3 FINDINGS AND IMPLICATIONS

NCSSF 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.

BUREAU OF LAND MANAGEMENT

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.*

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.

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.

NATIONAL PARKS SERVICE

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.

- 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). ■

Finding 1B
Stand-level diversity is influenced by legacies.

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.