity (C10). Other high priority needs identified by stakeholders in surveys and workshops (NCSSF R4) and examples of the projects that NCSSF is now conducting to address these users' needs include:

- determining public awareness, knowledge, and attitudes about biodiversity (C5)
- developing protocols for participatory monitoring and research (C8)
- identifying incentives for non-industrial landowners to address biodiversity (C2)
- conducting tool applications with diverse stakeholders on the ground (A8 II, R5)
- enhancing practitioners' knowledge of non-timber forest products (A4 II)
- improving measures of conservation success and applications (C3, B4, A8 II, A9)
- determining the impacts of sustainable forestry on invasives (C7)
- documenting how ownership changes influence biodiversity (C11).

- examining the consequences of plantations for biodiversity (C1)
- understanding the impacts of fire management strategies on biodiversity (C4).

These and other ongoing NCSSF projects are building a firmer basis for sustainable forestry and biodiversity conservation practices by practitioners, managers, and policy makers. The new projects begun in 2004 are described briefly below in Table 6.

Next Steps

Current funding will support one more round of project grants in 2005. NCSSF will be increasingly focused on providing information and tools to users through applications workshops, guide books, and other means of communication and technology transfer. The Commission also will work with current and potential new sponsors to frame the focus of the next five-year phase of the NCSSF program.

Over the next two years, NCSSF-funded work will yield additional useful findings. Equally important, NCSSF will generate additional practical tools based on science and tested for their utility to enable practitioners to achieve more progress where it counts—on the ground across America's diverse forest landscapes. Along the way, this work will also reveal gaps where yet more research is needed, guiding future efforts by NCSSF and others to advance sustainable forestry and biodiversity conservation.

Table 6
NCSSF Ongoing 2004-2005 Project Descriptions

NCSSF is supporting the following 17 new biodiversity and sustainable forestry efforts, initiated in June 2004. More detailed information can be found at **www.ncssf.org**. *(A list of all NCSSF projects is in Appendix Table A-I)*

A4 II: *Curriculum Development for Non-Timber Forest Products*—Will capture the wealth of information gained from A4 results to use as the foundation for development of new curriculum for academic and professional education programs. Expected results include (1) needs assessment report, (2) completion of a pilot academic course, (3) completion of a pilot short course for managers, (4) hard copy and CD-ROM of course materials, and (5) evaluation of courses and recommendations for future academic programs on non-timber forest products and biodiversity.

A5 West II: *Part 2—Assessment of the Scientific Basis for Standards/Practices at the Stand, Management Unit, Landscape, and Regional Level: Oregon Coast Range*—Will develop images and general insights about multi-scale management across ownerships, clarifying scientific knowledge and demonstrating what ecosystem science can contribute to environmental, social, and economic priorities. Expected results include (1) additional biodiversity indicators for the Coastal Landscape Analysis Modeling Study, (2) biodiversity implications of 1 to 2 new feasible policy alternatives, (3) new landscape simulation movies on the web, and (4) workshops.

A5 East II: *Part 2—Assessment of the Scientific Basis for Standards/Practices at the Stand, Management Unit, Landscape, and Regional Level: Southeastern U.S.*—The objective of this renewal includes developing new perspectives and insights about multi-scale management across ownerships. By providing a scientifically based picture of large areas over long-time frames, the work will provide new perspectives to managers, policy makers, and the public, and through these new perspectives help sharpen the focus of forest management debates.

A8 II: *Field Tests, Refinement, and Training of the NCSSF/Manomet Biodiversity Indicators Selection Protocol and Web-based Tool*—Will field test, refine, and implement the NCSSF/Manomet Protocol for selecting core indicators for biodiversity in sustainable forestry. Expected results include (1) field tests and review of the A8 indicators database and selection protocol, (2) refinement of both, and (3) "train the trainers" workshop(s) leading to people nationwide capable of training and assisting others in using the database and protocol.

A10 II: *Decision Support Systems for Forest Biodiversity Phase II: Requirements Analysis and Development Plan*—Will undertake a comprehensive requirement analysis to advance the next generation of decision support tools for policy makers, managers, and scientists in government, industry, academia, and nongovernmental organizations. Expected results include (1) a development plan for building a state-of-the-art tool, or suite of tools, for forest biodiversity management; (2) minimum and optimal data needs to make use of the tools; and (3) individuals and organizations capable of creating the needed tools.

C1: *Biodiversity & Intensive Even-Aged Forest Management*—Will compare the effects of modified intensive forest management systems on biodiversity for planted even-aged loblolly pine and Douglas Fir using bio-diversity indicators (see also NCSSF Project A8 report). Expected results include comparisons at the regional level, integrated evaluation of prescriptions and diversity effects, and recommendations for management alternatives.

C2: *Existing and Potential Incentives for Practicing Sustainable Forestry on Non-Industrial Private Forest Lands*—Addressing several of the needs identified at the NCSSF User Needs Workshops, this project will (1) review and compile summary information on "sustainable forestry" incentives available to non-industrial private landown-ers and (2) determine the incentives that are most attractive (e.g., cost-share for stewardship practices, preferen-tial tax-assessments, market incentives, etc.). Expected results include a written report and a web-based searchable database of incentive programs.

C3: *The Conservation Context of Forestry*—Will analyze Florida's existing state Comprehensive Wildlife Conservation Plans, which identify land and water areas requiring some form of conservation status for protection of the habitat of one or more species, to assess the range of areas and forest practices that could be compatible with conservation needs and values on non-industrial private forest lands. Expected results include case studies of important habitat areas.

C4: *Biodiversity Implications of Post-Fire Recovery Strategies*—Will facilitate the development of a knowledge base for managers and the public to better inform both parties about how different approaches to post-wildfire recovery—contour felling trees to reduce soil erosion, salvage logging, tree planting, vegetation control, etc.—affect ecosystem diversity and functions. Expected results include a written report and user-friendly products.
C4.1: *Looking At Soils and Soil Fungi under Oaks and Pines Following Fire in California*
C4.2: *Using Remote Sensing to evaluate the 2002 Biscuit Oregon Fire Post-fire Restoration (using A8 indicators)*
C4.3: *Understory Species Recovery in Rehabilitated and Un-rehabilitated Portions of the 2002 Hayman Colorado Fire*

C5: *Assessment of Public Knowledge, Values, and Attitudes toward Biodiversity and Sustainable Forestry*—Will assess the scope of research on public values about biodiversity with emphasis on public attitudes about biodiversity versus other forest values, e.g., water quality, wood production, recreation, carbon sequestration, etc. Expected results include a report assessing breadth and depth of current research, research methods, and data quality on this topic and recommendations for future survey research.

C7: *Understanding How Forest Management Practices Affect Species Invasions and Impacts*—Will synthesize learning about how forest management practices affect species invasions in forested ecosystems and derive prescriptions for minimizing the most harmful effects on forest biodiversity. Expected results include a written report.

C8: *Guidelines for Participatory Biodiversity Inventory and Monitoring of Sustainable Forest Management*—Will develop a broad-based biodiversity inventory and monitoring system for implementation by trained volunteers at the local level. Expected results include (1) a manual and implementation handbook and (2) a "train the trainer" curricula for use by forest managers.

C9: *Building a Common Understanding of Likely Global Market Changes for Forest Products and the Implications for Forest Biodiversity in the United States*—NCSSF will organize a forum of leading stakeholders and researchers to develop a common perspective on how projected market changes for forest products will influence forest harvesting, product mix, management intensity, rotation lengths, etc. as a basis for research and policies related to forests and biodiversity. Expected results include a written report.

C10: *Defining the Characteristics, Functions, and Strategies for Protecting and Perpetuating Old-growth and Late-successional Forests at Stand and Landscape Scales*—Will bring the best regional scientific thinking on old-growth and late-successional forest ecology, classification, and conservation together in the Northwest and Northeast to develop a synthesis useful for application to Federal forest policies such as the Healthy Forest Restoration Act of 2003. Expected results include a white paper.

C11: *Examining Non-industrial Ownership and Biodiversity in the Northeastern U.S.*—Will test hypotheses linking the effects of ownership on biodiversity through changes in major policies and on-the-ground practices, e.g., are there consistent differences in application of BMPs, type and level of forest certification sought, kind and extent of easements sold, etc? Expected results include evidence-based advice for regulators and purchasers of conservation easements.

Appendix

Syntheses and Survey Projects

A1	**Invasives Management and Biodiversity (Completed April, 2004)** *Synthesize Existing Science Relating Forest Management Practices to the Spread of Forest Diseases and Exotic Invasive Weeds,* Project Leader Elizabeth Chornesky: Conservation Science and Policy; CA. NCSSF Project Steward: Ann Bartuska
A2	**Hydrology and Aquatic Ecosystems (June 30, 2002–July 1, 2003)** *Synthesize Existing Science Connecting Forest Biodiversity/Complexity to Hydrologic Processes and Aquatic Ecosystems,* Project Leader Michael Huston: Interdisciplinary Solutions for Environmental Sustainability, Inc.; TN. NCSSF Project Steward: Norm Christensen
A3	**Survey of Sustainable Forestry Management Lessons Learned (June 30, 2002–Dec. 30, 2003)** *Survey the Lessons Learned about Managing Forests for Biodiversity and Sustainability Based on Practical Experiences,* Project Leader Steven R. Radosevich: Oregon State University. NCSSF Project Steward: Jim Brown
B1.1	**Land Use Impacts on Management—Northeastern U.S. (June 30, 2003–July 1, 2004)** *Land Use History Impact on Biodiversity: Implications for Management Strategies in the Northeastern US, including the Lake States,* Project Leader John Litvaitis: University of New Hampshire. NCSSF Project Steward: John Gordon
B1.2	**Land Use Impacts on Management—Southeastern U.S. (June 30, 2003–July 1, 2003)** *Land Use History Impact on Biodiversity: Implications for Management Strategies in the Southeastern U.S.,* Project Leader Josh McDaniel: Auburn University; AL. NCSSF Project Steward: Norm Christensen
B1.3	**Land Use Impacts on Management—Western U.S. (June 30, 2003–July 1, 2004)** *Land Use History Impact on Biodiversity: Implications for Management Strategies in the Western U.S.,* Project Leader Gary Nabhan: Northern Arizona University. NCSSF Project Steward: Norm Christensen
C1	**Plantations and Biodiversity (June 30, 2004–July 1, 2005)** *Biodiversity & Intensive Even-Aged Forest Management,* Project Leader Tom Hinkley: University of Washington. NCSSF Project Steward: John Gordon
C2	**Incentives for Sustainable Forest Management on Private Lands (June 30, 2004–July 1, 2005)** *Existing and Potential Incentives for Practicing Sustainable Forestry on Non-Industrial Private Forest Lands,* Project Leader John Greene: USDA Forest Service Southern Research Station; LA. NCSSF Project Steward: Al Sample
C11	**Ownership Changes and Biodiversity (June 30, 2004–July 1, 2005)** *Non-industrial Ownership and Biodiversity,* Project Leader John Hagan: Manomet Center for Conservations Sciences; ME. NCSSF Project Steward: John Gordon

Research and Assessments Projects

A4	**Non-Timber Forest Products and Biodiversity (June 30, 2002–December 30, 2003)** *Assess Knowledge about Non-Timber Forest Products Management Impacts on Biodiversity,* Project Leaders Rebecca McLain and Kathryn Lynch: Institute for Culture and Ecology; OR. NCSSF Project Steward: Joyce Berry

A5E I & II	**Science Basis for Management—Eastern U.S. (June 30, 2002–December 30, 2003/June 30, 2004–July 1, 2005)** *Assess the Scientific Basis for Standards/Practices at the Stand, Management Unit, and Landscape Levels in the Eastern United States,* Project Leader T. Bently Wigley: National Council for Air and Stream Improvement, Inc; SC. NCSSF Project Steward: Dave Perry
A5W I & II	**Science Basis for Management—Western U.S. (June 30, 2002–December 30, 2003/June 30, 2004–July 1, 2005)** *Assess the Scientific Basis for Standards/Practices at the Stand, Management Unit, and Landscape Levels in the Western United States,* Project Leader Thomas A. Spies: USDA Forest Service Pacific Northwest Research Station; OR. NCSSF Project Steward: Dave Perry
A6	**Ecosystem Restoration and Biodiversity (June 30, 2002–July 1, 2003)** *Evaluate the Role of Ecosystem Restoration on Biodiversity,* Project Leader Robert J. Mitchell: Joseph W. Jones Ecological Research Center; GA. NCSSF Project Steward: Norm Christensen
A7	**Forest Fragmentation and Research (June 30, 2002–July 1, 2003)** *Identify Biodiversity Research Needs Related to Forest Fragmentation,* Project Leader John Kupfer: University of Arizona. NCSSF Project Steward: Al Lucier
B2	**Calibration of Theory and Practice (June 30, 2003–July 1, 2004)** *Calibration of Conservation Theory and Principles Applied at Various Geographic Scales,* Project Leader Robert Mitchell: Joseph W. Jones Ecological Research Center; GA. NCSSF Project Steward: Hal Salwasser
C3	**Conservation Context for Forestry (June 30, 2004–July 1, 2005)** *Identification and Assessment of Conservation Compatible Forest Practices (CCFPs) on Private Forestlands,* Project Leader Janaki Alavalapati: University of Florida. NCSSF Project Steward: Norm Christensen
C4.1	**Post-Fire Strategies and Biodiversity (June 30, 2004–December 30, 2005)** *Looking At Soils and Soil Fungi Under Oaks and Pines Following Fire,* Project Leader Louise Egerton-Warburton: Chicago Botanic Gardens; IL NCSSF Project Steward: Dave Perry
C4.2	**Post-Fire Strategies and Biodiversity (June 30, 2004–December 30, 2005)** *Using Remote Sensing to Evaluate the 2002 Biscuit Fire Post-fire Restoration,* Project Leader Bernard Bormann: USDA Forest Service Pacific Northwest Research Station; OR. NCSSF Project Steward: Dave Perry
C4.3	**Post-Fire Strategies and Biodiversity (June 30, 2004–December 30, 2005)** *Understory Species Recovery in Rehabilitated and Unrehabilitated Portions of the 2002 Hayman Fire,* Project Leader Paula Fornwalt: USDA Forest Service Rocky Mountain Research Station; CO. NCSSF Project Steward: Dave Perry
C5	**Public Attitudes and Values: Biodiversity (June 30, 2004–July 1, 2005)** *Assess Public Knowledge, Values, and Attitudes toward Biodiversity and Sustainable Forestry,* Project Leader Michael Manfredo: Colorado State University. NCSSF Project Steward: Joyce Berry

Tool Development Projects

A8	**Biodiversity Indicators Selection System (June 30, 2002–July 1, 2003)** *Identify Core Biodiversity Indicators to Apply to Sustainable Forestry,* Project Leader John M. Hagan: Manomet Center for Conservation Sciences, ME. NCSSF Project Steward: Hal Salwasser

A8 II	**Pilot Applications of Indicator System (June 30, 2004–July 1, 2005)** *Field Tests, Refinement and Training of the NCSSF/Manomet Biodiversity Indicators Selection Protocol and Website,* Project Leader John M. Hagan: Manomet Center for Conservation Sciences, ME. NCSSF Project Steward: Hal Salwasser
A9	**Ecosystem Function Indicators (June 30, 2003–December 30, 2004)** *Evaluate Indicators of Ecosystem Function Applicable to Forest Management,* Project Leader Daniel Markewitz: University of Georgia. NCSSF Project Steward: Ron Pulliam
A10	**Evaluation Decision Support Systems (June 30, 2002–July 1, 2003)** *Evaluate the Needs And Requirements for Decision Support Systems,* Project Leader K. Norman Johnson: Oregon State University. NCSSF Project Steward: Chris Bernabo
A10 II	**Requirements for Improved Decision Support Systems (June 30 2004–July 1, 2005)** *Decision Support Systems for Forest Biodiversity Phase II: Requirements Analysis and Development Plan,* Project Leader K. Norman Johnson: Oregon State University. NCSSF Project Steward: Chris Bernabo
B4	**Risk Management Decision Support (June 30, 2003–December 30, 2004)** *Illuminating Choice in Sustainable Forest Management: A Comparative Risk Assessment Framework and Tools (CRAFT),* Project Leader Danny Lee: USDA Forest Service Pacific Southwest Research Station. NCSSF Project Steward: Hal Salwasser
C7	**Forest Management and Invasives (June 30, 2004–July 1, 2005)** *Understand How Forest Management Practices Affect Species Invasions and Impacts,* Project Leader Lisa Rew: Montana State University. NCSSF Project Steward: Ann Bartuska
C8	**Guidelines for Participatory Monitoring (June 30, 2004–July 1, 2005)** *Guidelines for Participatory Biodiversity Inventory and Monitoring of Sustainable Forest Management,* Project Leader David Pilz: Institute for Culture and Ecology; OR. NCSSF Project Steward: Joyce Berry

Communication and Outreach

A4 II	**Curriculum Development for Non-Timber Forest Products (June 30, 2004–July 1, 2005)** *Curriculum Development for Non-Timber Forest Products,* Project Leader Kathryn Lynch: Institute for Culture and Ecology; OR. NCSSF Project Steward: Joyce Berry
C9	**Global Markets and Biodiversity Forum (Winter 2005)** *Gain a Common Understanding of Likely Global Market Changes for Forest Products and the Implications for Forest Biodiversity in the United States,* NCSSF Project Steward: Scott Wallinger
C10	**Old Growth Workshops (Spring 2005)** *Defining the Characteristics, Functions and Strategies for Protecting and Perpetuating Old-growth and Late-successional Forests at Stand and Landscape Scales,* NCSSF Project Steward: John Gordon
R1	**State of The Science Report** (Completed February 2002). *NCSSF Report available*
R2	**Annual Symposium—Biodiversity in Forest Planning and Management** June 2002 Portland, OR. *NCSSF Report available*
R3	**Second Annual Symposium—Fire, Forest Health and Biodiversity** June 2003 Denver, CO. *NCSSF Report available*
R4	**Users' Needs Workshops Summary—Linking Science to Practice (in partnership with NFF)** April 2003—Alexandria, VA and September 2003—Missoula, MT. *NCSSF Report available*
R5	**Sustainable Forestry Tools and Applications Workshop (in partnership with NFF)** June 2004, Boulder CO. *NCSSF Report available*

Table A-II
NCSSF Phase 1 Program Timeline

Legend: C = completed, P = planned

Dates / Actions	Year 1 Oct–Dec 2001	Jan–Mar 2002	Apr–Jun 2002	Jul–Sep 2002	Year 2 Oct–Dec 2002	Jan–Mar 2003	Apr–Jun 2003	Jul–Sep 2003	Year 3 Oct–Dec 2003	Jan–Mar 2004	Apr–Jun 2004	Jul–Sep 2004	Year 4 Oct–Dec 2004	Jan–Mar 2005	Apr–Jun 2005	Jul–Sep 2005	Year 5 Oct–Dec 2005	Jan–Mar 2006	Apr–Jun 2006	Jul–Sep 2006
The Commission convenes	C	C			C	C			C	C			C	P			P	P		P
Users provide input	C		C		C		C		C		C				P		P		P	
1st annual round of RFPs—"A" series projects selected		C	C																	
"A" series projects underway				C	C	C	C	C	C	C	C	C	C							
"A" series results released								C	C	C	C	C	C	P						
2nd annual round of RFPs—"B" series projects selected						C	C													
"B" series projects underway								C	C	C	C	C	C							
"B" series results released												C	C	P						
3rd annual round of RFPs—"C" series projects selected										C	C									
"C" series projects underway												C	C	P	P	P				
C" series results released																P	P			
Findings Report produced								C	C	C	C	C	C							
4th annual round of RFPs—"D" series projects selected														P	P					
"D" series projects underway																	P	P	P	
"D" series results released																		P	P	P
Guide Book produced															P	P	P	P	P	P

■ completed   ■ planned

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