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PRIMER FOR FOREST ENVIRONMENTAL ISSUES: THE WEST

SPECIAL REPORT NO. 04-02

JUNE 2004

by

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NCASI West Coast Regional Center

Corvallis, Oregon

Acknowledgments

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PRESIDENT'S NOTE

The forest products industry is an important component of the economy of the West, and forests provide significant environmental values to the region. These values range from clean water and fish, to diverse wildlife and game. Despite state forest practice regulations and industry commitments to meeting environmental goals under AF&PA (American Forest and Paper Association)'s Sustainable Forestry Initiative, the Oregon Plan for Salmon and Watersheds, Washington Forests and Fish Agreement, and other initiatives, the public remains skeptical about how forest management activities affect the environment. Key practices such as clearcutting and the use of forest chemicals remain areas of concern that forest land managers must repeatedly address. The public also expresses worry about how management affects wildlife, both endangered species and big game. Herein we will provide an introduction to key environmental issues for forest management in the West.

This document is somewhat unusual for NCASI because we invited not only researchers to discuss the science of these issues, but also industry policy specialists. Our goal was to get a thumbnail sketch covering each issue's significance, policy implications, our understanding, and information needs. We hope that this document will be useful to NCASI member companies and the members of the cooperating industry organizations. We further hope that it will stimulate discussion and support for critical research to address the information needs identified.

Ronald A. Yeske

June 2004

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au service de la recherche environnementale pour l'industrie forestière depuis 1943

MOT DU PRÉSIDENT

L'industrie des produits forestiers est une importante composante de l'économie de l'ouest des États-Unis, et la forêt possède des valeurs environnementales significatives pour la population de cette région qui vont de la protection de l'eau et du poisson à la diversité de la faune et du gibier. Même si les États ont mis en place des règlements en matière de pratiques forestières et que l'industrie se soit engagée à se conformer à des objectifs environnementaux en vertu du *Sustainable Forestry Initiative®* de l'AF&PA, le *Oregon Plan for Salmon and Watersheds*, le *Forests and Fish Agreement* de l'état de Washington et d'autres initiatives, le public demeure sceptique face aux impacts des activités d'aménagement forestier sur l'environnement. Des pratiques fondamentales comme la coupe à blanc et l'utilisation de produits chimiques en forêt demeurent des préoccupations avec lesquelles les gestionnaires de ressources forestières doivent continuellement composer. Le public s'inquiète aussi des incidences qu'a l'aménagement forestier sur la faune, notamment sur les espèces en voie de disparition et le gros gibier. Le présent rapport constitue une introduction aux principaux enjeux environnementaux liés à l'aménagement forestier dans l'ouest des États-Unis.

Ce document est le fruit d'un travail quelque peu inhabituel pour NCASI. En effet, nous avons invité non seulement des chercheurs pour traiter des aspects scientifiques de ces questions mais aussi des spécialistes en matière de politiques industrielles. Notre objectif était de décrire de façon succincte l'importance de ces enjeux et leurs répercussions sur les politiques forestières, de même que partager notre compréhension de ce dossier et combler un besoin d'information. Nous espérons que ce document sera utile aux compagnies membres de NCASI ainsi qu'aux membres des organisations industrielles qui ont collaboré à ce projet. De plus, nous souhaitons qu'il encourage la discussion et soit un apport à toute recherche importante entreprise pour répondre aux besoins d'information identifiés dans ce rapport.

Ronald A. Yeske

Juin 2004

PRIMER FOR FOREST ENVIRONMENTAL ISSUES: THE WEST

SPECIAL REPORT NO. 04-02
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ABSTRACT

Key environmental issues for the forest industry in the Western United States are reviewed by teams of policy specialists and scientists. These key issues include clearcutting, water quality, forest chemicals, forest health and wildfire, salmon, headwater streams, the northern spotted owl and other endangered species, biodiversity, big game, climate change, and forest conversion. For each of these there is a discussion about the political and economic significance of the issue, our scientific understanding, and remaining research needs.

KEYWORDS

big game, biodiversity, clearcutting, climate change, endangered species, forest chemicals, forest conversion, forest health, headwater streams, salmon, spotted owl, water quality, wildfire

RELATED NCASI PUBLICATIONS

Technical Bulletin No. 862. (May 2003). *Influence of culvert crossings on movement of stream dwelling salmonids.*

Technical Bulletin No. 857. (January 2003). *Wildlife and biodiversity metrics in forest certification systems.*

Technical Bulletin No. 706. (December 1995). *Western state nonpoint source program review.*

NOTIONS ÉLÉMENTAIRES SUR LES ENJEUX ENVIRONNEMENTAUX LIÉS À LA FORÊT: L'OUEST DES ÉTATS-UNIS

RAPPORT SPÉCIAL NO. 04-02
JUIN 2004

RÉSUMÉ

Les principaux enjeux environnementaux touchant l'industrie des produits forestiers dans l'ouest des États-Unis sont révisés par des équipes composées de scientifiques et de spécialistes en matière de politiques forestières. La coupe à blanc, la qualité de l'eau, les produits chimiques utilisés en forêt, la santé des forêts et les incendies, le saumon, les cours d'eau en amont, la chouette tachetée du nord et autres espèces en voie de disparition, la biodiversité, le gros gibier, le changement climatique et la reconversion forestière font partie de la liste des principaux enjeux. Le présent rapport décrit l'importance économique et politique de chaque enjeu, les aspects scientifiques que nous connaissons et les besoins à combler en matière de recherche.

MOTS CLÉS

biodiversité, changement climatique, chouette tachetée, coupe à blanc, cours d'eau en amont, espèce en voie de disparition, feux hors contrôle, gros gibier, produits chimiques utilisés en forêt, qualité de l'eau, reconversion forestière, santé des forêts, saumon

AUTRES PUBLICATIONS DE NCASI DANS CE DOMAINE

Bulletin technique No. 862. (mai 2003). *Influence of culvert crossings on movement of stream dwelling salmonids.*

Bulletin technique No. 857. (janvier 2003). *Wildlife and biodiversity metrics in forest certification systems.*

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PRIMER FOR FOREST ENVIRONMENTAL ISSUES: THE WEST

1.0 CLEARCUTTING

Philip Aune, California Forestry Association; Tharon O'Dell, Simpson Resources Company; Drs. George Ice and Larry Irwin, National Council for Air and Stream Improvement, Inc.

1.1 Introduction

Clearcutting is a method of regenerating forests that involves cutting basically all trees at one time. A clearcut is defined as "a stand in which essentially all trees have been removed in one operation" (Helms 1998). Clearcutting is one of the most controversial issues for forest management. Not only does the public dislike the look of a clearcut, but concerns are raised about water quality and wildlife response to clearcutting, and whether this is an essential or even desirable method of managing timber. Here we will describe recent state initiatives and other efforts designed to eliminate clearcutting or modify its application. Then we will visit the role of clearcutting as a silvicultural tool, briefly touch on concerns about water quality and wildlife response, and conclude with some key information needs.

1.2 Controversy and Efforts to Restrict Clearcutting

Clearcutting has been one of the most complex political issues the forestry profession and forestland managers have ever faced. The political controversy is not new. Clearcutting was part of the early debate leading to the establishment of Adirondack Forest Reserves. The same could be said for the exploitation practices that led to the creation of the original forest reserves in 1891 and the 1897 Organic Act. As a result of clearcutting on the Bitterroot and Monongahela National Forests, the 1971 Church Hearings were held for the Senate Subcommittee on Interior and Insular Affairs on the subject of clearcutting. That hearing elicited three volumes and 1247 pages of testimony and records on the subject. The debate continued and resulted in the 1976 National Forest Management Act (NFMA), establishing current requirements for use of clearcutting on national forest lands. Unfortunately, the issue was not resolved with passage of NFMA.

The political clearcutting issue was focused principally on federal lands until 1990, when California faced "Big Green" and "Forest Forever" ballot initiatives. These failed initiatives led to even more attempts to deal with the issue by consensus building with the 1991 Sierra Accord and the 1992 Grand Accord. In 1994, California Board of Forestry rule-making efforts resulted in forest practice rules that imposed limits on the size of clearcuts (20 acres). Similar limits are found as part of AF&PA's Sustainable Forestry Initiative (120 acre limit on average, except where necessary to respond to forest health emergencies or other natural catastrophes) and the forest practice regulations for other states (e.g., 120 acres for "type 3" clearcuts in Oregon).

The controversy continues. In 2003, California had twelve legislative proposals directly or indirectly affecting clearcutting. California is not alone, as exemplified by the 1998 Proposition 64 efforts in Oregon and annual attempts to introduce a "son of '64" just about every year. These examples clearly demonstrate that "clearcutting" is a "wicked" political problem that is not easily solved. The political process does not lend itself to resolving the emotional values associated with clearcutting and the obvious fundamental biological, economic, and scientific rationales supporting the use of clearcutting.

1.3 Clearcutting as a Silvicultural Tool

The current position of the Society of American Foresters on clearcutting is that

> [t]he clearcutting method of forest stand regeneration plays an important role in sustainable forest management and can be used effectively to produce desired forest conditions. It can be the ***best silvicultural method*** [emphasis added] for regenerating shade-intolerant trees species, controlling forest insects and pathogens, and achieving other management goals (SAF 2003).

Specific situations listed by SAF (2003) where clearcutting is likely to be an appropriate regeneration method include

- Forest stands with primarily suppressed or deformed trees of low value or desirability
- Stand suffering damage due to insects, disease, windstorms, or fire
- Regeneration of shade-intolerant species
- Areas where edge habitat or early successional habitat will support key wildlife species
- Areas where large-scale natural disturbances (e.g., hurricanes, wildfires, insect and disease outbreaks, wind or ice storms) result in large patches of natural regeneration

SAF also lists conditions where clearcutting may be inappropriate:

- Visually sensitive areas
- Areas supporting key species dependent on large contiguous forest stands (e.g., interior forest dependent species)
- Areas where watershed functions (e.g., runoff, surface erosion, landslides) will be or already are negatively impaired by removal of the forest canopy

1.4 Water Quality Concerns about Clearcutting

Clearcutting has been repeatedly vilified because of potential effects on water quality and runoff. The Native Forest Network stated that clearcutting "…exposes soil to erosion…" One of the arguments in the OLIFE (Oregonians for Labor Intensive Forest Economics) initiative was that clearcut logging has resulted in "…serious degradation of Oregon's surface and ground water supplies by increasing sedimentation and turbidity, adversely altering the chemical composition of such waters…" Even the distinguished *National Geographic* ran an article that described "…serious problems for streams as dirt pours off clear-cut slopes…" (Mitchell and Essick 1996). While forestry and water quality issues will be discussed later, a brief response to these concerns about clearcutting and water quality is needed.

In a review of cumulative impacts from forest practices developed by Oregon State University scientists for the Oregon Department of Forestry, Beschta et al. (1995) found that

> [i]n most cases, it is not the fact that trees were harvested, but how they were harvested, where on the landscape, the methods of roading and yarding, the degree of riparian protection, and other factors that ultimately determine the impact of a forest practices operation.

Beschta et al. correctly point out that the harvesting of trees is not the most important factor in determining water quality response, but rather how and where trees are harvested. Recognizing this, today's forest operations are designed to maintain riparian management areas or buffers around streams and to avoid excessive soil disturbance. An excellent example is provided by the Alto Watershed Study in east Texas.

In the Alto Study, clearcutting followed by mechanical site preparation using shearing and windrowing resulted in a large increase in sediment losses, perhaps as much as a 10- to 100-fold increase the first year after treatment (Blackburn, Wood, and DeHaven 1986). (While this was a large change relative to the control watersheds, it was less than the annual sediment loss rates commonly accepted for agricultural sites. After a few years sediment losses returned to pretreatment levels.) This activity exposed nearly 57% bare soil, compared to 3% for the control watersheds. Does this confirm the Native Forest Network claim that clearcutting exposes soil to erosion? In the same study, clearcutting with a gentler type of mechanical site preparation method resulted in 16% bare soil and little if any change in sediment losses. Percent bare soil was a factor reported by Blackburn, Wood, and DeHaven to be significant in explaining differences in sediment loss rates between treatments. Today, those same watersheds are being tested for contemporary management practices, with more chemical site preparation and streamside management zones (SMZs). In the current study, clearcutting and SMZ thinning resulted in about 9% and 3% bare soil, respectively (Ice et al. 2003).

The point is that a clearcut today is not the same practice that most of the public envisions. There are residual trees left for wildlife habitat and riparian management areas around streams. Upslope erosion is minimized by the use of waterbars on skid trails, lopping and scattering debris, and other practices. Site preparation methods can be designed to fit site conditions and to minimize soil loss. Clearcuts with these types of features will not have "soils exposed to erosion" and will protect water quality.

1.5 Wildlife Concerns about Clearcutting

The hue and cry about clearcutting began in the early 1960s, with concerns largely about effects on visual quality and on wildlife in the Bitterroot National Forest in Montana and the Monongahela National Forest in Virginia. Until then, state wildlife agencies had encouraged increased clearcutting to provide food for edge-related game species such as grouse, deer, and elk, and to increase road access for hunters so that game herds could be properly managed. This was based upon extensive research suggesting that dispersed clearcuts interspersed with timber patches would provide optimal conditions for game species.

After Rachel Carson's *Silent Spring* was published in 1962, interest in non-game species rose dramatically. About the same time, wildlife ecology studies, particularly on non-game birds, shifted from acknowledging the overall physical and biotic environment to emphasizing vegetation stand structure and configuration. Subsequently, the rise of the island biogeography theory led to characterizing clearcuts as fragmenting intact forests into smaller and less connected stands. Studies on real islands demonstrated that island size and distance to mainland sources of colonists were related to the number of species living on the islands.

The island concept was extended to forests, in which remaining forest stands were described as island "patches" in a sea of clearcuts that increasingly were considered to be inhospitable to forest wildlife. Species were described as forest "interior" specialists that were ostensibly harmed by edge effects, and several studies did suggest that forest fragmentation may be a problem for many species, primarily birds. It wasn't long before saving biological diversity from clearcuts and associated forest fragmentation was part of the environmental battle cry.

More recently, scientists have modified the view about forest fragmentation, and asserted that the real issue is the amount of habitat, not its spatial geometry. It has also been found that wildlife responses to clearcutting depend upon where in the landscape the timber harvesting occurs (such as near riparian zones vs. ridge-tops), and that inherent productivity related to soils and climate and the regime of episodic and chronic disturbances are drivers of the display of biological diversity. Thus, there is great interest in the forestry community in attempting to match forest management intensity with the natural disturbance regime in relation to capability of the land, thereby creating a shifting mosaic of conditions that wax and wane over time across the forest landscape.

1.6 Information Needs

- How clearcutting affects water quality continues to be a politically important issue. There is a need to demonstrate the water quality response of clearcut harvesting with contemporary practices.
- One theory is that reduced canopy interception results in higher net precipitation intensities at the soil surface, leading to elevated positive pore pressures in soils and increased probability of landslides. This and other mechanisms and control opportunities for landslides need to be investigated and accepted or rejected.
- Landscape management tools are needed to project the shifting mosaic of forest conditions and suitability of wildlife habitat resulting from clearcutting across the forest over time.
- Forest managers need to reconstruct natural disturbance patterns to provide a template for emulating (but not reproducing) forest regeneration patterns.

1.7 Some Key Points

- Clearcutting can be the best silvicultural treatment under conditions where forest managers need to regenerate shade-intolerant species or control insect infestations, or where natural regeneration involved large stand-replacement mechanisms.
- Clearcutting and removal of trees does not per se cause erosion or water quality impacts. How and where harvesting, yarding, and site-preparation are conducted determines water quality impacts.
- Some wildlife species benefit while other may have a loss of habitat due to clearcutting. Managers can address these concerns in landscape planning, as part of a shifting mosaic of habitat conditions. How much suitable habitat is available may be more important than its spatial geometry.
- Clearcutting can provide some advantages to selective harvesting. These include reduced active road miles, easier application of low-impact cable yarding methods, and fewer entries to stands.
- Clearcuts today are not the same as 40 years ago. They are often limited in size, with residual trees for wildlife habitat, and equipment exclusion zones, riparian management zones, or buffers around stream channels and lakes.

1.8 References

Beschta, R.L. et al. 1995. *Cumulative effects of forest practices in Oregon*. Salem, OR: Oregon Department of Forestry.

Blackburn, W.H., Wood, J.C., and DeHaven, M.G. 1986. Storm flow and sediment losses from site-prepared forestland in East Texas. *Water Resources Research* 22(5):776-784.

Helms, J.A. [ed.]. 1998. *A dictionary of forestry*. Bethesda, MD: Society of American Foresters.

Ice, G.G., Megahan, W.F., McBroom, M.W., and Williams, T.M. (2003). Opportunities to assess past, current, and future impacts from forest management. In *Proceedings of the Second Conference on Watershed Management to Meet Emerging TMDL Environmental Regulations*. St. Joseph, MI: American Society of Agricultural Engineers.

Mitchell, J.G., and Essick, P. 1996. Our polluted runoff. *National Geographic* 189(2):106-126.

Society of American Foresters (SAF). 2003. *Clearcutting: A position of the Society of American Foresters*. http://www.safnet.org/policyandpress/psst/clearcut1202.cfm (September 11, 2003).

2.0 FORESTRY AND WATER QUALITY

Maryanne Reiter and Kevin Godbout, Weyerhaeuser Company; Dr. George Ice, National Council for Air and Stream Improvement, Inc.

2.1 Introduction

Concerns about forests and water quality date back to ancient times and are still a top concern with the public today. Today, as well as in earlier surveys, protecting water quality continues to be the most important environmental value to the public. A 2001 public opinion survey commissioned by the Oregon Department of Forestry (ODF) indicated that water quality and losing forestlands to development are the top two concerns about Oregon's forests. When Washington state voters were asked about the leading environmental concern in June 1998 and 2001, "water quality, pollution in streams and lakes, and usable water" were the top concerns both times. When asked about the most important use of private forestland in April 1997 and August 2002, Washington residents ranked "a source of clean water" as their number one priority, followed by "fish and wildlife habitat."

Forest managers who operate in the West recognize the importance of water quality to their forest management activities. Most of the numerous substantive changes in forest practice regulations over the last 20 years in Oregon, Washington, California, Idaho, and Montana have been directed at improved water quality and fish habitat protection. However, there are those who remain skeptical that forests can be actively managed and still protect water quality. For example, in California last month, the North Coast Water Quality Control Board released the *Phase II Report: Independent Science Review Panel on Sediment Impairment and Effects on Beneficial Uses of the Elk River and Stitz, Bear, Jordan and Freshwater Creeks* (ISRP 2003). That report finds that

> [i]n light of numerous existing studies showing detrimental water quality impacts from high rates of timber harvest, the burden of proof would appear to be on those arguing that timber harvesting is not damaging water quality.

The Independent Science Review Panel (ISRP) report is clearly skeptical of the ability of forest managers to carefully select management and mitigation practices to positively influence water quality while active management continues. Although there are examples of water quality impacts from poor forest management practices (e.g., Megahan, Potyondy, and Seyedbagheri 1992; Moring

1975; Hagans and Weaver 1987), this skepticism about our ability to manage for water quality protection is not consistent with recent monitoring and research across the United States.

The culmination of this type of skepticism about forest management and its impacts on water quality may have been the 1999 EPA TMDL rule proposal which included classification of many forest management activities as point sources (SAF and NASF 2000). Under this proposal, some forest activities would have been subject to National Pollution Discharge Elimination System (NPDES) permits and companies would have been more vulnerable to lawsuits. This precipitated a forestry community-wide response that resulted in the defeat of the EPA proposal. Although the industry was successful in defeating the national TMDL rule, litigation and rule-making activities have continued to drive the water quality agenda in the West.

2.1.1 *Political Issues Surrounding Water Quality*

For the past decade, we have not suffered from a shortage of political and litigation related activities regarding water quality issues in the West. Briefly, the regional and, in some situations, the national agendas have been driven by the following suite of actions:

- TMDL litigation/TMDL implementation in western states
    - Use of federal court system to establish enforceable timelines
    - Greater effort by state agencies and state legislatures to adequately fund state implementation of TMDL programs
    - More oversight by federal agencies
    - Enhanced focus on the role of non-point source(s)/designated management agency concept
    - Use of models and conservative assumptions (heat source/thermal potential) in calculating load allocations
- Revision of state water quality standards for selected criteria
    - Temperature, turbidity, sediment, toxics, habitat criteria
    - Antidegradation
    - High Quality waters
- Silvicultural exemptions associated with the dredge and fill requirements for roads and ditch systems
- Aerial chemical application and associated spray drift near streams
- Linkage of water quality issues with ESA listed fish
    - Regional temperature guidance project to facilitate Section 7 consultation
    - Forest and Fish Agreement in Washington State
    - Oregon plan for salmon and water quality restoration
    - Adaptive management and BMP (best management practices) effectiveness monitoring

2.1.2 *Forest Practices and Water Quality: Background and Current Science*

In general, the quality of water draining forested watersheds in the Pacific Northwest is high. An analysis of data for the Willamette Basin by the USGS (U.S. Geological Survey) found that it has generally higher water quality than other regions of the United States and that forest sites tended to have higher quality than other land uses (Bonn et al. 1995).

For example, total phosphorus concentrations were generally much less than the national median, and nitrate-nitrogen concentrations were less than the national median. Median concentrations of suspended sediment were "…(at least 50 times less) than the national concentrations for national sites with comparable land uses." Suspended sediment, nutrients, and temperatures were generally lower and dissolved oxygen concentrations higher and less variable in streams draining forested watersheds in the Willamette Valley. The Oregon state of the environment report for 2000 found "…instances of good or excellent water quality occur most often in the forested uplands of Oregon. Both forest practice rules on public and private forests and lack of development help explain this result" (OFIC nd). The following sections discuss the background and current issues surrounding the main water quality/quantity parameters that forest practices can affect.

Nutrients

Though a wide range of dissolved elements and compounds occur in forested streams, the main nutrients of concern for water quality are generally nitrogen and phosphorus. Both of these nutrients affect aquatic productivity and the quality of water for downstream uses.

Nitrogen (N) concentrates in soil and organic matter and is not generally found in rocks (Stednick 1991). The atmosphere contains a considerable part of the earth's total N as gas. A portion of this atmospheric N is delivered to the earth's surface via precipitation. Nitrogen can also be gained when certain soil organisms "fix" atmospheric nitrogen into forms that are usable by plants. For example, red alder (a species that fixes nitrogen via symbiotic nitrifying bacteria) stands in western Oregon can accumulate nitrogen at a rate of approximately 260 lb/ac/yr (Newton et al. 1968 as cited in Brown 1988). In general, most of the nitrogen in forests of the Pacific Northwest is readily used by plants. Because of this efficient use of N in forested ecosystems, maximum instantaneous nitrate-N (NO_3^-) concentrations of streams draining undisturbed forested watersheds are usually low. Typical nitrate-N concentrations are less than 1 mg/L.

Forest fertilization with urea plays an important role in improving productivity on commercial forest lands in the Douglas fir region of the Pacific Northwest. Many studies in the region have demonstrated that applying urea fertilizer to forest lands does not result in nitrogen concentrations in excess of recommended drinking water standards or aquatic toxicity thresholds (Bisson et al. 1992; Fredriksen, Moore, and Norris 1975). However, the public is still concerned that extensive fertilization above municipal water intakes could affect water quality (Reiter, Baitis, and Stark 1996; Shaheed 2003 pers. comm.).

One recent concern about fertilization involves the effect of nitrogen species on amphibians (Marco and Blaustein 1999). While the effect of fertilization on lakes has been widely studied, the accumulation and dynamics of nitrogen species in lakes, wetlands, or ponds following forest fertilization is not well known. A pilot project conducted by Weyerhaeuser in 2000 (Stark and Reiter 2000) found that forest fertilization did not increase Kjeldahl-N, nitrite-N, or nitrate-N above water quality standards or levels considered sensitive to Pacific Northwest larval amphibians. However, one site achieved ammonia-N levels that would be considered a risk to developing amphibians.

Phosphorus (P) is second in importance only to nitrogen as a nutrient element required by plants and microorganisms. The form in which phosphorus is likely to occur in natural water is somewhat uncertain, but it can be present in either dissolved or particulate forms. Although losses of soluble P from forested watersheds are generally small (often less than 0.1 mg/L orthophosphate), particulate P can enter streams as a result of erosion because it is often sorbed onto soil particles (Stednick 1991). Forest practices in forested watersheds of the Pacific Northwest are unlikely to increase instream phosphorus. Based on a broad range of Pacific Northwest studies, increased phosphorus concentrations as a result of harvesting practices are uncommon (Salminen and Beschta 1991).

States will soon be required to develop new nutrient standards and EPA has proposed ecoregion-based criteria. Ice and Binkley (2002) have raised concerns that these concentrations may not be achievable even for undisturbed forest streams. These findings are being echoed by others (e.g., Smith, Alexander, and Schwartz 2003).

Temperature

Stream temperature is critical to the health and survival of aquatic organisms (e.g., Brett 1956; Ice et al. 2004). The temperature of a stream is influenced by several factors, including elevation, air temperature, shade, and channel morphology. Early research showed that complete canopy removal can significantly increase stream temperatures. However, since complete canopy removal has not been allowed on fish-bearing streams for a long time, new research was needed to demonstrate the effects of current forest practices on stream temperature. For example, the Oregon Department of Forestry is currently conducting an extensive study on medium sized fish and domestic water streams and small fish streams. This detailed study was necessary to overcome concerns with previous studies that did not include pre-treatment data.

Another area of recent stream temperature concern has been small nonfish-bearing streams (see Section 6.0) because they traditionally did not require overstory retention. Current research results indicate that forest practices can increase, decrease or not change stream temperatures on these very small streams (Jackson, Sturm, and Ward 2001).

As with nutrients, a synthesis of literature and monitoring data for least-impaired streams indicates that current water quality standards may be unachievable in some cases (Ice, Light, and Reiter in press).

Sediment

The rate of sediment produced from forested basins in the Pacific Northwest is highly variable due to differences in storm patterns, steepness of topography, and varying geology (Swanson et al. 1987). For example, in southwest Oregon and northern California, geology and high rainfall combine to produce an estimated 5000 to 8000 tons/mi^2/yr of sediment, on average. In contrast, the western Cascades, which have less intense precipitation and more stable geology, produce an average of only 80 to 200 tons/mi^2/yr of sediment (Sullivan et al. 1987). Geologic parent materials are an important determinant affecting not only total sediment production but also the size of sediment particles from forested watersheds. For example, basins underlain by basalt in southwest Washington have a relatively high percentage of their sediment load in sand, while basins mainly underlain by sedimentary formations have higher percentages of clay, silt, and fine to medium sand-sized particles (Duncan and Ward 1985). In some watersheds, ultra-fine clay particles known as smectite, associated with deep-seated earthflows, have been linked to chronic turbidity problems (e.g., Bates et al. 1998). Forest practices that disturb these soils have the potential to increase turbidity, though the magnitude and extent of the problem is not well known.

Catastrophic wildfires can also cause significant increases in sediment yields from forested watersheds (McNabb and Swanson 1990) and are a concern of municipal watershed managers. Monitoring by MacDonald, Coe, and Litschert (2003) showed that sites suffering severe fires experienced sediment losses the first year after the fire that exceeded the loss rate from even unpaved forest roads.

Water quantity: Concern that forest practices can cause flooding in lowland areas during extreme events (e.g., February 1996)

Removal of the forest canopy through timber harvest, fire, or other land use changes has the potential to affect peak flows by altering soil moisture and snow accumulation and melt patterns. Forest roads have also been suspected of increasing peak flows (Jones and Grant 1996). However, the issue of forest practices increasing peak flows remains controversial. Most recent research suggests that a) peak flow changes due to forest practices are not detected on larger river systems; and b) effects of forest practices on peak flows in small basins are highly variable, but small peaks are apparently affected more than larger peaks (e.g., Thomas and Megahan 1998; Beschta et al. 2000).

2.2 How Much Have We Improved Water Quality Protection?

When the public or the Independent Science Review Panel concludes that forest management is inconsistent with water quality protection, they often base those conclusions on historic impacts. Clearly the Alsea Watershed Study demonstrated that stream temperatures and dissolved oxygen concentrations could be negatively impacted when clearcutting and burning were conducted to and through the stream channel (Moring 1975). The small watershed studies in the H.J. Andrews Experimental Forest demonstrated that logging and burning through the stream channel and poor road construction could drastically increase sediment (Swanson and Jones 2002). Perhaps it is not surprising that the public and even experts are skeptical of forest management. This is why it is important to test contemporary forest practices to demonstrate improvements.

One example of a comparison of contemporary and historic practices is the Caspar Creek Watershed Study. In 1961 a study began in northern California in paired forks of Caspar Creek, the 424 ha South Fork and the 473 ha North Fork (Ziemer 1998). Beginning in 1967, roads were constructed and selective harvesting was conducted throughout the South Fork. After 12 years of hydrologic recovery of the watershed, clearcut logging began in the North Fork in 1985. Selective tractor logging and roading along the stream in the South Fork prior to forest practice regulations was found to have increased suspended sediment yields 2.4 to 3.7 times over those measured with clearcutting and cable logging operations in the North Fork conducted with modern forest practice rules (Lewis et al. 2001). Numerous landslides were documented after road construction and logging in the South Fork, while the size and number of landslides through 1998 were similar in logged and unlogged units in the North Fork (Cafferata and Spittler 1998).

If these types of findings were unique, ongoing concerns would be justified. Quite to the contrary, these findings are consistent with what is being found in watershed studies across the United States. A study in Georgia and South Carolina found that the first year sediment impacts from harvesting a watershed with the elementary (compared to California) BMPs for South Carolina are about 10% of those that would be expected without BMPs (Williams et al. 1999). The Alsea Watershed Study showed that forest management impacts to stream temperature, dissolved oxygen concentrations, and other water quality parameters could be controlled using streamside management zones and other forest management tools (Moring 1975).

2.3 Water Quality Information Needs

With the continuing level of skepticism about forest management and water quality, we find several continuing needs for information.

- Several recent studies have found that water quality criteria set by states or proposed by EPA are sometimes not achievable even for least-impaired or unmanaged watersheds (Ice and Binkley 2002; Ice and Sugden 2003; Ice, Light, and Reiter in press). These are the performance measures used to judge the effectiveness of forest operations. There is a need to better model what is achievable and incorporate those findings into water quality criteria and tools such as thermal potential modeling or Use Attainability Analysis.

- Many states have very effective monitoring and research programs designed to test whether current forest practices are maintaining water quality in compliance with water quality criteria and protecting beneficial uses (Ice et al. 2004). With recent or ongoing revisions to state water quality standards for temperature for several western states, there is a need to test the effectiveness of current forest practice rules for the new standards.
- Contemporary forest practices need to be tested. An example is the Hinkle Creek Watershed Study in southern Oregon, designed to look at water quality and fish response to active forest management at a watershed scale.
- One of the unachieved goals of several state programs has been trend monitoring that can demonstrate that forest practice programs have resulted in improvements in water quality at a state level. Trends may be difficult to demonstrate today because gross impacts have been largely removed and there is a law of diminishing returns on water quality protection efforts. It may be possible to use retrospective assessment (comparing results from past and contemporary paired watersheds) and modeling to achieve these trend assessment goals.

2.4 References

Bates, D., Willis, K., Swanson, F., Glasmann, J.R., Halemeier, D., and Wujcik, H. 1998. North Santiam River turbidity study, 1996-1997. *Watershed Management Council Newsletter* Fall 1998:1-17.

Bisson, P.A., Ice, G.G., Perrin, C.J., and Bilby, R.E. 1992. Effects of forest fertilization on water quality and aquatic resources in the Douglas-fir region. 179-193 in Chappell, H.N., Weetman, G.F., and Miller, R.E. (eds.). *Forest fertilization: Sustaining and improving nutrition and growth of western forests*. Seattle: University of Washington, Institute of Forest Resources.

Beschta, R.L., Pyles, M.R., Skaugset, A.E., and Surfleet, C.G. 2000. Peakflow responses to forest practices in the western Cascades of Oregon, USA. *Journal of Hydrology* 233:102-120.

Bonn, B.A., Hinkle, S.R., Wentz, D.A., and Uhrich, M.A. 1995. *Analysis of nutrient and ancillary water-quality data for surface and ground water of the Willamette Basin, Oregon, 1980-90*. Water Resources Investigations Report 95-4036. Portland, OR: U.S. Geological Survey.

Brett, J.R. 1956. Some principles in the thermal requirements of fishes. *Quarterly Review of Biology* 31:75-87.

Brown, G.W. 1988. *Forestry and water quality*. Corvallis: Oregon State University Bookstores, Inc. 142 pp.

Cafferata, P.H., and Spittler, T.E. 1998. Logging impacts of the 1970s vs. the 1990s in the Caspar Creek Watershed. 103-15 in Ziemer, R.R. (technical coordinator). *Proceedings from the Conference on Coastal Watersheds: The Caspar Creek Story, May 8, 1998, Ukiah, CA*. General Technical Report PSW GTR-168. Albany, CA: USDA Forest Service, Pacific Southwest Research Station.

Duncan, S.H. and S.W. Ward. 1985. The influence of watershed geology and forest roads on the composition of salmon spawning gravel. *Northwest Science* 59(3):204-212.

Fredriksen, R.L., Moore, D., and Norris, L. 1975. The impact of timber harvest, fertilization, and herbicide treatment on streamwater quality in western Oregon and Washington. 283-313 in Bernier, B., and Winger, C. (eds.). *Forest soils and land management*. Quebec: Laval University Press.

Hagans, D.K., and Weaver, W.E. 1987. Magnitude, cause and basin response to fluvial erosion, Redwood Creek basin, northern California. 419-428 in *Erosion and Sedimentation in the Pacific Rim*. IAHS Publication 165. Washington, DC: International Association of Hydrological Sciences.

Ice, G., and Binkley, D. 2002. Forest streamwater concentrations of nitrogen and phosphorus: A comparison with EPA's proposed water quality criteria. *Journal of Forestry* 101(1):21-28.

Ice, G., Dent, L., Robben, J., Cafferata, P., Light, J., Sugden, B., and Cundy, T. (2004). Programs assessing implementation and effectiveness of state forest practice rules and BMPs in the West. *Water, Air and Soil Pollution: Focus* 4(1):143-169.

Ice, G.G., Light, J., and Reiter, M. (in press). Use of natural temperature patterns to identify achievable stream temperature criteria for forest streams. *Western Journal of Applied Forestry*.

Ice, G., and Sugden, B. 2003. Summer dissolved oxygen concentrations in forested streams of northern Louisiana. *Southern Journal of Applied Forestry* 27(2):92-99.

Independent Science Review Panel (ISRP). 2003. *Phase II Report: Independent Science Review Panel on Sediment Impairment and Effects on Beneficial Uses of the Elk River and Stitz, Bear, Jordan and Freshwater Creeks*. Santa Rosa, CA: North Coast Water Quality Control Board.

Jackson, C.R., Sturm, C.A., and Ward, J.M. 2001. Timber harvest impacts on small headwater stream channels in the Coast Ranges of Washington. *Journal of the American Water Resources Association* 37(6):1533-1549.

Jones, J.A., and Grant, G.E. 1996. Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon. *Water Resources Research* 32(4):959-974.

Lewis, J., Mori, S.R., Keppeler, E.T., and Ziemer, R.R. 2001. Impacts of logging on storm peak flows, flow volumes and suspended sediment loads in Caspar Creek, California. 85-125 in Wigmosta, M.S., and Burges, S.J. (eds.). *Land use and watersheds: Human influence on hydrology and geomorphology in urban and forest areas. Water science and application Volume 2*. Washington, DC: American Geophysical Union.

MacDonald, L.H., Coe, D., and Litschert, S. 2003. Assessing cumulative watershed effects in the central Sierra Nevada: Hillslope measurement and catchment-scale modeling. Fort Collins: Colorado State University, Department of Forest, Range, and Watershed Stewardship.

Marco, A., and Blaustein, A. 1999. The effect of nitrite on behavior and metamorphosis in Cascades frogs (*Rana cascadae*). *Environmental Toxicology and Chemistry* 18(5):946-949.

McNabb, D.H., and Swanson, F.J. 1990. The effects of fire on soil erosion. 159-176 in Walstad, J.D., and Radosevich, S.R. (eds.). *Natural and prescribed fire in Pacific Northwest forests*. Corvallis: Oregon State University Press.

Megahan, W.F., Potyondy, J.P., and Seyedbagheri, K.A. 1992. Best management practices and cumulative effects from sedimentation in the South Fork Salmon River: An Idaho case study. 401-414 in *Watershed management: Balancing sustainability and environmental change*. Naiman, R.J. (ed.). New York: Springer-Verlag.

Moring, J.R. 1975. *The Alsea Watershed Study: Effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part II.-Changes in environmental conditions*. Res. Rep. 9. Corvallis: Oregon Department of Fish and Wildlife.

Oregon Forest Resources Institute (OFIC). Nd. *Drinking water & forestry: How a healthy forest ecosystem helps keep streams clean and water quality high*. Portland: Oregon Forest Resources Institute.

Reiter, M, Baitis, K, and Stark, J. 1996. The effects of forest fertilization on water quality in Calapooya Creek. Weyerhaeuser Company Research and Development Technical Report. 12 pp.

Salminen, E.M., and Beschta, R.L. 1991. *Phosphorus and forest streams: The effects of environmental conditions and management activities*. Corvallis: Oregon State University, Department of Forest Engineering. 185 pp.

Smith, R.A., Alexander, R.B., and Schwartz, G.E. 2003. Natural background concentrations of nutrients in streams and rivers of the conterminous United States. *Environmental Science and Technology* 37(14):3039-3047.

Society of American Foresters (SAF) and National Association of State Foresters (NASF). 2000. *A review of waterbodies listed as impaired by silvicultural operations*. Bethesda, MD: Society of American Foresters.

Stark, J., and Reiter, M. 2000. Water quality effects of forest fertilization on potential aquatic amphibian habitat. Weyerhaeuser Company Technical Report. Proprietary.

Stednick, J.D. 1991. *Wildland water quality sampling and analysis*. San Diego, CA: Academic Press.

Sullivan, K., Lisle, T.E., Dolloff, C.A., Grant, G.E., and Reid, L.M. 1987. Stream channels: The link between forests and fishes. 39-97 in Salo, E.O., and Cundy, T.W. (eds.). *Proceedings of the symposium on streamside management: Forestry fisheries interactions*. Contribution 57. Seattle, WA: University of Washington, Institute of Forest Resources.

Swanson, F.J., Benda, L.E., Duncan, S.H., Grant, G.E., Megahan, W.F., Reid, L.M., and Ziemer, R.R. 1987. Mass failures and other processes of sediment production in the Pacific Northwest forest landscape. 9-38 in Salo, E.O., and Cundy, T.W. (eds.). *Proceedings of the symposium on streamside management: Forestry fisheries interactions*. Contribution 57. Seattle, WA: University of Washington, Institute of Forest Resources.

Swanson, F.J. and Jones, J.A. 2002. Geomorphology and hydrology of the H.J. Andrews Experimental Forest, Blue River, Oregon. In *Field Guide to Geologic Processes in Cascadia*. Special Paper 36. Salem: Oregon Department of Geology and Mineral Industries.

Thomas, R.B., and Megahan, W.F. 1998. Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon: A second opinion. *Water Resources Research* 34(12):3393-3403.

Williams, T.M., Hook, D.D., Lipscomb, D.J., Zeng, X., and Albiston, J.W. 1999. Effectiveness of best management practices to protect water quality in the South Carolina Piedmont. 271-277 in *Proceedings of the Tenth Biennial Southern Silvicultural Research Conference*. General Technical Report SRS-30. Asheville, NC: USDA Forest Service, Southern Research Station.

Ziemer, R.R. (technical coordinator). 1998. *Proceedings of the Conference on Coastal Watersheds: The Caspar Creek Story, May 6, 1998, Ukiah, CA*. General Technical Report PSW GTR-168. USDA Forest Service, Pacific Southwest Research Station. 149 pp. http://www.rsl.psw.fs.us/projects/water/caspubs.html (March 18, 2003).

3.0 FOREST CHEMICALS

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3.1 Introduction

The use of forest chemicals remains an emotional issue for many people. Pesticides are accused of causing a range of problems from spontaneous abortions in humans to interfering with salmon migration. Chemicals are a sparingly used, but in some cases essential, tool in forestry; used for reforestation, site release, and control of insects and disease. They provide the promise of producing more wood on fewer acres over fewer years. In many cases, chemicals can be an environmentally preferred option for meeting forest management objectives. Recent court rulings and failed state initiatives demonstrate the risk to the forestry community that these chemicals will be removed as management tools. Here we describe the importance of chemicals to forest managers, a history of controversy about their use, state initiatives dealing with forest chemicals, court cases and rulings on chemical use, and our understanding and gaps in knowledge about forest chemicals.

3.2 Why Are Chemicals Important to the Forest Industry?

We are living in the "do more with less" era. While populations and demands on forest products continue to increase, the area available to manage forests for timber products in the United States is decreasing. Commercial forest operations in the U.S. face increasing competition from wood production in Canada, Chile, New Zealand, and elsewhere. Herbicides, the most commonly used forest chemicals, can accelerate the establishment and growth of commercial forests. In some cases, stand establishment is dependent on chemical control. An example of the growth advantages that chemical can provide is work from British Columbia looking at the response of Douglas fir to treatment with glyphosate (Simard and Heineman 1996). They found that "…within two years of treatment, stem diameter of Douglas fir seedlings was significantly larger…" and "this difference increased through year 9…" Nine years into the study the crowns of the Douglas fir seedlings on the untreated plots had still not grown past the competition, while the seedlings on the treated plots were released the first year after treatment. By reducing the time necessary to release seedling from competition and focusing photosynthetic resources on crop trees, we can shorten rotations and increase productivity.

Insecticides and other chemicals can also be important tools under special circumstances. In the Northwest, the potential for an outbreak of either European or Asia gypsy moths is a significant threat to the region's ecosystem. A disease that is likely to enter much of the West soon is the West Nile virus. The public has tended to focus on the human risks associated with this virus and mosquito control options near populated areas, but West Nile virus is likely to create risks to wildlife species and is reported to have decimated bird populations in some parts of the East. Exotic species in general are a major threat to forest systems. Nationwide, it is estimated that exotic species are costing the economy $130 billion annually (Carruthers 2003), and chemicals are often one of the most effective treatment options.

3.3 History of Controversy

Given the small amount of forest pesticides used compared to other pesticide uses, there is a surprisingly visceral history of controversy. One example is the Alsea Miscarriage Study, know as Alsea II (USEPA 1979). The Alsea II study compared the number of miscarriages among residents living near heavily forested areas to urban and non-urban control groups. Those in the forested area were presumed to be exposed to 2,4,5-T and silvex. Both these herbicides were used in forest management at the time and both contained trace dioxin contaminants. The Alsea II study found that there were higher miscarriages for women living in the forested areas, and that seasonal patterns fit the period of herbicide application. These findings resulted in a ban by EPA on the use of 2,4,5-T and silvex for forest applications, but not for use on some food crops. Only after the ban were serious flaws found in the Alsea II study. At least eighteen independent reviewers came to the conclusion that EPA could not justify the study conclusions (NFPA 1979). One of the study flaws involved the use of hospitalized spontaneous abortions, not total abortions. It was found that the ratio of hospitalized to total spontaneous abortions for the study area was 70% compared to 30% for one of the controls. There was no record for the other control. The "tell-tell" seasonal pattern was found to have not considered seasonal patterns in pregnancies.

In addition to court cases, there is a history of state referendums and bills to ban or restrict chemical use (Ice, Schmedding, and Shepard 1998). The failed measure 64 in Oregon (November 1998 election) would have prohibited the use of forest chemicals and imposed a ban on clearcut harvesting in the state. The proper use of herbicides and other pesticides is certainly not helped by cases like the recent deliberate poisoning of dogs in Portland parks with the herbicide paraquat.

3.4 Recent Court Rulings

Three recent court ruling on the use of pesticides raise concerns about their availability to forest managers over the long term. At least two other pending lawsuits, one in California and one in Maryland, demand Endangered Species Act (ESA) consultation on various chemicals, some of which are used in forestry.

3.4.1 *Californians for Alternatives to Toxic Substances v. EPA*

In this case, the plaintiffs challenged EPA about its failure to comply with §7(a)(2) of the ESA (requiring federal agencies to consult with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (FWS) about listed species) when it registers chemicals. The parties reached a settlement in September 2002 under which EPA agreed to a schedule for review under the ESA on the effects of eighteen pesticides on listed salmon and eight pesticides on listed forest plants. The eight pesticides are all used in forestry operations, and all but one are also on the salmon list. The settlement agreement specified the level of review, including initiation of formal consultation for some products. The agreement also provided that no protective measures would be imposed on pesticide use while the agencies conduct the reviews.

3.4.2 *League of Wilderness Defenders v. Forsgren*

In November 2002, the U.S. Court of Appeals for the Ninth Circuit ruled that aerial spraying of national forests to control Douglas fir tussock moth is point source pollution and requires an NPDES permit. The immediate consequence of this decision was that the state of Oregon prepared an NPDES permit to address an outbreak of gypsy moths in the Five Rivers area of Oregon. NPDES permits for aerial applications of pesticides could lead to delays in management and create more vulnerability for companies to citizen lawsuits. Environmental groups are already citing this decision in advanced notices to sue the Department of Agriculture on control of agricultural pests, including grasshoppers and Mormon crickets. EPA has recently issued some proposed guidance that would blunt this court decision.

3.4.3 *Washington Toxics Coalition v. EPA*

In this case, the plaintiffs argue that EPA had violated the ESA by failing to consult with NMFS about 55 pesticides detected in streams with endangered salmonids. The chemical monitoring data were from the USGS National Water Quality Assessment Program (NAWQA). The court ruled in 2002 that EPA did violate the ESA and ordered the agency to initiate and complete chemical-specific consultations at the appropriate level for each listed salmonid population. The court has now concluded that buffers are required to protect salmon streams until EPA completes a consultation and is considering whether to impose a 300 foot buffer for all the 55 chemicals around streams that listed fish could access.

3.5 What Do We Know?

Each chemical has its own physical and biological characteristics. Key chemical properties include solubility, octanol/water partition coefficient, volatility, and toxicity. The risk of an ecological effect from herbicides is determined by both the toxicity of the chemical and the potential for exposure of non-target organisms (Brown 1980). The choice of chemical, in combination with many other site and application variables, can influence both toxicity and potential for exposure. Foresters must weigh multiple factors in choosing the appropriate chemical, including the efficacy and cost of alternative herbicides, against risks for undesired ecological effects. Is the chemical going to be effective in treating the weed problem? Is the chemical likely to be transported to streams adjacent to the spray unit? Are the expected concentrations sufficient to cause lethal or sublethal effects to aquatic organisms?

Forest pesticides include herbicides, insecticides, fungicides, and rodenticides. These are all generally referred to as poisons by those opposed to chemical use. However, many of the herbicides used on forests act on plant-specific processes and are essentially non-toxic to humans. In assessing risks to wildlife from herbicide application, it is almost always habitat change that raises the most concern, not direct toxicity. Assessments of food consumption by humans of edible plants (e.g., blackberries) in riparian buffers following typical spray applications indicate little or no risk to humans.

Some new herbicides provide dose advantages over traditional chemicals. One example is the introduction of sulfonylureas, which are effective herbicides at doses of ounces per acre compared to pounds per acre (Kearney 1987). Recommended doses for sulfometuron methyl (Oust) for site preparation are 1 to 2 orders of magnitude (10 to 100 times) less than for other commonly used herbicides such as picloram, glyphosate, imazapyr, 2,4-D, and hexazinone.

Forestry is traditionally a minor applier of herbicides and insecticides. Herbicides are generally used only once or twice in a 40 to 60 year rotation, and the latest figures suggest only 1% of pesticides applied in Oregon are on forest lands (Ice, Schmedding, and Shepard 1998). Long-term USGS monitoring finds numerous chemicals in watersheds draining agricultural or urban watersheds but few or no chemicals in runoff from forested watersheds (Wentz et al. 1998). Munn and Gruber (1997) monitored organochlorine compounds in streambed sediments and fish tissues in forest, dryland and irrigated farming, and urban reaches of the Central Columbia Plateau in Washington and Idaho. They found that "…forest was the only land use with no detection of organochlorine compounds in either fish or bed sediment."

Historically, the highest concentrations observed in streams have been from either accidental spills or direct overspray of water, followed by drift, then runoff generated by storms. Newton and Norgren (1977) reported that before buffers were commonly used, concentrations of herbicides in streams rarely exceeded 50 mg/L. With overspray and drift controls, concentrations observed for streams are rarely more than a few μg/L, and even these peak concentrations occur for only a few minutes or hours (Rashin and Graber 1993; Dent and Robben 2000). Drift models such as AgDISP and AgDRIFT have had extensive field validation and can model the effectiveness of alternative equipment and management decisions, both to reduce drift and to achieve acceptable efficacy (Teske et al. 2000; Teske and Ice 2002).

Today, storm-generated runoff may be a relatively more important source of chemical introduction to streams, although meager monitoring has sometimes exaggerated the exposure risk caused by forest applications (Alsea Citizens Monitoring Team 2000). Storm-generated runoff of chemicals usually decays rapidly with storm events. More persistent storm-generated runoff may occur with intensive management, especially where repeated applications occur. Again, this is probably site- and chemical-specific.

3.6 What Do We Need to Know?

While we are currently able to model many of the management and equipment variables that affect drift, there are some control practices, such as drift control adjuvants, the use of half-booms, and interception by riparian canopy, that need to be field tested. Another research area is drift in complex topography. Storm-generated runoff of pesticides is another area that deserves more research and modeling.

Environmental groups commonly criticize ecological effects assessments because we do not have sufficient information about the toxicity of inerts, surfactants and other adjuvants, and spray mix combinations. The classic example is glyphosate. By itself, glyphosate has an extremely low toxicity to fish, with a recommended water quality criterion of 6800 μg/L for an average 24 hour concentration (Kerkvliet in Dent and Robben 2000). With a surfactant, the recommended water quality criterion is 13 μg/L.

As forest managers and chemical applicators have succeeded in reducing chemical concentrations in streams to concentrations below those that will cause acute toxicity to fish or humans, concerns about other chemical effects have been raised. These include endocrine disruption (e.g., hormone mimicry affecting gender of species), effects on aquatic plants or macroinvertebrates, and sublethal effects on fish. Sublethal effects are becoming increasingly important as part of concerns about salmon. While there is some indication that sublethal effects (reduced predator avoidance and ability to return to natal streams) can occur in salmon at high concentrations of a few chemicals (Scholtz et al. 2000), there is little or no evidence of this response for most chemicals.

3.7 Summary of Key Points

- Monitoring across the West has shown that forest chemicals rarely exceed proposed water quality criteria even immediately after applications.
- The use of buffers to avoid overspray and drift of chemicals is an effective means of reducing chemical concentrations in streams, but it is only one of a family of decisions that are used to minimize introduction to streams. Forest practice regulations incorporate findings about how to protect streams.

- Well calibrated and validated models are available to test alternative management practices to reduce introduction of chemicals to streams.
- Any risk from chemicals is a result of the combination of the chemical properties and the manner and conditions under which the chemical was applied.

3.8 References

Alsea Citizens Monitoring Team. 2000. *Herbicide concentrations in stream runoff after rain events in the Alsea River Basin*. Salem: Oregon Watershed Enhancement Board.

Brown, G.W. 1980. *Forestry and water quality*. Corvallis: Oregon State University Book Store.

Carruthers, R.I. 2003. Invasive species research in the United States Department of Agriculture-Agricultural Research Service. *Pest Management Science* 59(6-7):827-834.

Dent, L., and Robben, J. 2000. *Oregon Department of Forestry: Aerial pesticide application monitoring final report*. Technical Report No. 7. Salem: Oregon Department of Forestry, Forest Practices Monitoring Program.

Ice, G.G., Schmedding, D.W., and Shepard, J.P. 1998. State restrictions and initiatives to restrict the use of silvicultural chemicals: What we know and need to know. 303-325 in *Proceedings of the 1998 NCASI Northeast Regional Meeting*. Research Triangle Park, NC: National Council for Air and Stream Improvement, Inc.

Kearney, P.C. 1987. In summary. 135-137 in *Fate of pesticides in the environment*. Publication 3320. Oakland: University of California, Agricultural Experiment Station, Division of Agriculture and Natural Resources.

Munn, M.D., and Gruber, S.J. 1997. The relationship between land use and organochlorine compounds in streambed sediment and fish tissue in the central Columbia Plateau, Washington and Idaho, USA. *Environmental Toxicology and Chemistry* 16(9):1877-1887.

National Forest Products Association (NFPA). 1979. *Forest Chemical News* 1(2):1.

Newton, M., and Norgren, J.A. 1977. *Silvicultural chemicals and protection of water quality*. Seattle, WA: United States Environmental Protection Agency, Region X.

Rashin, E., and Graber, C. 1993. *Effectiveness of best management practices for aerial application of forest pesticides.* TFW-WQ1-93-001. Olympia: Washington Department of Ecology.

Scholz, N.L., Truelove, N.K., French, B.L., Berejikian, B.A., Quinn, T.P., Casilla, E., and Collier, T.K. 2000. Diazinon disrupts antipredator and homing behavior in Chinook salmon (*Oncorhynchus tshawytscha*). *Canadian Journal of Fisheries and Aquatic Science* 57:1911-1918.

Simard, S., and Heineman, J. 1996. *Nine-year response of Douglas-fir and the mixed hardwood-shrub complex to chemical and manual release treatments on an ICHmw2 site near Salmon Arm.* FRDA Report No. 257. Victoria, BC: Canadian Forest Service and British Columbia Ministry of Forestry.

Teske, M.E., Bird, S.L., Esterly, D.M., Curbishley, T.B., Ray, S.L. and Perry, S.G. 2000. AgDRIFT: A model for estimating near-field spray drift from aerial applications. *Environmental Toxicology and Chemistry* 21:659-71.

Teske, M.E., and Ice, G.G. 2002. A one-dimensional model for aerial spray assessment in forest streams. *Journal of Forestry* 100(3):40-45.

United States Environmental Protection Agency (USEPA). 1979. *Report on assessment of a field investigation of six-year spontaneous abortion rates in three Oregon areas in relation to forest 2,4,5-T spray practices*. Washington, DC: United States Environmental Protection Agency.

Wentz, D.A., Bonn, B.A., Carpenter, K.D., Hinkle, S.R., Janet, M.L., Rinella, F.A., Uhrich, M.A., Waite, I.R., Laenen, A., and Bencala, K.E. 1998. *Water quality in the Willamette River Basin, Oregon, 1991-1995*. Circular 1161. Reston, VA: United States Department of Interior, United States Geological Survey.

4.0 FOREST HEALTH AND WILDFIRE

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4.1 Overview

Forest health is a loose metaphor linked to human health. The human health process has three major steps:

Diagnosis – based on symptoms of disease-problem identification

Prognosis – implications of disease, or forecast

Treatment – or prescription

The focus on forest health implies that health is lacking. The topic linkage to wildfire limits the problem to symptoms related to “uncharacteristic” (larger and more intense than normal) wildfire. For this section, the diagnostic tool for forest health is Schmidt et al. (2002), which offers Fire Regime Current Condition Classes as a way to describe and map wildfire hazard and the consequent risk of losing key ecosystem components to uncharacteristic wildfire.

Applying the human health process steps to the forest health problem, we conclude

- The forest health problem is generally chronic and widespread throughout the drier parts of the federal forests in the West.
- While the problem is treatable, treatment is expensive and has many economic and political barriers. Without effective treatment the problem will soon (5 to 15 years) become generally acute.
- The National Fire Plan (NFP) is the chosen treatment but it faces many barriers, including public denial of the disease, inadequate federal funding, legal and administrative hurdles, and perceptions of competing ecological illnesses. The latter may be the most serious, as it is a significant impediment to NFP implementation.

One view of competing ecological illnesses holds that some threatened and endangered species listed under the Endangered Species Act (ESA) are declining at least in part because of excessive active forest management. A competing view is that declining forest health is related to inadequate or absent active forest management. The interactions of causes and symptoms of the “competing” illnesses have seldom been recognized. For example, establishing and maintaining unmanaged reserves in fire-prone forest habitats to protect ESA listed species has in some cases worsened conditions for both listed species and forests. A balancing of risks is indicated.

4.2 The West

Coarse-scale risk assessments (Schmidt et al. 2002) have been completed and the results are disturbing. Of 100,000,000 acres of ponderosa pine, Douglas fir, and mixed conifers in the eleven western states, 77% are at risk of uncharacteristic wildfire. The risk of losing key ecosystem components because of changes in fire size (larger), intensity (higher), severity (greater), and landscape pattern (simplified) is high to moderate. The problem results from changed fire regimes in dry forests related to increasing fuels and tree density. The change has been from frequent, low intensity ground fires that did not kill forests, to infrequent, high intensity crown fires that do.

Artificially long (missed) fire return intervals have resulted in dramatic increases in tree densities and fuels that lead to troubling management implications. For example, nearly 28,000,000 acres of forestland in California is at high to moderate risk of uncharacteristic wildfire. Short-term protection of forests at risk has resulted in unintended longer-term effects. High value conservation assets are at risk of uncharacteristic wildfire. Most late succession reserves (LSRs) established under the Northwest Forest Plan (NFP) have high to moderate fire hazards. Much northern spotted owl (NSO) critical habitat is at high risk. Uncharacteristic wildfires have reduced total owl habitat. Active management can reduce fire hazards and risks and help sustain NSOs and their habitat. The 2002 Biscuit Fire in Oregon adversely affected marbled murrelets, NSOs, Coho salmon, and LSRs. Recent wildfires indicate that the **absence** of active management may represent the greatest threat to listed species. The wisdom of attempting to maintain unmanaged reserves in fire-prone forests is questionable.

4.3 The Pacific Northwest

Eighty-six percent of the forestland in the national forests of Oregon is at high to moderate risk of uncharacteristic wildfire, 83 % is at high to moderate risk in Idaho, while 74% is in a similar condition in Washington. In Oregon, 90% of the late successional/old growth forest is at moderate to high risk (56% high risk), 87% is at risk in Idaho, and 63% is at risk in Washington. About 75% of Inventoried Roadless Areas (IRAs) in the three states is at risk of uncharacteristic wildfire, while about 20% of the LSRs in Oregon and Washington are at high risk. Virtually all of the “eastside” NSO critical habitat in Oregon and Washington is at high risk.

4.4 Oregon

Seventy-seven percent of Oregon’s 32 million acres of forestland is at risk of uncharacteristic wildfire; 35% is at high risk. Most of the watersheds occupied by listed species of Chinook salmon, steelhead and bull trout are at high to moderate risk. These risks in Oregon are real, as evidenced by the effects of the 500,000 acre Biscuit Fire in 2002. About two-thirds of the marbled murrelet and NSO critical habitat, Coho salmon watersheds, and LSRs burned with heavy or high moderate mortality.

4.5 Discussion

The absence of relative risk assessments, comparing the short-term risks of active management to the long-term risks of management inaction in fire-prone forests, is a major barrier to implementing the NFP. In Oregon, 5.6 million acres are protected in LSRs, much of it in dry “eastside” settings where significant conservation values are at risk, including NSOs. Current Section 7 ESA consultation processes take a “precautionary principle” driven, “zero” short-term risk approach to active forest management proposals, discounting the long-term benefits of such treatments. The net effect is to preclude forest health treatments in "at risk" areas. This short-term "protection" may result in long-term detrimental effects to the resources targeted for protection, as in the case of the Biscuit Fire. The short-term, risk-averse policy of federal agencies could be refined through improved tools to assess the long-term effects of "no action" management. Relative risk assessment process and tool development were showcased at the conference on *Risk Assessment for Decision-Making Related to Uncharacteristic Wildfire*, November 17-19, 2003, in Portland, Oregon.

4.6 Summary and Conclusions

Coarse-scale fire risk assessments have been completed and the results are disturbing.

- In drier (mostly pine) forests, changes in fuels (increases) and forests (denser) have resulted in a change in fire regime from low severity to high severity (uncharacteristic) wildfire. "In recent times, the acreage with lethal fire regimes has more than doubled. This poses a significant threat to ecological integrity, water quality, species recovery and homes in rural areas" (Quigley and Cole 1997).
- Of nearly 100 million acres of NFS pine, dry Douglas fir, and mixed conifers, 77% are now at risk of adverse and, in some cases, seldom seen effects of uncharacteristic wildfire.

Artificially long (missed) fire return intervals result in dramatic changes to vegetation that lead to troubling management implications.

- Most (77%) of Oregon's 32 million acres of forest is at risk of losing key ecosystem components because fire regimes have been altered from historical ranges.
- Fire frequencies have departed (decreased) from historical frequencies by multiple return intervals, changing fire size, frequency, intensity, severity, or landscape pattern. Because there are more trees and more fuel than before, fires which once burned frequently but with low intensity now burn infrequently but with high intensity. Fires are larger and hotter than ever before. In the eleven western states, wildfire area burned and burn intensity increased dramatically during the last decade compared with the previous 40 years.
- Short-term protection of "forests at risk" to uncharacteristic wildfire has resulted in unintended longer-term detrimental effects to protected values, including wildlife and biodiversity, because of unmitigated hazards and risks.

High value conservation assets are at risk of uncharacteristic wildfire.

- Virtually all LSRs are in moderate or high hazard forests and are at risk of uncharacteristic wildfire without restoration.
- Much of the "dry" spotted owl critical habitat in Oregon, Washington, and California is in fire-prone forest and is at "high risk."
- Uncharacteristic wildfires since 1994 in fire-prone owl habitat has reduced total owl habitat.
- The sustainability of spotted owls and their habitats in fire-prone forests appears doubtful without active management to reduce risks of uncharacteristic wildfires.
- In the Biscuit Fire burned area, about 65% of marbled murrelet and spotted owl critical habitat, Coho watersheds, and LSRs had at least "high moderate" (>50%) canopy mortality; about half the acres had heavy (>75%) mortality.

- The effects of the Biscuit Fire and other recent uncharacteristic wildfires in Oregon and elsewhere in the West indicate that in some high hazard reserves, the **absence** of careful restoration management represents a significant threat to species.
- These conditions raise concerns about the wisdom of attempting to maintain essentially unmanaged reserves in forests prone to uncharacteristic wildfire.

The absence of relative risk assessments is a barrier to implementing the National Fire Plan.

- The absence of relative risk assessments (comparing the short-term risks of active restoration management to the long-term risks of management inaction) is a significant barrier to implementing the NFP and restoring critical habitat for listed species at risk from uncharacteristic wildfire.
- The ESA Section 7 Consultation Handbook (USFWS/NOAA-Fisheries 1998) takes a "zero short-term risk" approach in defining "Not Likely to Adversely Affect" (NLAA) determinations, which do not require formal consultation. Relative risks may be considered only in formal (and time consuming) consultations.

The short-term, risk-averse policy of federal regulatory agencies could be refined through improved tools to assess long-term effects of "No Action" management.

- Short-term protection (no forest health management) for species and water in high-hazard forested habitat may result in unintended long-term detrimental effects to those same resources because of unmitigated hazards.
- The "precautionary principle" driven short-term, risk-averse policy in administering the ESA and CWA may lead to the long-term detriment of the resources agencies are trying to protect.
- A remedy is to develop and apply analytical tools and processes that can quantitatively disclose the relative risks of management action and inaction in high hazard forests.
- A partnership conference, with significant NCASI leadership, *Risk Assessment For Decision-Making Related To Uncharacteristic Wildfire*, November 17-19, 2003 in Portland, Oregon, explored such tools and processes.

4.7 References

Quigley, T.M., and Cole, H.B. 1997. *Highlighted scientific findings of the Interior Columbia Basin Ecosystem Management Project*. General Technical Report PNW-GTR-404. Portland, OR: USDA Forest Service, Pacific Northwest Research Station and USDI Bureau of Land Management.

Schmidt, K.M., Menakis, J., Hardy, C., Hann, W., and Bunnell, D. 2002. *Development of coarse-scale data for wildland fire and fuel management*. General Technical Report RMRS-GTR-87. Ogden, UT: USDA Forest service, Rocky Mountain Research Station.

U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration-National Marine Fisheries Service (NOAA-Fisheries). 1998. *Endangered species act consultation handbook: Procedures for conducting Section 7 consultations and conferences*. http://www.nv.blm.gov/t&e/documents/s7book.pdf (June7, 2004).

5.0 SALMON AND FORESTS

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5.1 Introduction

The people of the Pacific Northwest have a special relationship with salmon and forests. These icons not only define the region geographically, but culturally, environmentally, and economically as well. Salmon have been part of Native American culture since humans first arrived on the scene, and salmon fisheries represented one of the first major industries in the region. Today, salmon remain the most important species in commercial and sport fisheries along the Pacific coast from San Francisco to Alaska. No other group of fishes, or for that matter animal species, impacts the natural, economic, and social environment of the Northwest quite like salmon. People who live in the Pacific Northwest are often accused of being "salmon crazy" because of the amount of time, energy, and money expended to raise, protect, study, and catch salmon (http://www.wa.gov/wdfw/outreach/education/naturmap.pdf).

Forests also define the region by their unique characteristics. The Pacific Northwest is home to the most productive temperate forests in the northern hemisphere (http://www.ucmp.berkeley.edu/glossary/gloss5/biome/foreste.html). The region has earned the reputation of "timber country," as the climate and soils create conditions in which tree growing capacity and lumber production is among the greatest in the entire United States.

Changing values and priorities about our use of salmon and forest resources, along with a better understanding of the biological role salmon plays in a healthy forest environment, have resulted in changes to forest practices and the need for further scientific inquiry about the interaction with these resources.

5.2 Forest Practices and Salmon Habitat

The effects of forest practices on salmon habitat have long been a contentious issue in the Pacific Northwest. Prior to enactment of forest practices laws in Washington, Oregon, and California in the 1970s, there were few restrictions governing the manner in which streams were treated on forest land. Many of the historical practices were highly damaging to salmon habitat, with a notable example being the practice of splash damming. Road and railroad construction and timber harvest practices employed at the time also had negative impacts, including the production of large amounts of sediment, removal of future sources of wood from the riparian area of many streams, and blocking salmon access to important habitat.

Values and attitudes about salmon and forests have changed over the last century from utilization toward protection. This is reflected in the politics, regulations, practices, and use of these resources. Declines in salmon populations led to the listing of 26 populations of these fishes under the Endangered Species Act during the 1990s. These listings considerably raised the regulatory stakes and elevated concerns regarding land use effects on salmon habitat. Other fish species also have been listed in other areas of the western United States. However, the issues around Pacific salmon, both policy-related and scientific, are perhaps the best developed and most hotly debated, and this aspect of forest management and fish habitat will be the focus in the following discussion. Furthermore, much of the discussion about policy issues and some of the scientific information are applicable to other regions where the impacts of forest practices on fish populations are an issue.

5.3 Politics and Public Opinion

As with many natural resource issues, a variety of stakeholders bring diverse perspectives to the question of how best to utilize and manage the salmon and forest resources. In addition to the variety of positions, there are layers of legal and regulatory directives and responsible agencies which influence how these resources are managed. Further complicating the issue is the scope of land management and environmental policies. Land and public resources are managed by private, public, or tribal entities. Environmental policy is developed and implemented by local, regional, state, tribal, national, and international authorities.

The politics of salmon and the development of public policy around this resource stems directly from public opinion and scientific knowledge. The expression of collective values and the understanding about the relationship between forest practices and stream habitat is embodied in voluntary and regulatory measures, such as voluntary Habitat Conservation Plans, local watershed planning processes, state forest practices regulations, best management practices, ant the federal Endangered Species Act and Clean Water Act. These measures to address the protection of salmon habitat are influenced through public processes, such as the court system, legislative action, public initiative or appeals, and voluntary efforts. The influence of public opinion on the policies regarding the protection and utilization of our natural resources, such as salmon and forests, cannot be underestimated. For over a decade, when the public has been asked what is the most important use of forestlands, protection of air and water quality ranks at the top of the list, followed by fish and wildlife habitat. These priorities are reflected in the regulations that have been implemented.

A variety of factors influence the health and survival of Pacific salmon, from ocean conditions, to hatchery policy, commercial and sports harvesting, hydroelectric dams, and stream habitat protection measures. The state and tribal governments in Washington, Oregon, and California recognize the importance of forested habitat to salmon survival, and have responded to the decline in salmon runs by implementing the Forests & Fish Agreement, Oregon Plan, and California Coastal Salmon and Watersheds Program. While each uses a slightly different approach, they all aim to protect salmon habitat and maintain an economic base in forestry.

Balancing the often conflicting but ultimately complimentary goals of environmental protection and economic interests is generally more successful when a collaborative process is used to develop solutions.

5.4 Forestry and Salmon: Science Considerations

Forest practices designed to protect salmon habitat have evolved rapidly since the implementation of the initial rules 30 years ago. The basic premise underlying these regulations has been that by identifying and protecting those portions of the landscape that interact most directly and intensely with streams, salmon habitat can be restored within the context of profitable forest management. Streams supporting fish habitat are now provided with forested buffers during timber harvest to provide shade, litter, and a future source of large wood. Unstable slopes and roads have been identified and addressed, reducing the frequency of occurrence of mass failures. Changes in surfacing materials, location, and drainage of forest roads have reduced the delivery of sediment to streams from the erosion of road surfaces and ditches. There is increasing evidence that these practices are contributing to improvements in channel form and water quality on commercial forest land. However, there are still those who contend that the current practices are insufficient to enable salmon recovery. Unfortunately, there is very little scientific evidence, positive or negative, about the manner in which the salmon themselves are responding to the application of these protective measures. The lack of quantitative data on salmon populations is in part responsible for this deficiency.

5.5 Salmon Population Data Needed

There are very few locations in the Pacific Northwest where sufficient fish population data have been collected to determine response to habitat protection or restoration measures. The one type of fish data that has been collected at enough sites over a sufficient period of time to examine time trends in abundance is spawner counts. These data were recently used to examine the relationship between Coho salmon abundance and land use in the Snohomish River basin the western Washington (Pess et al. 2002). This analysis found that nearly all the monitored locations supporting large populations of spawning Coho salmon were on commercial forest land. Streams draining developed or agricultural areas supported very few fish by comparison. Although this analysis does not directly indicate that forest practices are sufficient to protect salmon habitat, it does suggest that habitat on some commercial forest land is capable of supporting very large populations of these fish. Additional work using existing fish data, coupled with a concerted effort to collect data that will enable the effects of forest practices on salmon to be directly assessed, should be a priority of both land owners and regulatory agencies.

The relationship between productivity of fish populations and actions to protect or restore habitat has traditionally been examined at fine spatial scales (short stream reaches) over relatively short periods of time (one to several years). The goal of much of this research has been to establish functional links between the application of a forest management practice, the effect on habitat condition, and a life-stage-specific response by salmon, such as the effect of road abandonment on fine sediment and the consequent change in the survival of incubating eggs (Everest et al. 1987). In fact, these types of studies have provided the scientific foundation on which many changes in forest practices have been based. Although these types of studies are important for identifying the various factors affecting salmon in freshwater, they do not provide an indication of the role individual habitat factors play in determining the productivity of a salmon population.

Part of the difficulty in quantifying the response of salmon to the application of a suite of forest management prescriptions stems from the fact that these fish require a diversity of habitat types to complete freshwater rearing. Preferred habitats change through the period of freshwater rearing (e.g., spawning habitat consists of gravel bedded riffles, preferred summer rearing habitat is pools). The relative availability and distribution of the numerous habitat types required over the entire freshwater life cycle plays a key role in determining the survival rate and productivity of a fish population. Therefore, determination of the response of a fish population to the application of a suite of forest management practices requires comprehensive fish population data, including the number of adult fish spawning, fry and parr density and distribution, and the number of smolts leaving for the ocean. These data have been collected in relatively few locations in the Pacific Northwest and have not been used to evaluate the effects of forestry since the Alsea Watershed Studies in the 1960s (Hall, Brown, and Lantz 1987).

This lack of knowledge about the manner in which salmon are responding to the forest practice prescriptions being applied in the region is the largest gap in our understanding on this subject, but is also an opportunity. Evaluating the response of salmon populations to habitat protection measures will require replicated observational studies or intensive, research-level experiments conducted at large spatial and long temporal scales. Lack of such efforts is in part due to the considerable expense and effort required to implement these studies. Nonetheless, without these types of efforts, determination of the effectiveness of forest practices for salmon will continue to rely on various surrogate measures (e.g., abundance of large wood, shade, invertebrate community characteristics) that may bear little or no relationship to the response of the fish.

Ideally, salmon response to forest management would be evaluated using a series of paired treatment-reference watersheds where the survival, growth, and abundance of salmon at various stages during freshwater rearing could be related to habitat conditions. The effect of forest practices on the habitat attributes found to be key in controlling salmon population performance also would be evaluated. By concentrating monitoring efforts in a few watersheds, sufficient data to determine the linkages between management action, habitat condition, and fish response could be collected. This concentrated monitoring approach would also provide the ability to connect site-level responses of habitat and fish to a specific forest management prescription with the contribution these specific responses make to changes in production of smolts from the watershed.

5.6 Current Research Efforts

A few efforts currently underway in the region are collecting the type of fish data necessary to evaluate responses to forest management. The Oregon Department of Fish and Wildlife has been collecting spawner and smolt data on a series of watersheds along the Oregon coast for several years. These sites are termed “life history monitoring watersheds.” However, the purpose of these sites is not to evaluate the effectiveness of various land management practices. The watersheds are not paired, and experimentation with habitat is not part of the design. However, these sites might prove suitable as reference sites for a series of comparable watersheds where forest practices could be applied and evaluated. An effort in Washington termed “Intensive Watershed Monitoring” is just beginning. This effort does include paired watersheds and is intended to evaluate the effect of various habitat manipulations on salmon production. Some of the treatments that may be evaluated in this program include forest practices, watershed restoration measures, and urban/residential development.

These embryonic efforts to truly understand salmon response to various factors that may affect freshwater habitat may offer a huge opportunity to alter the manner in which the efficacies of various land management practices are assessed. From the standpoint of forestry, these projects represent one of the few attempts to actually measure the response of a resource of primary concern to the application or measure intended to benefit that resource. These monitoring efforts may enable us to move away from performance measures based on easily measured, but possibly meaningless, parameters to measures that are based directly on the resources that are the ultimate target of the management actions: the fish.

5.7 Summary of Key Points

- The people of the Pacific Northwest have a special relationship with salmon and forests.
- Changing values and priorities about the use of salmon and forest resources have resulted in changes to forest practices, reflected in the politics, regulations, and use of these resources.
- The effects of forest practices on salmon habitat have long been a contentious issue in the Pacific Northwest.
- The politics of salmon or the development of public policy around this resource stems directly from public opinion and scientific knowledge.
- Balancing the often conflicting but ultimately complimentary goals of environmental protection and economic interests is generally more successful when a collaborative process is used to develop solutions.
- Forest practices designed to protect salmon habitat have evolved rapidly since the implementation of the initial rules 30 years ago, but there is very little scientific evidence,

positive or negative, about the manner in which the salmon themselves are responding to the application of these protective measures. This gap in knowledge presents an opportunity to conduct key research.

- Determination of the response of a fish population to the application of a suite of forest management practices will require comprehensive fish population data.

5.8 References

Everest, F.H., Beschta, R.L., Scrivener, J.C., Koski, K.V., Sedell, J.R., and Cederholm, C.J. 1987. Fine sediment and salmonid production: A paradox. 98-142 in Salo, E.O., and Cundy, T.W. (eds.). *Streamside management: Forestry and fishery interactions*. Contribution Number 57. Seattle: University of Washington, Institute of Forest Resources.

Hall, J.D., Brown, G.W., and Lantz, R.L. 1987. The Alsea Watershed Study: A retrospective. 399-416 in Salo, E.O., and Cundy, T.W. (eds.). *Streamside management: Forestry and fishery interactions*. Contribution Number 57. Seattle: University of Washington, Institute of Forest Resources.

Pess, G.R., Montgomery, D.R., Steel, E.A., Bilby, R.E., Feist, B.E., and Greenberg, H.M. 2002. Landscape characteristics, land use, can coho salmon (*Oncorhynchus kisutch*) abundance, Snohomish River, Wash., U.S.A. *Canadian Journal of Fisheries and Aquatic Sciences* 59:613-623.

6.0 HEADWATER STREAMS

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6.1 Introduction

Small headwater streams, often including streams that do not support fish, can represent most of the total length of a stream network. Depending on the classification and buffer strategy applied to headwater streams, the area of special management (buffers, filter strips, riparian management areas) around these small streams can represent a large fraction of the watershed. In some cases there have been recommendations for wider buffers around smaller streams. Here we review the importance of decisions surrounding headwater streams, what we know about them and what we need to learn, and active research to explore headwater stream functions and patterns.

The state of Washington's Cooperative Monitoring Evaluation and Research (CMER) Committee recently completed a ranking of effectiveness and validation programs for forest practices. This ranking process involved stakeholder assessments of the uncertainty (lack of understanding) and risk to the resource for different categories of questions about forest operations. Of the sixteen program areas assessed, two of the top three priority research programs involved headwater Type N (non-fish-bearing) streams. These were Type N stream buffer characteristics, integrity, and function; and Type N stream amphibian response. It is estimated that the programs designed to reduce this uncertainty to an acceptable level for just these two questions will cost $850,000. This assessment would normally be the perfect introduction to the importance of headwater stream research, but at least two other recent events further define the level of controversy and need for credible information about headwater streams.

In December 2002, an Oregon court rejected a motion to dismiss a lawsuit against the State Forester regarding violation of the federal Endangered Species Act for failure to protect coastal coho salmon.

The issues raised by the plaintiffs include clearcut logging on high landslide risk sites; logging near small- and medium-sized fish-bearing streams; and logging without a no-cut buffer on small non-fish-bearing streams that feed into salmon habitat. The federal administration is also considering reclassification of waters of the United States to remove intermittent streams and isolated wetlands. It is estimated that 20 to 30% of wetlands and possibly 60% of streams would be affected.

What is apparent with a quick review of forest watershed issues at state, regional, national, or even international levels, is that headwater streams are consistently found to be important to aquatic resources, yet there is tremendous uncertainty about the impact of management on these streams. Here we discuss key reasons why headwater streams remain a source of uncertainty and controversy, and describe the growing recognition of a need to conduct focused research on these streams.

6.2 Extent of Headwater Streams and Basis for Proposed Protection

It is not surprising that much of the rancor about forest practice regulations today revolves around small stream issues. These are the Type IV and V streams in Washington (now Type N), the small Type N streams in Oregon, Class II streams in Idaho, and Class III streams in California. It is recognized that "[t]he ecology of headwater systems and their importance to downstream habitats and functions is not well understood" (Alverts et al. 2001).

The proportion of a stream network in headwater reaches depends on both the classification scheme used and the nature of the drainage system. Still, it is commonly accepted that headwater streams represent a high percent of the drainage network, somewhere between 60 and 90% of the total drainage network's length.

Because there is uncertainty about the ecological functions of headwater streams, and because management of riparian areas around these streams can represent a large investment, there is considerable controversy. One example of how significant headwater streams can be to the area of a watershed in special management is an analysis of the Mica Creek Watershed. The President's Forest Plan (FEMAT 1993) proposed riparian reserves ranging from about 100 to 300 feet wide, depending on stream type. Potlatch Corporation tested these proposals on the Mica Creek Watershed in northern Idaho using its Geographic Information System (GIS) database. It found that under the proposed guidelines, 33% of the watershed would be in riparian reserves (Ice and Van Deusen 1994). Most of the area in riparian reserves, perhaps two-thirds or more, was in Class II or first-order streams, reaches that do not have fish and would be classified as headwater reaches. This large fraction also had much narrower riparian reserves (100 to 150 feet) around the headwater reaches compared to 300 foot reserves around fish-bearing streams. Stream densities tend to be higher in many coastal Northwest and western Cascade watersheds than in interior mountain watersheds such as Mica Creek, so this example of percent of area in riparian reserves may be generally low.

Creating even further controversy are proposals to have wider buffers on smaller streams. An example is a recommendation to the Maine Department of Environmental Quality based on *A Review of the Effects of Forest Practices on Water Quality in Maine* (Kahl 1996). Kahl concluded that

> [s]mall streams need wider buffer (filter) strips than large streams. This recommendation is the reverse of present BMPs. Buffer strip widths should reflect the relative importance of the riparian zone to a particular stream watershed. The present 75-foot buffer zone may include the entire watershed of the smallest streams, but the 250 foot buffer strip along the Penobscot River is insignificant for that watershed. Buffer strips are essential for temperature control in small streams, but irrelevant for temperature control in large streams. The topography in the buffer strip of small streams is typically steep, requiring a wider buffer to minimize sediment transport to the stream.

At the 2001 Forest Best Management Practices (BMPs) Research Symposium held in Atlanta, Georgia, small headwater streams were identified as a research priority. At that symposium the focus was on the East, particularly the Southeast. Two specific issues were “differences in water quality patterns produced by small forest streams compared to point sources and large streams” and “how can and should we protect ephemeral streams from forest management impacts?” (Shepard 2002).

The Ohio Environmental Protection Agency (OEPA) is increasing its monitoring and research into headwater streams. It reported that “Small streams are ‘feeder’ streams that play a vital role in the health of larger streams and rivers” (OEPA 2003).

At the 2001 Headwater Research Workshop in Oregon it was found that “[t]he ecology of headwater systems and their importance to downstream habitats and functions is not well understood” (Alverts et al. 2001). The sufficiency analysis of the Oregon Forest Practices Rules found that “[c]urrent research and monitoring results show current practices may result in short-term (two to three years) temperature increases on some Type N [non-fish-bearing] streams. The significance of potential temperature increases on Type N streams to downstream fish-bearing streams and at a watershed (or sub-basin) scale is uncertain.” The sufficiency analysis went on to say that “[t]here is increasing scientific evidence that small non-fish-bearing streams prone to debris flows provide an important source of large wood for downstream fish habitat” (ODF and ODEQ 2002).

A paper presented at the “small streams” symposium in British Columbia last year concluded that “[c]urrent small stream riparian management may not be sufficient to fully protect small streams in both the short and long term” (Macdonald et al. 2002).

This collection of quotes represents a brief sampling of some of the thoughts and ongoing debate about small headwater streams, their ecological importance, and appropriate management options. While each of these quotes reflects a current debate about headwater streams and their management, it is remarkable that they come from four different areas. In order, they are from the East (Maine, Southeast), Pacific Northwest (Oregon), Midwest (Ohio), and Canada (British Columbia). This emerging debate about small headwater streams became particularly clear when within the span of a year: the Oregon Headwater Research Cooperative (OHRC) sponsored a Workshop on Headwater Streams in Corvallis, Oregon; a Symposium on Small Stream Channels and Their Riparian Zone was held in Vancouver, British Columbia; and the Forestry BMP Research Symposium in Atlanta, Georgia, identified research needs for small, ephemeral streams. A check of website listings for headwater streams finds over 19,000 hits.

6.3 What We Know

Traditionally, headwater streams have had less vegetative retention (e.g., a narrower riparian management or equipment exclusion zone) because the focus has been on retention near or adjacent to fish habitat. Still, smaller headwater streams will generally have larger changes in water quality with similar levels of disturbance. For example, other factors being equal, a shallow stream heats up more than a deep stream as it passes through an opening in the shade. Similar inputs of sediment or nutrients to smaller discharge streams will be diluted less than in larger discharge streams. Thus it is true that small headwater streams can respond more to disturbance than larger streams. Many use this reasoning to support proposals for wider buffers.

The problem with this perspective is that it is a static view of the watershed, not considering temporal and spatial patterns. An example of this logic problem is the concentration of herbicides observed in the Mississippi River at Baton Rouge, Louisiana, and North Fork of Rabbit Creek (NFRC), Washington. Goolsby (1997) reported that “…measurable levels of herbicides (greater than 0.05 μg/L) occur year-round in most Midwestern streams and the lower reaches of the Mississippi due to releases from reservoirs, aquifers, and leaching of more persistent herbicides, such as atrazine from soils." This can be contrasted with results from monitoring to assess the effectiveness of forest practice rules in Washington (Rashin and Graber 1993). Peak concentrations observed for the Mississippi (atrazine) and NFRC (glyphosate) were nearly identical. However, herbicide concentrations in the Mississippi River persisted for weeks to months while herbicide in the Washington stream was detected for only minutes to hours immediately following spray operations. NFRC represents one of the most remote and lowest discharge streams ever monitored for herbicides. Flow in the NFRC was about 0.003 cubic meters per second (cms) during monitoring. This compares to discharge for the Mississippi River at Baton Rouge of between 10,000 and 50,000 cms, or about 3,000,000 to 17,000,000 times the flow of NFRC. Thus while both streams experienced approximately the same peak concentrations, the exposure was only ephemeral in NFRC, and unlikely to impact downstream reaches (Teske and Ice 2002).

Given this discussion, management strategies need to recognize the five Rs of headwater streams: redundancy, resiliency, recovery, recolonization, and rejuvenation.

6.3.1 *Redundancy*

Because so much of the stream network is composed of headwater streams, there is great redundancy in headwater functions. Gomi, Sidle, and Richardson (2002) indicated that about 70 to 80% of the total basin area drains to headwater streams. In a letter to EPA responding to an advanced notice of rulemaking concerning headwater streams, the president of the Society of Wetland Scientists stated that "[i]t has been well documented that greater than 70 percent of the total stream miles in most watersheds consists of headwater streams" (Day 2003). In another response to the proposed revisions to Clean Water Act rules on headwater streams, the Natural Resources Defense Council (2003) wrote that for the Baltimore, Maryland, water supply "…more than 90 percent of total stream miles are composed of creeks and small streams…"

At the 2001 Oregon Workshop on Headwater Streams, Dr. Stan Gregory of Oregon State University pointed out that headwater streams have a less dominant position if we consider stream network volume; the volume of headwater streams and larger, higher-order streams is about equal. This is certainly true from a stream ecologist's view of the world. However, for a land manager it is length or density of the stream network that creates the greatest management controversies. Protection of substantial lengths of headwater streams with restrictions on practices adjacent to them can result in large reductions in management options (loss of economic value). The cost to landowners of the new riparian rules in Washington has been estimated at $3 billion. The area in riparian protection per unit area is primarily a function of three factors: streamside management zone widths imposed; types of streams protected; and stream density. Economic costs are determined by the area affected, the restrictions imposed, the cost of those restrictions, and secondary economic costs (e.g., isolated units not worth harvesting, cost of rerouting roads, etc.).

6.3.2 *Resiliency*

While water quality or habitat disturbance can be greater for smaller headwater streams, they can also display much greater resilience to disturbance. For example, for small streams with narrow channels, smaller pieces of large woody debris can be stable and provide habitat diversity (Bilby and Ward 1989). Brush and hardwoods can rapidly restore lost shade for narrow streams, but may take decades to restore similar functions for wider streams (Andrus and Froehlich 1988).

6.3.3 *Recovery*

Recovery downstream from water quality impacts observed in small streams can be very rapid. Where there is sufficient light, primary production can be stimulated to take up biologically available nutrients. Elevated peak stream temperatures can be rapidly attenuated. For example, Zwieniecki and Newton (1999) found that once elevated, stream temperatures tend to move back toward the expected temperature profile as they move downstream. Johnson and Jones (2000) found that temperature peaks caused by water moving through an exposed reach (due to past debris torrents) rapidly attenuated as the water moved into and mixed with water in debris deposits. Hagan (2000) and Moore et al. (2003) reported similar rapid cooling as water moved through sediment wedges in forest streams.

6.3.4 *Recolonization*

Headwater reaches can support amphibian and macroinvertebrate communities that are different from larger fish-bearing reaches. Isolation from fish can be an important factor in the survival of some organisms. As stream drainages become more ephemeral in nature, the communities begin to resemble those found in upland sites. Still, headwater reaches can be important for certain amphibians and macroinvertebrates. Many macroinvertebrates can rapidly recolonize disturbed sites (e.g., Duncan and Brusven 1985). Because most western forests have experienced at least one harvest and amphibians are found in these systems, we believe that they can survive or recolonize in harvested sites. One important information need is how to leave residual forest components to encourage recolonization.

6.3.5 *Rejuvenation*

Headwater streams, especially ephemeral upland reaches, will experience periodic disturbances from a range of events from wildfires to debris torrents (Ice and Schoenholtz 2003). These disturbances not only reset processes within the headwater reaches, but also contribute to downstream functions. One of the key issues for steep, debris torrent prone headwater reaches is their role in large wood recruitment to downstream, fish-bearing reaches.

We often think that we have little appreciation for how headwater streams function and respond to forest management. Actually, that is not true. Most forest watershed studies have been directed at what would be classified as headwater reaches. It is at this scale that we can manipulate enough of the watershed to cause a detectable change. Examples include the small watershed studies in the H.J. Andrews Experimental Forest and portions of the Caspar Creek and Mica Creek Studies. While small headwater streams are the focus of much research, our interpretation of effects has emphasis on response in downstream network reaches, especially those supporting fish. What is changing is that we must now assess response based on both downstream and on-site effects to key beneficial uses.

6.4 What We Need to Know

The following are some of the key reasons for uncertainty about headwater streams.

- Most research has been directed at streams with fish. Many of the concerns about headwater streams are still often couched in terms of a fish-centric view of stream networks. Thus we hear the argument that headwater streams are vital to the health of larger streams. An example is the lawsuit in Oregon, where small non-fish-bearing streams are an issue because of their potential impact on fish-bearing streams. Still, both the value of headwater streams by themselves and the connections between headwater tributaries and their receiving waters are poorly defined.

- Small headwater streams, with shallow flows and close connections with adjacent riparian zones, are inherently more susceptible to changes in water quality (temperature, sediment, nutrients) than large streams. It takes less energy or material to cause a similar magnitude change in water quality for a small volume compared to a large volume. Any practical assessment of headwater streams must consider both sensitivity and overall spatial and functional patterns as represented by the five headwater Rs (redundancy, resiliency, recovery, recolonization, and rejuvenation).

- Small headwater streams can be very difficult to monitor. A study of riparian buffers for headwater streams in Maine by Hagan of the Manomet Center for Conservation Science reported that "Interpretation of the stream water temperature data is complicated by the fact that most streams went dry…" each year of the study (Hagan 2002). Similarly, at the Alto Watershed Project in Texas, interpretation of sediment and nutrient loads in response to timber harvesting is complicated by headwater streams that go dry and flow that is discontinuous along channel lengths (Beasley et al. 2001).
- The hydrology and water quality of headwater streams is quite variable, and may depend on geology, climate, disturbance patterns, and other factors. This variability is only now beginning to be documented. A recent study of small streams in the Washington Olympic Peninsula found that a majority of streams, including those that were unharvested, did not meet current or proposed temperature standards (Black 2001). Thus, it is not surprising that OHRC-funded projects are largely assessing the physical and biological variability of headwater streams in Oregon and attempting to understand what controls that variability.

After the 2001 Headwater Streams Research Workshop (Alverts et al. 2001), Atlanta BMP Conference (Shepard 2002), CMER research priority setting, and other efforts, it would be redundant to list specific headwater research needs. We encourage resource managers to visit these resources to identify key research topics. Still, some information needs patterns emerge.

- What is the physical and biological variability of headwater streams, both spatially and temporally?
- What determines this variability?
- What are acceptable changes or management impacts?
- What is the value of headwater streams to receiving waters?
- What is the value of headwater streams on their own?
- What are the economic consequences of alternative management options?

Proposed research might best be judged by asking "Will this research help define the value of the headwater stream and the benefits and costs of management options?"

6.5 Oregon Headwater Research Cooperative

The Oregon Headwater Research Cooperative (OHRC) has recently formed to support research on headwater streams. "The purpose of the OHRC is to investigate local and downstream effects of forest management on biota and habitat characteristics of headwater stream systems" (Dent and Danehy 2002). In October 2001, the OHRC convened scientists at a workshop to identify priority research and information needs. The findings from that workshop, the proceedings of a January 2003 forum on headwater research, and summaries and updates of research currently being supported by the OHRC are available at http://www.headwatersresearch.org.

6.6 References

Alverts, B., Danehy, B., Dambacher, J., Dent, L., Hafele, R., Ice, G., Moore, K., Reiter, M., Roberts, K., and Russell, K. 2001. *Headwater Research Cooperative: Workshop summary*. Oregon Department of Forestry Technical Report #16. http://www.odf.state.or.us/FP/fpmp/TechReport.htm (August 7, 2003).

Andrus, C.W., and Froehlich, H.A. 1988. Riparian forest development after logging or fire in Oregon Coast Range: Wildlife habitat and timber value. In *Symposium on streamside management: Riparian wildlife and forestry interactions*. Seattle: University of Washington.

Beasley, S., Chang, M., Ice, G.G., Gowan, B., and McBroom, M. 2001. A study of intensive forest management for small southern watersheds (Alto Watershed Project). 54-59 in *Forest Resources Institute 2001 annual report*. Nacogdoches, TX: Stephen F. Austin State University, Arthur Temple College of Forestry.

Bilby, R.E., and Ward, J.W. 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. *Transactions of the American Fisheries Society* 118:368-378.

Black, J. 2001. Summer temperatures in small stream sources on managed Olympic Peninsula timberlands. Master's thesis. Seattle: University of Washington.

Day, F. 2003. Letter to Donna Downing, U.S. Environmental Protection Agency, and Ted Rugiel, U.S. Army Corps of Engineers, on advanced notice of proposed rulemaking April 16, 2003. http://www/sws/org/regional/northcentral/SWS_ANPRM.html (August 8, 2003).

Dent, L., and Danehy, B. 2002. Little streams, big impact: Oregon Headwaters Research Cooperative. *Western Forester* 47(5):10-11.

Duncan, W.F.A., and Brusven, M.A. 1985. Benthic macroinvertebrates in logged and unlogged low-order southeast Alaskan streams. *Freshwater Invertebrate Biology* 4(3):125-133.

Forest Ecosystem Management Assessment Team (FEMAT). 1993. *Forest ecosystem management: An ecological, economic, and social assessment*. Portland, OR.

Gomi, T., Sidle, R.C., and Richardson, J.S. 2002. Understanding processes and downstream linkages of headwater streams. *BioScience* 52(10):905-916.

Goolsby, D.A. 1997. *Midcontinent Herbicide Initiative: Significant findings*. United States Geological Survey.

Hagan, J.M. 2000. Water temperature profile of a western Maine headwater stream with adjacent clearcuts. *Mosaic Science Notes #2000-1*. Brunswick, ME: Manomet Center for Conservation Science.

Hagan, J.M. 2002. *CFRU annual report: The effectiveness of different buffer widths for protecting riparian values on headwater streams*. Brunswick, ME: Manomet Center for Conservation Science.

Ice, G., and Schoenholtz, S. 2003. Understanding how extremes influence water quality: Experience from forest watersheds. *Hydrological Sciences and Technology* 19(1-4):99-108.

Ice, G., and Van Deusen, P. 1994. An analysis of alternative riparian protection requirements on land available for management and their cost to landowners. Paper presented at the 1994 NCASI West Coast Regional Meeting. Available from the NCASI West Coast Regional Center, Corvallis, OR.

Johnson, S.L., and Jones, J.A. 2000. Stream temperature responses to forest harvest and debris flows in western Cascades, Oregon. *Canadian Journal of Fisheries and Aquatic Sciences* 57(Suppl. 2):30-39.

Kahl, S. 1996. *A review of the effects of forest practices on water quality in Maine*. Augusta: Maine Department of Environmental Quality, Bureau of Land and Water Quality Control.

Macdonald, J.S., Macisaac, E.A., Herunter, H., and Beaudry, P.G. 2002. The effects of variable retention riparian buffers on discharge, temperature, and suspended sediment in small headwater streams in the northern interior of British Columbia. Abstract in *Symposium on small streams channels and their riparian zone: Their form, function and ecological importance in a watershed context*. Vancouver, BC.

Moore, R.D., Mellina, E., Story, A., and Sutherland, P. 2003. Headwater stream temperature response to forest harvesting as a hydrologic problem. In *Headwater stream ecology research forum*. Oregon Headwaters Research Cooperative. http://www.headwatersresearch.org.

Natural Resources Defense Council. 2003. Press backgrounder-Limiting Clean Water Act protection could contaminate drinking water. http://www.nrdc.org/media/pressreleases/030611a.asp (August 28, 2003).

Ohio Environmental Protection Agency (OEPA). 2003. Ohio primary headwater habitat streams. http://www.epa.state.oh.us/dsw/wqs/headwaters/ (January 15, 2003).

Oregon Department of Forestry (ODF) and Oregon Department of Environmental Quality (ODEQ). 2002. *Oregon Department of Forestry and Department of Environmental Quality sufficiency analysis: A statewide evaluation of FPA effectiveness in protecting water quality*. Salem: Oregon Department of Forestry.

Rashin, E., and Graber, C. 1993. *Effectiveness of best management practices for aerial application of forest pesticides*. Timber, Fish, and Wildlife Report TFW-WQ1-93-001. Olympia: Washington State Department of Ecology.

Shepard, J. 2002. Synthesis of BMP research needs. *2001 Forest Best Management Practices Research Symposium*, April 2002, Atlanta, GA.

Teske, M.E., and Ice, G.G. 2002. A one-dimensional model for aerial spray assessment in forest streams. *Journal of Forestry* 100(3):40-45.

Zwieniecki, M.A., and Newton, M. 1999. Influence of streamside cover and stream features on temperature trends in forested streams of western Oregon. *Western Journal of Applied Forestry* 14(2):106-113.

7.0 THE SPOTTED OWL AND ENDANGERED SPECIES

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7.1 Introduction

Numerous petitions have been submitted to list various forest wildlife species as threatened or endangered under the Endangered Species Act (ESA) of 1973. The apparent purpose was to protect uncommon wildlife from habitat loss. The most widely publicized and debated is the northern spotted owl (NSO or "owl"), Latin name *Strix occidentalis caurina*. The NSO and its small mammal prey are widely believed to be dependent upon late-successional and old-growth forests (LSF). Timber harvest reduction of the abundance of LSF and edge effects from fragmenting such forests into smaller, scattered patches were thought to cause populations of spotted owls and other uncommon species to decline. Such perspectives generally have rejected the premise that well-managed forests can accommodate such apparently specialized wildlife. Here, we discuss these topics and suggest some means for managing the continuing socio-political debates.

7.2 Why Are the Owl and Threatened and Endangered Species Important?

The NSO captured the minds of government agencies and the hearts of the public, and was listed as threatened under the ESA in 1990. Marbled murrelets were listed in 1992, and the Canada lynx, bull trout, and various salmon stocks were listed shortly thereafter. Petitions to list the California spotted owl, northern goshawk, and western gray squirrel were rejected, largely because those animals were more abundant and widely distributed than suggested by the petitioners. A proposal to list the Pacific fisher, a large member of the weasel family, is pending. After listing occurs, the associated regulatory agencies are required to specify critical habitats and develop strategies for recovery.

Critical habitat designations and recovery strategies often determine the levels of forest management that can occur on federal timberlands, and the law specifies that no one can "take" (i.e., kill, harass, or harm) a listed species. As a result, all segments of the forest industry are impacted. The resulting policies often result in a) major opportunity costs associated with reduced access to wood supplies; b) noteworthy costs of constraints on forestry operations; c) social and economic costs in terms of job losses and mill closures; d) political costs in terms of social and public support for continued forestry; and e) trade imbalances as companies seek wood and fiber from non-U.S. sources. The latter change undoubtedly creates environmental consequences in countries with less stringent environmental protection mechanisms. For the Pacific Northwest, estimates of costs associated with listings have been high. Since 1988, over 300 mills have closed in Washington, Oregon, and California.

The environmental concerns about forestry on federal lands did not end with the listing of the owl. The 1992 draft recovery plan for the NSO proposed setting aside some 8 million acres of timberland in a network of large forest blocks, and the ultimate recovery strategy included about 40% more land. By then, the marbled murrelet had been listed, and President Clinton's Northwest Forest Plan expanded the proposed network of conservation areas for the owl to 11.5 million acres. The total number of acres set aside increased to 21 million acres to accommodate other species associated with LSF in the range of the NSO.

During the draft stage, the Northwest Forest Plan was to reduce the annual harvest of wood from federal timberlands from about 4 billion board feet per year to about 1.1 billion board feet. However, when the final plan was signed into law in 1994, it institutionalized a set of streamside constraints for protecting aquatic species that were intended to be interim strategies until definitive research could be completed. Doing so resulted in an annual harvest of about 0.1 billion board feet of wood from federal timberlands. Thus, original protection for the threatened spotted owl was transformed and resulted in a virtual stoppage of all timber harvesting on federal timberlands. In addition, planning for the NSO institutionalized untested concepts of island biogeography theory as a basis for planning ecosystem management at the landscape level.

To be sure, ten large areas were identified as Adaptive Management Areas (AMAs) to learn how to manage forests for species associated with LSF and to modify the streamside "guidelines." However, over the past decade, these AMAs have not been used as originally intended and virtually no research has been conducted as foreseen by the drafters of the plan. No federal studies have addressed adaptive management for the NSO, despite having a detailed strategy for doing so in the document provided by Interagency Committee of Scientists in 1990, whose work the Northwest Forest Plan was based on.

President Clinton's Northwest Forest Plan seems to be solidly established. To its credit, the Plan is simple. It is map-based. Therefore, it was easily marketed and understood by the public and policy makers. And it has withstood legal challenges—federal judges now put more weight on the precautionary principle than trust in the skills and artistry of professional forest managers. Human economic values would appear to some observers to be subordinately considered compared to the social environmental imperative.

7.3 History of Debate

7.3.1 *Federal Laws*

Far-reaching federal mandates such as NEPA (National Environmental Policy Act) in 1969, the ESA (Endangered Species Act) in 1973, and FLPMA (Federal Land Policy and Management Act) and NFMA (National Forest Management Act) in 1976, along with their associated regulations, provided stronger environmental protection than did previous legislation such as the Multiple Use and Sustained Yield Act of 1964. These recent mandates also gave life to what some have called the environmental conflict industry. Now, motivated by fear of unknown consequences of environmental change, policy makers and federal judges require those who propose to modify habitats to demonstrate, ahead of the event, that no significant impacts will occur.

7.3.2 *The Owl May Not Qualify as an Endangered Species Act Listable Species*

The NSO was listed during a time when very little was known about it. The U.S. Fish and Wildlife Service is currently reviewing the status of the NSO and the marbled murrelet as required by the ESA. Much has changed since the original listing. Research concerning habitat definition and use, effects of fragmentation, demography, and genetics is questioning the foundation of the original listing decision. Recognition that the NSO and California spotted owl form one continuous species may lead to a decision that the species does not qualify as listable.

7.3.3 *The Owl May Not Have Been the Real Problem*

A progression of federal actions and environmental activism ultimately demonstrated that the real debates about forestry may not have been about protecting uncommon wildlife such as spotted owls, as suggested by both FEMAT (Forest Ecosystem Management Assessment Team) and the Interagency Committee of Scientists in 1990. On the other hand, some consider that the debate was actually born in the late 1960s, and was, and still is, about stopping all active forest management on all forest lands, public and private.

7.4 What Do We Know about Northern Spotted Owls and Forestry?

Almost by definition, little is generally known about rare species because their rarity and/or their cryptic behavior cause them to be more difficult and expensive to study. NCASI was asked to clarify habitat use and habitat definitions for the northern spotted owl, because it was apparent that late successional forest did not predict their distributions or their population performance. It also seemed plausible that many other apparently rare species either were not really rare or could be accommodated in managed forests.

For example, the northern spotted owl, now known to number in the range of several thousand pairs, is not comparatively rare for a predatory bird. Recent research at Oregon State University indicates that their genetic distinction with the California subspecies of spotted owls is dubious. If that research changes the taxonomists' opinion, it would mean that the overall owl population is much larger and more geographically extensive than first thought, as was the case with the celebrated snail darter in Tennessee. Similarly, it is now known that the northern spotted owl is not restricted to late successional and old-growth forests (LSFs). Extensive second-growth redwood forests in California that were completely harvested to help rebuild San Francisco after the 1906 earthquake contain lively and dense populations of owls. Thus, NCASI's strategy has been to identify and demonstrate silvicultural options for managing owl habitat, so that habitat might be understood to wax and wane across a mosaic mix of managed forests, perhaps in various combinations with forests that have been set aside for other reasons.

Extensive research efforts by NCASI and other institutions removed a significant amount of scientific uncertainty after the northern spotted owl was listed in 1990. Recent science indicates that the definition of suitable habitat in 1990 was incomplete and that habitat is more complex than late successional and old-growth forests. As a result, a reliable assessment of the past, current, and future habitat supplies for the owl cannot simply apply the 1990 definition, or even the 1994 definition from the Final Supplemental Environmental Impact Statement (FSEIS) that institutionalized the Northwest Forest Plan.

In fact, a single habitat description throughout the range of the owl is also insufficient. A basic habitat dichotomy exists in which ecological differences between relatively dry mixed conifer (MC) forests and moist Douglas fir/western hemlock (DF/WH) forests have been shown to affect owl population performance. The owl's primary prey differs between the two types (e.g., woodrats in MC and flying squirrels in DF/WH). Those differences translate into different habitat definitions and distinct models for assessing and managing habitats in each broad forest category.

For example, thinning in young DF/WH forests appears to improve habitat conditions for several spotted owl prey species. Therefore, regulatory agencies should account for the conservation contributions of recently thinned forests. Similarly, habitat definitions for DF/WH forests should now include forests with trees as small as 10 inches in diameter, at least in western Oregon and northern California. Further, many owl sites in MC forests are at risk to uncharacteristic wildfires. These areas would especially benefit from President Bush's Healthy Forests Initiative that should result in fuels management programs to promote long-term persistence of the owl. Recent studies suggest that judicious thinning and partial harvesting should actually improve MC forest habitat for spotted owls while reducing risk to catastrophic wildfires. Riparian zones contain important habitat components for owls in both DF/WH and MC vegetation zones. Regulatory mechanisms exist in each state that protect riparian zones, although such protection and contributions to owl persistence were not generally acknowledged as important in 1990.

Innovative research methods have aided in acquiring more reliable data since 1990. The newer methods accord better with the multiple and interacting habitat and environmental factors that influence owl population performance. As a result, revised definitions of NSO habitat now include more factors than forests. For example, glaciated landforms in Washington produce few owls, despite the presence of significant amounts of LSF. Forest fragmentation, considered a threat to NSOs in 1990, now is understood to benefit owls in MC forests, within limits. There, spotted owls hunt near ecotones or edges of 15 to 40 year old stands that contain hardwoods and provide woodrats to the owls, supporting high rates of reproduction.

Importantly, recent science shows that LSF, smaller tree-size classes, and a suite of environmental factors (e.g., local climate, elevation, riparian zones, indices of productivity) can be integrated into models to predict owl locations, assess habitat supplies, and predict the number of northern spotted owls. Habitat carrying capacity for northern spotted owls can be assessed via resource selection probability function (RSPF) models that have been developed for various physiographic provinces. GIS-based layers of vegetation and other demonstrated influences, all of which are available to the U.S. Fish and Wildlife Service, drive RSPF models. By including the full suite of factors that influence northern spotted owls, RSPFs can be used to map current habitat supplies and estimate overall population size. RSPF models have been developed for other federally listed species as well. By linking with models that project forest growth and with forest management or forest health restoration strategies, RSPFs can account for future gains and losses in habitat supplies and, thereby, future population sizes. These models provide an improved habitat-based mechanism for predicting future persistence of threatened or endangered species such as the northern spotted owl.

Recently, the spotted owl's eastern cousin, the barred owl, has invaded the West Coast. There is some evidence that barred owls have occupied sites formerly used by the spotted owl in some mesic DF/WH forests but not in drier MC forests. If so, there will be a premium on silvicultural practices that maintain the owl's habitat in the face of forest diseases, insect epidemics, and threats of uncharacteristic wildfires.

7.5 What Do We Need to Know?

We would all do well to remember Aldo Leopold's adage that the same factors that previously destroyed wildlife and their habitats can be used judiciously to restore them: fire, cow, plow, gun, and axe. Translated, this means that the forestry community needs to demonstrate widely that it can accommodate forest-dwelling species, including uncommon or rare ones. In so doing, the forestry community must develop a compelling scientific basis for accommodating various species of conservation concern, including NSOs, in carefully managed forests. Such scientific development should spawn opportunities for industry to demonstrate its collective ability to protect our wildlife legacy and, in general, help rebuild public support for maintaining franchises to grow and harvest timber profitably.

How to get there involves developing and marketing a greater scientific understanding of the forest ecosystem, as well as its processes and functioning. The environmental concerns in the Pacific Northwest were led by comments about saving the misnomer, "old-growth ecosystem." Despite the emphasis on the word, the ecosystem needs to be re-emphasized in the ongoing policy debate about whether or not forestry should occur on federal lands. Deeper ecosystem science is needed to support forest management on private lands as well. Finally, we need to know how to integrate factors that drive ecosystem processes into forest-wildlife models that can be used to support forest management decisions.

The science and new information gathered by NCASI and others suggest that forestry can have positive effects on spotted owls and other forest wildlife. This is particularly apparent in mixed conifer forests, where natural disturbance frequencies were high and where the owl does best and its densities are highest. There are also numerous opportunities to accommodate the owl and other wildlife in Douglas fir/hemlock forests. One important thing we need to know involves how to make the demonstrations so compelling that the associated science is accepted and widely applied. Such stewardship demonstrations are part and parcel of repainting the forest industry's image as a benevolent caretaker of the land and its wildlife and in regaining the public trust. This requires an integrated educational effort, because forest ecosystems are complex and not easily understood. Therefore, policy initiatives for continued forest management will be challenging to market to a doubting public.

It seems possible that the definitions of suitable habitat for apparently specialized species such as the owl can be accepted as being broader than old forest, and that forestry can be said to have positive consequences for suitable habitat for a host of other species. If so, then in concert with a concerted public education strategy, forest management options for access to wood supplies should expand and forestry operations should be less constrained than in the past.

For the owl, NCASI's current work involves expanding upon a working hypothesis that providing 120 to 150 square feet of basal area per acre, along with a few large trees and coarse woody debris, creates optimal habitat for the owl in mixed conifer forests. That work may well lead to other demonstrations that a sustainable forest and sustainable wildlife populations are compatible in well-managed forests. If the anticipated demonstrations are successful in all aspects, and if the results can be effectively communicated, they would represent an enormous breakthrough for sustainable forestry.

7.6 Summary of Key Points

- Conservation of the NSO is only one of several technical problems that arose from a broader social debate about forestry and environmental protection.
- Recent science indicates that the definition of suitable habitat developed in 1990, when the northern spotted owl was listed as threatened under the ESA, or even the 1994 definition under the FSEIS for the Northwest Forest Plan, was incomplete. Habitat is both broader and more complex than LSF.
- The classification of the northern and California spotted owl as separate subspecies has been found to be unsupportable based on all widely held standards.
- A single habitat description throughout the range of the owl is insufficient. A basic habitat dichotomy exists in which ecological differences between relatively dry mixed conifer forests, such as those found in southwestern Oregon, and relatively moist Douglas fir/western hemlock forests result in differences in owl population performance.
- Across the geographic range of the species from Canada to Mexico, spotted owls are most abundant in mixed conifer forests.
- The owl's prey base differs between the two primary forest types. Owl diets are broader in mixed conifer forests where woodrats generally are the primary prey, while flying squirrels predominate owl diets in Douglas fir/western hemlock forests.
- The differences in prey base translate into differences in a) owl-habitat relationships; b) definitions of suitable habitat; c) conservation problems and opportunities; and d) models for assessing and managing habitats in each forest type.
- Northern spotted owls living in mixed conifer forests have higher population densities and occupy smaller home ranges than those living in Douglas fir/western hemlock forests.

- In mixed conifer forests, relatively young successional stages are important because they provide important sources of prey and thereby promote reproductive success, whereas access to some older patches promotes over-winter survival.
- Many owl sites in mixed conifer forests are at risk to uncharacteristic wildfires. In fact, in some forests, the locations where owl pairs are most productive are at greatest risk to wildfire. A custodial management strategy in such forests is not sustainable.
- In mixed conifer forests, spotted owl habitat quality increases as tree density increases to an optimal density, beyond which quality decreases as stands become overstocked and risk of catastrophic wildfire increases.
- Judicious thinning and partial harvesting should improve mixed conifer forest habitat for spotted owls while reducing risk to catastrophic wildfires.
- Forest fragmentation, within limits, is now understood to benefit owls in mixed conifer forests. There, spotted owls hunt near edges of 15 to 40 year old stands, often near riparian zones that contain hardwoods and that provide woodrats for the owls.
- Demonstrating compatibility between forestry and the owl is a prerequisite for demonstrating that other species can be accommodated in well-managed forests.
- The forest industry is challenged with demonstrating and marketing to a doubting public that modern, science-based forestry, involving habitat conditions that shift through time across managed forest mosaics, can sustain our rich wildlife heritage.

7.7 Additional Information Sources

Agee, J.K., and Edmonds, R.L. 1992. Forest protection guidelines for the northern spotted owl. 181-244 in *USDI Recovery plan for the northern spotted owl—final draft*. Vol. 2. Washington, DC: U.S. Government Printing Office.

Anthony, R.G., Olson, G., Forsman, E., Reid, J., Loschl, P., Ripple, W., Glenn, E., and Harkins, K. 2000. *Predicting abundance and demographic performance of northern spotted owls from vegetative characteristics. Report on Phase I: Evaluation of different methods for habitat mapping*. Corvallis: Oregon State University, Oregon Cooperative Wildlife Research Unit. 100 pp.

Bart, J., and Forsman, E.D. 1992. Dependence of northern spotted owls (*Strix occidentalis caurina*) on old-growth forests in the western USA. *Biology Conservation* 62:95-100.

Bingham, B.B., and Noon, B.R. 1997. Mitigation of habitat "take"; application to habitat conservation planning. *Conservation Biology* 11:127-139.

Boyce, M.S., Meyer, J.S., and Irwin, L.L. 1994. Habitat-based PVA for the northern spotted owl. 63-85 in Fletcher, D.J., and Manly, B.F.J. (eds.). *Statistics in ecology and environmental monitoring*. Otago Conference Series 2. Dunedin, NZ: University of Otago.

Buchanan, J.B., Irwin, L.L., and McCutchen, E.L. 1995. Within-stand nest site selection by spotted owls in the eastern Washington Cascades. *Journal of Wildlife Management* 59:301-310.

Buchanan, J.B., Irwin, L.L., and McCutchen, E.L. 1993. Characteristics of spotted owl nest trees in the Wenatchee National Forest. *Journal of Raptor Research* 27:1-7.

Burnham, K.P., Anderson, D.R., and White, G.C. 1996. Meta-analysis of vital rates of the northern spotted owl. *Studies in Avian Biology* 17:92-101.

Carey, A.B., and Peeler, K.C. 1995. Spotted owls: Resource and space use in mosaic landscapes. *Journal of Raptor Research* 29:223-239.

Covington, W.W., Everett, R.L., Steele, R., Irwin, L.L., Daer, T.A., and Auclair, A.N.D. 1994. Historical and anticipated changes in forest ecosystems of the inland west of the United States. *Journal of Sustainable Forestry* 2:13-63.

DeBell, D.S., Curtis, R.O., Harrington, C.A., and Tappeiner, J.C. 1997. Shaping stand development through silvicultural practices. 41-164 in Kohm, K.A., and Franklin, J.A. (eds.). *Creating a forestry for the 21st century*. Washington, DC: Island Press.

Everett, R.L., Schellhaas, R., Keenum, D., Spurbeck, D., and Ohlson, P. 2000. Fire history in the ponderosa/Douglas-fir forests on the east slope of the Washington Cascades. *Forest Ecology Management* 129:207-225.

Forest Ecosystem Management and Assessment Team (FEMAT). 1993. *Forest ecosystem management: An ecological, economic and social assessment*. Portland, OR: USDA Forest Service, USDC National Oceanic and Atmospheric Administration, USDC National Marine Fisheries Service, USDI Bureau of Land Management, USDI Fish and Wildlife Service, and USDI Environmental Protection Agency. 1004 pp.

Forsman, E.D., Meslow, E.C., and Wight, H.M. 1984. Distribution and biology of the spotted owl in Oregon. *Wildlife Monographs* No. 87.

Franklin, A.B., Anderson, D.R., Gutiérrez, R.J., and Burnham, K.P. 2000. Climate, habitat quality and fitness in northern spotted owl populations in northwestern California. *Ecology Monographs* 70:539-590.

Franklin, A.B., Burnham, K.P., White, G.C., Anthony, R.J., Forsman, E.D., Schwartz, C., Nichols, J.D., and Hines, J. 1999. *Range wide status and trends in northern spotted owl populations*. Ft. Collins, CO: USDA Geological Survey, Colorado Cooperative Fish and Wildlife Research Unit. 72 pp.

Hayes, J.P., Chan, S.S., Emmingham, W.H., Tappeiner, J.C., Kellogg, L.D., and Bailery, J.D. 1997. Wildlife response to thinning young forest in the Pacific Northwest. *Journal of Forestry* 95:28-33.

Irwin, L.L. 1994. A process for improving wildlife habitat models for assessing forest ecosystem health. *Journal of Sustainable Forestry* 2:293-306.

Irwin, L.L., Fleming, T.L., and Beebe, J. (in press). Are spotted owl populations sustainable in fire-prone forests? *Journal of Sustainable Forestry*.

Irwin, L.L, Rock, D.F., and Miller, G.P. 2000. Stand structures used by northern spotted owls in managed forests. *Journal of Raptor Research* 34:175-186.

Irwin, L.L., and Wigley, T.B. 1993. Toward an experimental basis for protecting forest wildlife. *Ecological Applications* 3:213-217.

Meyer, J.S., Irwin, L.L., and Boyce, M.S. 1998. Influence of habitat abundance and fragmentation on northern spotted owls in western Oregon. *Wildlife Monographs* No. 139. 51 pp.

Paton, P.W.C. 1994. The effect of edge on avian nest success: How strong is the evidence? *Conservation Biology* 8:17-26.

Paton, P.W.C., Zabel, C.J., Neal, D.L., Steger, G.N., Tilghman, N.G., and Noon, B.R. 1991. Effects of radio tags on spotted owls. *Journal of Wildlife Management* 55:617-622.

Ransome, D.B., and Sullivan, T.P. 2002. Short-term population dynamics of *Glaucomy sabrinus* and *Tamiasciurus douglasii* in commercially thinned and unthinned stands of coastal coniferous forests. *Canadian Journal of Forest Research* 32:2043-2050.

Suzuki, N., and Hayes, J.P. 2003. Effects of thinning on small mammals in Oregon coastal forests. *Journal of Wildlife Management* 67:352-371.

Swindle, K.A., Ripple, W.J., Meslow, E.C., and Shafer, D. 1999. Old-forest distribution around spotted owl nests in the central Cascade Mountains, Oregon. *Journal of Wildlife Management* 63:1212-1221.

Thomas, J.W., Forsman, E.D., Lint, J.B., Meslow, E.C., Noon, B.R., and Verner, J. 1990. *A conservation strategy for the northern spotted owl*. Report of the Interagency Scientific Committee to address the conservation of the northern spotted owl. Portland, OR: USDA Forest Service. Washington, DC: U.S. Government Printing Office. 458 pp.

Thomas, J.W., et al. 1993. *Forest ecosystem management: An ecological, economic, and social assessment*. Doc. 1999-793-071. Report of the Forest Ecosystem Management Assessment Team. Washington, DC: U.S. Government Printing Office.

USDA/USDI. 1994. Final supplemental environmental impact statement on management of habitat for late successional and old-growth forest related species within the range of the northern spotted owl.

Zabel, C.J., Roberts, L.M., Mulder, B.S., Stouffer, H.B., Dunk, J.R., Wolcott, K., Solis, D., Gertsch, M., Woodbridge, B., Wright, A., Goldsmith, G., and Keckler, C. 2003. A collaborative approach in adaptive management at a large-landscape scale. Chap. 19 in Scott, J.M., Heglund, P.J., Morrison, M.L., Haufler, J.B., Raphael, M.G., Wall, W.A., and Samson, F.B. (eds.). *Predicting species occurrences: Issues of scale and accuracy*. Covelo, CA: Island Press. 840 pp.

8.0 BIODIVERSITY

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8.1 Introduction

Although there are many alternative definitions for biological diversity, or "biodiversity," most authors have defined it as variety of life and the processes that support it. Biological diversity is often considered to have several levels of organization (i.e., genetic, species, and ecosystem levels), and it may vary spatially and temporally. Although biological diversity per se is a somewhat vague concept for many people, it encompasses many topics that elicit strong public concern, such as old-growth forests, endangered species, and forests of high conservation priority. In this section, we discuss some common paradigms related to biodiversity, the importance of this topic to forest managers, contributions of managed forests to the support of biodiversity, key findings of industry research related to biodiversity, and important information needs.

8.2 Paradigms Related to Biodiversity

Two paradigms and their associated corollaries have strongly influenced public perception about biodiversity and the responsibility of forest managers for protecting it.

8.2.1 *We Are in a Period of Unusual Species Loss*

Perhaps the most fundamental form of biodiversity loss is the loss of species (Noss 1991). In 1988, Wilson (1988) estimated that there were 5 to 30 million species of all kinds inhabiting Earth. However, it is widely perceived that species are disappearing at a rate that far exceeds the normal background rate for extinctions. Because it is difficult to document extinctions of species, the perception of widespread species loss is largely based upon extrapolations of measured and predicted habitat "loss" and estimates of species richness in those habitats.

8.2.2 *Human Activities are Commonly Perceived to be the Primary Cause of Species Loss*

A wide variety of human activities have been identified as threats to biodiversity, including urban development, roads, agriculture, forestry, climate change, and pollution. These "threats" are considered to impact biodiversity by causing loss and/or degradation of habitats. Ironically, historic and modern subsistence activities of humans (e.g., firewood gathering, slash and burn agriculture, hunting) can also affect biodiversity.

For many reasons, biodiversity associated with old-growth forest is held in special esteem, in part due to the time required for forests to reach late succession. Thus, loss of old-growth forest is often cited as a major threat to biodiversity. Human activities can reduce the area of old growth and change its spatial pattern, thus "fragmenting" formerly large forests into small isolated stands. Concerns about fragmentation largely stem from the theory of island biogeography, which states that fewer species are able to persist in small habitat fragments than in the original unfragmented habitat. Furthermore, it is widely perceived that species associated with late-successional forests have difficulty dispersing or moving for other purposes across other habitat types.

These theories about old-growth fragmentation are rarely substantiated with data. While it is of course true that terrestrial species have trouble crossing water to reach real islands, it does not follow that young forest (or merely forest younger than old growth) truly acts as a barrier to movement. In some cases, it has been shown that species that nest in old growth may actually prefer to forage in younger growth or use prey species that are most abundant in younger forests (e.g., goshawk and spotted owls). The dogma about old growth is flatly contradicted in some cases. For example, while the Forest Service classifies lynx as an old-growth dependent species, its primary food, snowshoe hares, is not found in old growth to any appreciable extent.

As another example of the problems caused by uncritical extrapolation of island biogeography theory, data that clearly show that deforestation causes species loss (e.g., in the Amazon) are often used to "prove" that clearcuts cause species loss by implicitly equating a clearcut to deforestation. This is in spite of the temporary nature of vegetative conditions in a clearcut and other data showing high levels of diversity associated with early successional stages.

8.3 Biodiversity in Certification Systems

Maintenance of biological diversity is now commonly viewed as a key feature of sustainable forestry and an important component of forest certification systems. The linkage between sustainability and biodiversity began in the 1980s when concerns about slash and burn agriculture in tropical forests were especially prominent. In 1992, these concerns expanded when forestry issues associated with temperate and boreal forests were discussed in Rio de Janeiro at the United Nations Conference on

Environment and Development (UNCED). One outcome of the Rio meeting was the widespread acceptance of consideration for biodiversity as a critical component of "sustainable development" and processes (e.g., Montreal and Helsinki Process) to define the essential elements of sustainable forest management.

Thus, forest certification systems based on agreements in the UNCED outcome typically include criteria, indicators, or principles that address biodiversity. Biological diversity is addressed most comprehensively within the Sustainable Forestry Initiative in Objective 4, which notes that SFI participants should "[m]anage the quality and distribution of wildlife habitats and contribute to the conservation of biological diversity by developing and implementing stand- and landscape-level measures that promote habitat diversity and the conservation of forest plants and animals including aquatic fauna" (AF&PA 2002). Performance measures associated with this objective are a) policies to promote habitat diversity at stand and landscape levels; b) funding for research to improve the science and understanding of wildlife management at stand or landscape levels, ecosystem functions, and the conservation of biological diversity; and c) the application of knowledge gained through research, science, technology, and field experience to manage wildlife habitat and contribute to the conservation of biological diversity.

The SFI also contains provisions related to biodiversity outside the United States. Performance measure 4.2.1.1.9 asks participants to adopt "[p]rocurement policies that promote conservation of biodiversity hotspots and major tropical wilderness areas." Biodiversity hotspots are defined within the SFI as biogeographic conservation regions within which more than 1500 plant species are endemic and which retain less than 30% of their historical extent of habitat.

8.4 Forest Management Opportunities to Maintain Biodiversity

There are two widely recommended approaches to maintaining biodiversity—the coarse filter approach and the fine filter approach. The coarse filter approach focuses on managing ecosystems and ecological processes at the landscape scale. It is commonly assumed that biodiversity can be maintained by maintaining forest patterns and successional stages that are similar to the historic variety of ecosystems in natural landscapes. Haufler, Mehl, and Roloff (1996) recommended the following steps as part of a coarse filter approach: a) delineate the planning landscape; b) develop an ecosystem diversity matrix; c) describe historical disturbance regimes; d) quantify existing conditions; e) identify adequate ecological representation using the coarse filter; and f) check adequate ecological representation with species assessments.

Under the coarse filter approach, it is commonly recommended that stand-level management activities emulate natural disturbances to the extent practicable. Clearly, alteration of forest structural features at the stand scale (e.g., snags, stem density, species composition) is probably the most important way that forestry practices affect biodiversity by enhancing or diminishing current and future habitat for selected wildlife species (e.g., forest bats that roost in large hardwood or pine trees). Many authors have suggested that forest structural features and habitat configurations at different spatial scales can serve as indicators of biological diversity (e.g., Brown et al. 2001). Obviously, the ability of landowners to emulate natural disturbance with silviculture depends in part upon the compatibility of that goal with their ownership objectives.

The objective of the fine filter approach to biodiversity management is to meet the needs of a particular species or vegetation community. This approach is particularly useful when addressing the habitat needs (e.g., large-diameter trees) of high-priority species (e.g., federally listed species). Of course, managing ecosystems species by species can be complex due to potential conflicts among species with different habitat needs. However, by giving special attention to some structural features, landowners significantly enhance habitat conditions for a variety of species.

While the coarse filter/fine filter framework is sensible in many respects, there are significant questions about the scale at which it should be implemented. Clearly, implementing it at the ownership scale would not be appropriate for many landowners and could potentially cause significant conflicts with some ownership objectives. Implementing the framework collaboratively among ownerships within a landscape offers advantages. However, it has not been fully implemented even by federal agencies such as the USDA Forest Service. Furthermore, in the Forest Service planning process, even small-scale management activities are subjected to public comment, and are often appealed because every management action will temporarily reduce habitat quality for some species (but increase it for others). Regardless, planning biodiversity at larger spatial scales might facilitate more management flexibility on some ownerships, particularly when the species involved could be impacted locally and temporarily but are regionally abundant.

8.5 Key Findings of Recent Research

8.5.1 *Managed Forests Support High Levels of Biological Diversity*

While it is popularly believed that managed forests are biological deserts, available data do not support such a negative view. In fact, managed forests may be higher in diversity than unmanaged forests. In a recent Arkansas landscape study, there were both more birds and more species of birds in the most managed watersheds (Tappe et al. 2004). Species of high conservation priority, including some commonly designated as interior, old-growth, or hardwood associates, also were found in South Carolina landscapes dominated by pine plantations (Wigley et al. 2000). Recent analyses of data across these and other industry-managed landscapes have revealed very similar community profiles for birds in very different habitats (e.g., unmanaged hardwood forest and forests dominated by southern pine) (C. Loehle, NCASI, pers. comm.). Clearly, biodiversity cannot be fully understood by focusing only on one structural class or forest type within a landscape. Rather, in managed forest landscapes, one must examine the full range of structural and compositional classes.

8.5.2 *Forests Are Naturally Dynamic*

The widespread assumption that pristine old-growth wilderness is the natural state for forests is simply untenable. Forests are constantly subject to disturbance at all scales. In the West, catastrophic fires can exceed a million acres in size, which may create clearings free of trees for a century or longer. In eastern forests, constant minor disturbances lead to an unending change in species composition. Species that could not move about, disperse to find new habitat, or adapt in other ways would have become extinct long ago. Disturbance of forests often leads to enhanced diversity at some spatial scales. Not surprisingly, the intermediate disturbance hypothesis (Connell 1978; Rosenzweig 1995) suggests that a seral sequence will support higher levels of diversity than an area composed of one seral stage.

8.5.3 *Abiotic Factors Heavily Influence Biodiversity*

Abiotic factors clearly influence biodiversity and may have influences that equal or exceed those of forest structure. Huston (1999) noted that patterns of diversity in plants and animals are heavily influenced by factors that affect competitive exclusion, specifically disturbance regime and site productivity. He suggested that, due to low rates of competitive exclusion, plant diversity often is highest at relatively low levels of plant productivity. Conversely, he indicated that diversity of organisms at higher trophic levels is most likely to be highest where plant productivity and resulting available energy is high.

In an ongoing industry-sponsored Pacific Northwest landscape study, up to 80% of the tree, shrub, and bird diversity variance can be explained by factors such as net primary productivity (NPP), number of vegetation communities, and climatic variables (C. Loehle, NCASI, pers. comm.). The effect of NPP seems to be unimodal for all three groups, with the most productive sites having lower diversity than intermediate productivity sites. This is because closed canopy, high-productivity forests limit understory vegetation and succeed to a climax condition that limits the life forms that can be present. Thus, the most diverse regions for birds, trees, and shrubs in the Pacific Northwest appear to be in the Siskiyous, the eastside Cascades, and the Okanogan Highlands, not in the coastal Douglas fir forest. The perception that the coastal zone dominated by giant Douglas fir trees is the most valuable forest in terms of diversity is based more on aesthetics than on reality.

8.5.4 *Forest Management Does Not Necessarily Result in "Fragmentation" Effects*

Because of island biogeography theory, there is a common perception that management activities "fragment" forests, particularly late-successional forests, thereby reducing habitat for species associated with late-successional forest, isolating the remaining unharvested habitat, and causing other adverse effects (e.g., constrained reproductive success and dispersal). Fragmentation supposedly separates the formerly continuously distributed population into multiple, isolated and smaller populations that interact through dispersal (i.e., a "metapopulation").

Island biogeography theory has been extended to terrestrial habitats based on percolation models which assume that habitats are either "suitable" or are non-habitat. Based on percolation models, young forests have often been equated to non-habitat across which many species associated with old-growth cannot move. Therefore, extinction thresholds have been proposed for these species when about 60% of old growth is lost within a landscape and corridors have been recommended to connect old growth remnants. However, the metapopulation/island biogeography framework is largely founded on assumptions with many difficulties. For example, if even modest movement occurs by dispersing animals across "non-habitat," corridors cannot be demonstrated to be either needed or helpful. Furthermore, the assumption that young forest is a barrier to movement has rarely been demonstrated. The scale of current forest management is unlikely to exceed the movement capabilities of most species on the landscape to find suitable habitat.

8.5.5 *Factors beyond the Control of Forest Managers Can Have Significant Impacts on Biological Diversity*

Sometimes, biodiversity is constrained in forest ecosystems due to factors unrelated to forest management. For example, species such as brook trout, lake trout, and bullfrogs have been introduced into aquatic ecosystems or have expanded beyond their normal range and now compete with native aquatic species. Barred owls, which currently are expanding their range, are displacing northern spotted owls in some locations. Because of such challenges that are often unrelated to forest management, forest managers may have difficulty in meeting biodiversity objectives.

8.6 Important Information Needs

We believe there are several important information needs that, if met, would help managers enhance forest biodiversity.

8.6.1 *Better Tools to Predict Responses of Biodiversity to Management*

Many models to predict biodiversity are study-area specific and not based upon a theoretical framework that allows their application across broad areas. Models that can be used by multiple landowners across broad regions would facilitate better planning across multiple ownerships. There is also a need to incorporate predictive models into forest planning software (e.g., harvest scheduling software) so managers can evaluate the ecological consequences of alternative management strategies.

8.6.2 *Incentives to Manage for Biodiversity*

At present, there is little incentive to manage for high levels of diversity. In fact, current social pressure and legislation makes the presence of a rare species or community a disincentive for many landowners. Why should landowners promote habitat for a federally endangered species if the end result is the loss of current and future management options? Research is needed to explore incentives that might encourage landowners to promote high levels of diversity.

8.6.3 *Better Understanding of the Relative Contributions by Abiotic and Biotic Factors to the Support of Biological Diversity*

There is a widespread assumption that forest structure is the primary determinant of biodiversity in forested ecosystems. However, ongoing research suggests that where the land is located, its productivity, and other abiotic factors also have significant influence. Thus, when, where, and how forest management practices are employed are important issues, and more research is need to improve our understanding of these considerations.

8.7 Summary of Key Points

- Biodiversity and forests are dynamic, not static. Rather than residing in one successional class or forest type, biological diversity in forests usually is a function of variety in forest conditions across space and time.
- Managed forests support high levels of biodiversity, including species and communities of high conservation priority.
- Abiotic considerations such as site productivity, rainfall, sunlight, and ambient temperature all have significant influences on biodiversity. Where and when we manage appear to be important considerations.
- Much of landscape theory is derived from percolation models and island biogeography, but is not realistic on real terrestrial landscapes.
- Factors beyond the control of forest managers, such as invasive species, can have significant impacts on biological diversity.
- More research is needed to develop better tools for predicting biodiversity in managed forests, to identify incentives that would encourage landowners to promote biodiversity, and to help us understand the relative contributions of biotic and abiotic factors to the support of biodiversity.

8.8 References

American Forest and Paper Association (AF&PA). 2002. 2002-2004 Edition Sustainable Forestry Initiative (SFI) Program. Washington, DC: Sustainable Forestry Initiative Sustainable Forestry Board and the American Forest & Paper Association.

Brown, N.R., Noss, R.F., Diamond, D.D., and Myers, M.N. 2001. Conservation biology and forest conservation: Working together toward ecological sustainability. *Journal of Forestry* 99(8):18-25.

Connell, J.H. 1978. Diversity in tropical rain forests and coral reefs. *Science* 199:1302-1310.

Haufler, J.B., Mehl, C.A., and Roloff, G.J. 1996. Using a coarse-filter approach with species assessment for ecosystem management. *Wildlife Society Bulletin* 24(2):200-208.

Huston, M.A. 1999. Forest productivity and diversity: Using ecological theory and landscape models to guide sustainable forest management. 329-341 in Aguirre-Bravo, C., and Franco, C.R. (comps.). *North American Science Symposium: Toward a unified framework for inventorying and monitoring forest ecosystem resources*. USDA Forest Service Proceedings RMRS-P-12.

Noss, R.F. 1991. From endangered species to biodiversity. 227-246 in Kohm, K.A. (ed.). *Balancing on the brink of extinction: The Endangered Species Act and lessons for the future*. Washington, DC: Island Press.

Rosenzweig, M.L. 1995. *Species diversity in space and time*. Cambridge: Cambridge University Press.

Tappe, P.A., Thill, R.E., Melchiors, M.A., and Wigley, T.B. 2004. Breeding bird communities on four watersheds under different management scenarios in the Ouachita Mountains of Arkansas. In *A symposium on ecosystem management research in the Ouachita and Ozark Mountains*, J.M. Guldin (tech. comp.), 154-163. General Technical Report SRS-74. Asheville, NC: USDA Forest Service.

Wigley, T.B., Baughman, W.M., Dorcas, M.E., Gerwin, J.A., Gibbons, J.W., Guynn, D.C. Jr., Lancia, R.A., Leiden, Y.A., Mitchell, M.S., and Russell, K.R. 2000. Contributions of intensively managed forests to the sustainability of wildlife communities in the South. In *Sustaining southern forests: The science of forest assessment*. USDA Forest Service, Southern Forest Resource Assessment. http://www.srs.fs.fed.us/sustain/conf/abs/wigley.htm

Wilson, E.O. 1988. The current state of biodiversity. 3-18 in Wilson, E.O., and Peter, F.M. (eds.). *Biodiversity*. Washington, DC: National Academy Press. 521 pp.

9.0 RELATIONS BETWEEN FORESTRY AND BIG GAME: DOES IT MATTER ANYMORE?

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9.1 Introduction

Of the three primary factors involved in assessing habitat quality for big game (cover, disturbance, and forage), forestry's influence on cover and disturbance has received by far the greatest emphasis in research and management conducted on behalf of big game. This research, and resulting management guidelines and restrictions, implicates the effects of forestry as being largely harmful.

Planning approaches and models based on relatively old research, dating back to the 1960s, are still being used to guide forest management on behalf of big game.

Big game is a highly valuable commodity in the western U.S. Hunters spend millions of dollars annually to pursue them, providing economic expenditures to strapped rural communities. Sales of licenses also underwrite operations of western state wildlife agencies. The once large, productive herds of the region are not only an economically valuable resource, but a source of pride to the region's public as well. However, many deer and elk herds in the Northwest are now in a state of decline, which appears to be expanding in scope and increasing in severity. This situation is attracting attention. Blame and finger pointing are escalating and, not surprisingly, are being directed at the forest products industry.

Nevertheless, there are potential opportunities. The declines have created new interest in rigorous science that addresses those operative factors that contribute to reproduction and survival, basic demographic factors that influence herd productivity and population growth and decline. Of the habitat factors that contribute to herd productivity, there is a long line of evidence that nutrition, a function of forage quality and quantity, is of inordinate importance. Although forestry may reduce cover and increase access and disturbance, forestry can also greatly increase abundance and quality of forage. New research is needed to clarify the link between this benefit of forest management and the well-being and productivity of big game herds. It is entirely possible that this new research will identify a potentially crucial role for active timber management in maintaining elk and deer herds in the future.

9.2 History

If one goes back far enough into the published record, before about 1970, big game biologists generally recognized that timber harvest could provide improvements in habitat. This occurred mainly by improving the amount and, perhaps, the nutritive content of forage, effects that were considered to be of appreciable value to big game. This started to change by the 1970s due largely to the high levels of timber harvest across most of the west. Biologists charged with maintaining elk and deer habitat began scrambling to "provide guidance for foresters so their efforts will not so strongly negate his [the wildlifer's] efforts and can be made to complement them" (Giles 1962).

By the mid-1970s, big game research increasingly began to focus on the negative effects of timber harvest (e.g., more roads, removal of hiding and thermal cover, increased human disturbance). The general result was a planning system that land managers and resource planners could use for predicting the negative effects of "timber management activities and intensities on deer and elk use" (Black, Scherzinger, and Thomas 1976).

Using data from numerous field studies, the initial efforts eventually evolved into several modeling efforts in the form of habitat suitability or habitat effectiveness index models. Of considerable relevance, nearly all the research conducted at the time was based on newly developed radio-telemetry techniques. Radio-telemetry, as typically conducted, is fundamentally adept at illustrating the negative effects of forestry, but is less effective at documenting improvements in the foraging substrate and, particularly, the effect of these improvements on survival and reproduction, those factors that have considerable bearing on herd productivity. Thus, by their nature*, these studies and modeling efforts were destined to emphasize the negative effects and overlook positive benefits of forestry.*

The models built on this research provided quantitative guidelines that met with surprisingly rapid acceptance, and by the mid-1980s were used routinely for development of national forest plans and a variety of other planning purposes (Edge, Olson-Edge, and Irwin 1990). In fact, virtually every

National Forest and Bureau of Land Management district in the West that supported an appreciable elk resource incorporated some form of these models into their planning processes. It is perhaps the ultimate example of successful and rapid technology transfer from research to management application for wildlife. Certainly, this process has resulted in the most concerted, widespread habitat planning on behalf of elk, across more total area than for any other wildlife species on the planet.

The conventional wisdom emanating from this work regarding forestry effects on elk is the following:

- Removal of thermal cover reduces survival in winter and reproductive success in summer.
- Removal of hiding cover increases vulnerability of elk to legal hunters and to poachers.
- Increasing road density increases vulnerability and poaching and redistributes elk to potentially less valuable habitats, with the latter indirectly reducing survival and reproduction.
- Increasing road density and reductions in hiding cover have resulted in over harvest of mature bulls, in turn disrupting and delaying breeding and ultimately reducing calf production and survival.
- The improvements in forage biomass resulting from timber harvest, particularly on summer range, provide little or no benefit to elk, because forage is not limiting to elk populations in most ecological settings.

9.3 Current Status and Perceptions

Most of these perceived effects of timber harvest are at best infrequently tested, or at worst completely untested, yet most are now embedded in the published elk literature and current planning models and processes. Nevertheless, much has changed that has bearing on the relevance of the research of 20 to 30 years ago.

First, the virtual elimination of timber harvest on federal lands over the last decade and federal policy that placed great emphasis on converting vast landscapes to late successional stages has eliminated building of new roads, increased hiding and thermal cover due to plant successional development, and, undoubtedly, reduced forage availability, also due to plant succession. Just how relevant are planning tools that were developed 20-30 years ago to reduce the negative impacts of timber harvest, now that timber harvest has been eliminated?

In addition, elk herds are not faring well in many areas of the Northwest. Consider the following:

- In western Washington, population declines have ranged from 20 to 75% over the last 15 years, resulting in conservation closures (hunting terminated) for two herds in the region. One herd that supported trophy bull hunting in the 1980s could be reduced to virtual extirpation within the next two decades.
- Overall, in Washington hunters harvested about 12,000 elk per year in the 1970s, but annual harvest has dropped to only about 5500 elk in recent years (roughly a 54% decline). Concurrently, statewide elk license sales declined from about 110,000 to 70,000 annually, despite continued high demand by hunters for elk licenses. In Washington’s Blue Mountains, the annual harvest of all sex and age classes has now dropped below 400 animals.
- In Oregon and Idaho, fully one-third of game management units now support late winter calf/cow ratios of less than 30 calves/100 cows, with some ratios dipping below 20 calves/100 cows. At best, these low calf ratios are indicative of populations that can barely maintain themselves,

much less support historical levels of hunter recreation. Oregon's calf ratios have declined more or less consistently since the 1960s, from highs approaching 60 calves/100 cows in some herds.

- In eastern Oregon, population declines have ranged from 12 to 67% over the last decade.
- Harvest of elk in Oregon's Wenaha-Snake management zone, historically the core area for elk hunting in Oregon's Blue Mountains, declined from 4644 in 1979 to only 1119 in 1998 (a 76% decline). Harvest in the adjacent Wallowa zone declined from 1405 to 816 over the same period (a 42% decline).
- In Idaho, the elk population in the Clearwater Basin has declined roughly 20% over the last decade.
- In Idaho's Lolo management zone (Units 10 and 12, the Lochsa) total elk harvest has declined 84%, from an average of 1732 in 1982 to 1986, to an average of only 275 in the years 1997 to 2001. Over this same time interval, total elk harvest in the Selway (Unit 17) declined 61% from an average of 532 to an average of only 205.

For wildlife biologists charged with maintaining elk herds, these declines have several implications. First, to the extent that habitat quality may be contributing to the declines, the old models and paradigms are inadequate to prevent declines, perhaps calling into question their adequacy for providing good elk habitat. Second, in areas where declines are occurring there is markedly new interest in obtaining a better understanding of what is causing these declines and what can be done to reverse them. In other words, the declines highlight new information needs that were not addressed in the old days of elk research; in particular, what operative factors are truly relevant in the context of reproduction, survival, and herd productivity?

For the timber industry, the declines also have several important implications:

- Without supporting scientific evidence, the declines in deer and elk have reinvigorated accusations that forestry is bad for big game; namely that intensive forest management, including herbicide use, tight stocking control, and other such practices, are contributing factors. Such accusations have the potential to add local hunting publics, a group that often supported forestry in the region, to the list of environmental organizations that oppose intensive forestry.
- New interest in obtaining a better understanding of factors that contribute to the decline continues to provide opportunities for new, collaborative research that revisits the old paradigms and "rewrites the book" about what constitutes good big game habitat. Research that focuses on carrying capacity and herd productivity, rather than habitat selection per se (Hobbs and Hanley 1990; Morrison 2001), has considerable potential to better document the value of increasing and improving forage, forestry's most obvious positive contribution to big game.
- Such new research has the potential to establish the positive role of the timber industry in supporting big game herds, particularly in coastal and Cascade habitats in the Northwest. The abundant forage in early successional habitats that apparently is crucial for big game herds is largely being produced only on private forestlands. Therefore, these private forestlands may increasingly be required to maintain big game herds in the coming decades. Thus, there may be a very positive story to tell regarding forestry and big game, but focused, rigorous research is required to provide a basis to do so.

9.4 Conclusions

Changes in the bio-political setting in the context of big game and forestry should fundamentally change the focus and priorities of management and research. To do so, however, research will first have to provide insights into better approaches and paradigms, because information collected over the last 30 years is inadequate as a basis for this change. To be of value to the forest products industry, new research will have to focus on forestry's effect on forage characteristics and resultant big game nutrition. The potential for such research to be fruitful is considerable.

It can be argued that catastrophic fires in the late 19th and early 20th centuries, which created vast acreages of early successional habitat, enhanced during the 1950s through the 1980s with widespread timber harvest, supported the rapid increases and maintained for a over a half century the world renown herds of the Northwest. Prevalence of this early successional habitat is waning across most landscapes in forest ecosystems that support big game. It hardly seems coincidental that many big game herds are also declining. The time and spatial scales of this series of events are so large that their lessons are easy to overlook. Nevertheless, the eruption of Mount Saint Helens, and the subsequent increase and eventual decline of the elk herd in the blast zone as forests began to attain their previous development and distribution, provides a reminder of just how important early successional vegetation is to big game even over relatively short time scales in the Pacific Northwest.

Research that is already underway has begun chipping away at the old paradigms. Research has largely discounted thermal cover as an important contributing influence on survival and reproduction. On the other hand, additional research on high road density continues to support the contention that a high density of open roads creates problems with poaching and redistribution of animals. In many cases, however, these can be and have been mitigated simply by closing roads. Currently, much research is being directed at the influences of forestry on the forage base, and is in fact documenting the crucial contributions of early successional stages to the nutritional status and productivity of big game. Ultimate success in "rewriting the book" regarding what constitutes good elk habitat, however, will require continuation and completion of this work.

9.5 References

Black, H., Jr., Scherzinger, R., and Thomas, J.W. 1976. Relationships of Rocky Mountain elk and Rocky Mountain mule deer to timber management in the Blue Mountains of Oregon and Washington. 11-13 in *Elk-logging-roads: Proceedings of a symposium*. Hieb, S.R. (ed.). Moscow: University of Idaho, Forest, Wildlife, and Range Experiment Station.

Edge, W.D., Olson-Edge, S.L., and Irwin, L.L. 1990. Planning for wildlife in National Forests: Elk and mule deer habitats as an example. *Wildlife Society Bulletin* 18:87-88.

Giles, R.H., Jr. 1962. Timber-wildlife coordination concepts for large eastern forests. *Transactions of the North American Wildlife and Natural Resources Conference* 27:402-412.

Hobbs, N.T., and Hanley, T.A. 1990. Habitat evaluation: Do use/availability data reflect carrying capacity? *Journal of Wildlife Management* 49:814-822.

Morrison, M.L. 2001. A proposed research emphasis to overcome the limits of wildlife-habitat relationship studies. *Journal of Wildlife Management* 65:613-623.

10.0 NCASI'S BIG GAME PROGRAM: HIGHLIGHTS OF A DECADE OF RESEARCH

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10.1 Introduction

Habitat management on behalf of deer, and particularly elk, in the Pacific Northwest is based largely on research conducted during the 1960s through the 1980s. Findings of this research resulted in habitat planning models and processes that have been and continue to be widely used throughout the western U.S. by federal and state regulatory agencies. The primary emphasis of this research was to document the negative effects of forestry on big game, with specific focus on such topics as reductions in thermal and hiding cover and increasing roads, the latter of which may alter animal distribution and increase vulnerability to legal and illegal harvest.

Much has changed over the last decade. Timber harvest has been greatly curtailed on federal lands, calling into question the current relevance of the old research, at least on federal lands. Moreover, elk and deer herds are in a state of decline in many areas of the Northwest. This has fueled accusations that intensive forestry, particularly on private timberlands, is to some degree responsible. On the other hand, understanding the causes of the declines has emerged in many areas as the primary topic of concern for big game, and biologists now need a far greater understanding of factors that contribute to population productivity and population increase and decline. Thus, recognition of the need for new research is increasing, including a realization that the old research approaches and designs are insufficient to answer crucial questions originating over the last decade.

Ultimately inherent to the discussion of herd productivity and population declines is the topic of forage quality and quantity and the effects of these on nutritional status, because nutrition can have a fundamental influence on virtually every life process that is linked to reproduction and survival. Nevertheless, one of the findings of the old research was that nutrition was rarely limiting to any appreciable degree. This finding naturally contributed to the conclusion that increases in forage abundance resulting from forest management provided little or no real value to big game, particularly on elk and deer summer ranges, but there was very little hard evidence that documented this perception.

NCASI initiated a research program on big game in 1990. From the beginning, this program was inherently designed to address questions about the influences of habitat, including forestry's effect on habitat, reproduction, and survival, and, by extension, herd productivity and population dynamics. This work has been collaborative with regulatory agencies, thereby preempting, to an appreciable extent, criticisms that often arise from unilateral investigations. NCASI's early work focused on the contributions of thermal cover, finding that the relevance of this habitat attribute in the context of survival and reproduction was substantially overrated. Then, in 1995, NCASI embarked on work to examine nutrition's fundamental contribution to survival and reproduction, and to develop new techniques for field use that would help biologists better measure the nutritional status of wild big game. Finally, NCASI has extended the focus of this work to explicitly examine the extent to which nutrition influences wild herds, and to examine the extent to which forest management can influence the nutritional status of these herds. This section provides a review of the findings of these studies and a discussion of future research needs and direction.

10.2 Thermal Cover Effects

Because many biologists accepted the concept that the weather-sheltering effect of dense forest cover (i.e., thermal cover) reduces energy expenditure and enhances survival and reproduction, providing thermal cover became a key habitat management objective for western deer and elk ranges. Over time, development of the thermal cover concept included explicit criteria that defined thermal cover in terms of stand structure, height, and overstory closure, criteria that appreciably restrained timber harvest (Smith and Long 1987).

Whatever the case, rigorous evaluations had not been conducted to demonstrate that thermal cover actually provides significant benefits. During 1991 to 1995, NCASI and the U.S. Forest Service, along with Boise Cascade Corporation, tested the thermal cover hypothesis for Rocky Mountain elk across four winters and two summers under an experimental setting using captive animals. No positive effect of thermal cover on weight dynamics and body condition of calf and yearling elk was found during any of the experiments, despite highly variable weather ranging from mild to relatively harsh in winter and unusually hot and dry in summer. This result corroborates findings of three other studies using deer during winter, and together these indicate that benefits of thermal cover are probably non-existent, or at least are normally too small to be of much practical relevance. Findings indicate that other attributes of habitat, particularly those demonstrably fundamental to survival and reproduction, such as security and forage adequacy in summer and winter, should receive appreciably greater emphasis than thermal cover for management of habitat on behalf of big game. The findings of this study were published as a *Wildlife Monograph* (Cook et al. 1998). The monograph received several national and regional awards, and has been the focus of several newspaper articles, a U.S. Forest Service Science Findings publication, and a WFPA FYI article.

10.3 Nutritional Influences on Reproduction and Survival

In the mid-1990s, when the causes of elk declines began to be debated, NCASI and the Oregon Department of Fish and Wildlife, along with the U.S. Forest Service and Boise Cascade Corporation, embarked on research to provide information on fundamental relationships between nutrition and productivity of elk. A better understanding was needed prior to more applied field research, in order to help guide and focus future research. This study focused primarily on nutrition in summer and autumn, mainly to begin directly evaluating the old perception that nutrition on summer ranges was not limiting to big game. Moreover, landscapes used by elk and deer in summer are far more relevant to forestry than landscapes used in winter.

Experiments conducted with captive elk indicated that summer and autumn nutrition had marked effects on calf growth and their ability to survive in winter, yearling growth, fat accretion in cows, probability of pregnancy in adult and yearling cows, and over-winter survival probability of adult cows. The study also firmly established nutritional requirements for reproducing elk in summer and autumn, which were markedly higher than previously reported. Accurate estimates of requirements are needed as a basis for forage evaluations in natural settings. Finally, the study established that seemingly small nutritional deficiencies had relatively great effects on performance. Given the findings of this study, it will be difficult to categorically dismiss the importance of nutrition in summer and autumn in the context of reproduction, survival, and herd productivity, at least in the absence of strong supporting empirical evidence (Cook et al. 2004; see also Cook et al. 1996; Cook et al. 2001c; and Cook 2002).

An offshoot of this study was intended to develop new techniques that could be used to evaluate the nutritional status of free-ranging elk, a necessary prerequisite to extrapolating the results of the study to wild herds. A new system based on body scoring techniques and ultrasonography was developed and rigorously tested (Cook et al. 2001a, 2001b), and these techniques are receiving widespread use in the Northwest and are starting to be used in the Rocky Mountain Region. Additional techniques regarding pregnancy detection and estimating body weight were published from data collected in this study (Cook et al. 2002, 2003).

This study also addressed the relative importance of birth date on reproduction and survival of elk. This topic was included in the study to begin addressing the implications of very small numbers of bull elk in elk populations. Too few bulls were shown to delay breeding, in turn suggesting that insufficient bulls would delay birthing and, in turn, reduce calf survival. Although this topic might not at first glance seem important to the timber industry, it very well might have been. Allegations that started to surface in the early 1990s were that the extensive network of roads resulting from timber harvest in the past contributed to overharvest of bulls that in turn reduced calf survival and therefore was contributing to declines in elk populations. A test of the effects of delayed breeding on calf growth, development, and survival probability indicated that delayed breeding, at a level that could be expected due to a virtually complete absence of mature bulls in the population, had little effect on calves and their ability to survive. This was the first study to "draw the curtain" on this scenario; additional research with wild elk (Bender et al. 2002) has further identified it as being largely non-relevant.

10.4 Nutritional Status of Wild Elk

Although the nutrition study conducted with captive elk indicated a crucial contribution of nutrition to performance of elk, the study per se could not address the extent to which nutrition was an important operative influence on wild elk herds. Using body condition evaluation techniques developed in the captive elk nutrition study, NCASI has since 1998 been evaluating nutritional status of wild elk herds across the Northwest region, including Yellowstone and Rocky Mountain National Park. This study is an observational, opportunistic effort wherein data are being collected in conjunction with wild elk capture efforts by state wildlife agencies, Indian tribes, and the National Park Service. Based on body fat levels determined in early spring and mid-autumn for 19 elk herds, data show substantial differences among herds, but indicate that nutritional inadequacy is a widespread phenomenon in the Northwest throughout much of the annual cycle, such that in many cases elk are seriously challenged to obtain diets that satisfy their needs during much of the year. The data clearly refute the old perception of a nutritional "utopia" in summer and autumn (Cook, Cook, and Irwin 2003). By extension, how habitats on elk summer ranges are managed may have appreciable influences on herd productivity in many ecosystems. This ongoing study will continue to accumulate data on additional herds as opportunities with other organizations and agencies arise.

10.5 Forestry Effects on Nutritive Values of Managed Landscapes

In 2000, NCASI began an additional study that moved beyond preliminary topics about nutrition's effects to the ultimate goal of the program—to identify influences of forest management on herd productivity and dynamics with explicit focus on forage characteristics operating through nutritional pathways. This study involved transporting the captive elk from their pens to native habitats in order to directly measure the nutritional responses of elk to a variety of habitat conditions in intensively managed forests in the coastal foothills and Cascades of western Oregon and Washington.

Data on foraging dynamics with the captive elk were collected on three study areas during summer and autumn of 2000, 2001, and 2002 (one year at each area), and on fat levels (a measure of nutritional status) of wild elk that occupied the study areas. Data analyses continue, but preliminary analysis indicates that early successional stages produced by forestry are of inordinate importance to the nutritional well-being of wild elk. Other successional stages either produced too little forage to benefit elk, or supported plant communities dominated by plant taxa that are highly unpalatable and low in nutritive value. In general, forage in these other successional stages was markedly inadequate to support reproducing elk in summer and autumn. These data support what some biologists have long believed, that the large and productive elk herds within forest ecosystems of the Northwest are largely a product of the huge catastrophic disturbances early in the 20th century (mainly wildfire, but also a volcano and appreciable timber harvest more recently) that created vast areas of early successional habitat. Data from this study are defining the explicit mechanisms underlying this perception, providing a basis to predict the future consequences to elk of federal policy that favors a preponderance of late successional vegetation, and providing rigorous scientific evidence of the value to big game of early successional vegetation produced by forest management.

10.6 Future Research

Much has been accomplished over the last ten years, but the work is not complete and a number of opportunities exist to further "drive home" its implications, mainly to facilitate the process of converting research results into management action and policy. The nutrition work on the west side provides a basis, using GIS techniques to a) evaluate long-term carrying capacity and herd productivity and population trajectories into the future as a function of federal land management policy; and b) compare and contrast the contributions of intensive forestry on private timberlands to the policies of federal and state agencies for maintaining the elk herds of the Pacific Northwest. We now have the best data available anywhere to do this. Further collaboration with state wildlife agencies will continue to provide opportunities to document the nutritional status of wild elk herds, and we anticipate that this work will reveal additional settings in which nutrition has important influences on elk of the region.

A considerable impediment to the widespread acceptance of the work done on the west side is a perception that the findings are not applicable elsewhere because habitat conditions are different than those in the Inland Northwest and Rocky Mountain region. Differences in habitat certainly exist, yet there is no hard evidence to categorically conclude that the role of forestry in producing elk is only important on the west side. Due to a fortunate set of circumstances involving research programs of the U.S. Forest Service and the Oregon Department of Fish and Wildlife on private and public timberlands in the Blue Mountains of the Inland Northwest, there is an inordinate opportunity to continue collaborative work on forestry influences on big game, outside the confines of the west side corridor. In cooperation with Boise Cascade Corporation, Oregon State University, the Pacific Northwest Station of the U.S. Forest Service, and the Oregon Department of Fish and Wildlife, NCASI is gearing up to begin new research in this ecological province.

10.7 Summary of Key Points

- Current management of habitat on behalf of elk and deer in the region largely reflects research conducted a quarter-century ago. Much has changed biopolitically, including marked reductions in timber harvest on federal lands, and, perhaps not coincidentally, declining populations of many deer and elk herds in the Northwest. Such changes indicate that new and more relevant research needs to be directed at those factors that affect survival and reproduction in deer and elk herds, including the contributions of forest management in providing good habitat for these animals.

- Despite a lack of strong scientific data, reductions in dense forests that provided thermal cover via timber harvest were believed to reduce survival and reproduction of elk. Research conducted in collaboration with the U.S. Forest Service and others strongly refuted this hypothesis and indicated that other features of habitat, namely security cover and forage quality and quantity, should receive greater research and management focus.

- Abundant and nutritious forage on summer ranges of big game has long contributed to the perception of a nutritional "utopia" in summer and autumn. Such a perception precludes the possibility that improvements in forage from forest management provide important benefits to big game. NCASI's research has shown that a) nutritional requirements for reproduction are far higher in summer and autumn than previously recognized; b) nutritional deficiencies in this season have relatively big effects on animal performance; and c) forage conditions in summer and autumn often are inadequate to satisfy the nutritional needs of big game.

- Recent NCASI research is documenting that early successional vegetation produced by timber harvest is crucial for maintaining large and productive elk herds in coastal and Cascade habitats of western Oregon and Washington.
- More work is needed to facilitate the process of converting research results into management action and to continue work defining forestry's influence on elk habitat in inland Northwest ecosystems.

10.8 References

Bender, L.C., Fowler, P.E., Bernatowicz, J.A., Musser, J.L., and Stream, L.E. 2002. Effects of open-entry spike bull, limited-entry branched bull harvesting on elk composition in Washington. *Wildlife Society Bulletin* 30:1078-1084.

Cook, J.G. 2002. Nutrition and food. 259-349 in Toweill, D.E., and Thomas, J.W. (eds.). *North American elk: Ecology and management*. Washington, DC: Smithsonian Institution Press.

Cook, J.G., Cook, R.C., Bender, L.C., Hall, B., and Irwin, L.L. 2003**.** Nutritional influences on northwestern elk herds: Wild elk capture and nutritional condition assessment. Progress Report. La Grande, OR: National Council for Air and Stream Improvement, Inc.

Cook, J.G., Irwin, L.L., Bryant, L.D., Riggs, R.A., and Thomas, J.W. 1998. Relations of forest cover and condition of elk: A test of the thermal cover hypothesis in summer and winter. *Wildlife Monographs* 141.

Cook, J.G., Johnson, B.K., Cook, R.C., Riggs, R.A., Delcurto, T., Bryant, L.D., and Irwin, L.L. (2004). Effects of summer-autumn nutrition and parturition date on reproduction and survival of elk. *Wildlife Monographs* 155:1-61.

Cook, J.G., Quinlan, L.J., Irwin, L.L., Bryant, L.D., Riggs, R.A., and Thomas, J.W. 1996. Nutrition-growth relations of elk calves during late summer and fall. *Journal of Wildlife Management* 60:528-541.

Cook, R.C., Cook, J.G., Garrott, R.A., Irwin, L.L., and Monfort, S.L. 2002. Effects of diet and body condition on fecal progestagen excretion in elk. *Journal of Wildlife Diseases* 38:558-565.

Cook, R.C., Cook, J.G., and Irwin, L.L. 2003. Estimating elk body mass using chest-girth circumference. *Wildlife Society Bulletin* 31:536-543.

Cook, R.C., Cook, J.G., Murray, D.L., Zager, P., Johnson, B.K., and Gratson, M.W. 2001a. Development of predictive models of nutritional condition for Rocky Mountain elk. *Journal of Wildlife Management* 65:973-987.

Cook, R.C., Cook, J.G., Murray, D.L., Zager, P., Johnson, B.K., and Gratson, M.W. 2001b. Nutritional condition models for elk: Which are the most sensitive, accurate, and precise? *Journal of Wildlife Management* 65:988-997.

Cook, R.C., Murray, D.L., Cook, J.G., Zager, P., and Gratson, M.W. 2001c. Nutritional influences on breeding dynamics in elk. *Canadian Journal of Zoology* 79:845-853.

Smith, F.W., and Long, J.N. 1987. Elk hiding and thermal cover guidelines in the context of lodgepole pine stand density. *Western Journal of Applied Forestry* 2:6-10.

11.0 Climate Change

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11.1 Political and Economic Implications

In January 2003, the American Forest and Paper Association (AF&PA) congratulated the Bush Administration on addressing the global climate change issue through enhanced research in technology and science, incentives, and voluntary efforts from all sectors of the American economy to reduce greenhouse gas emissions. AF&PA supported the Bush Administration's "Climate Vision" by addressing emissions reductions and carbon sequestration increases through an industry sector commitment. As such, the AF&PA indicated that through existing programs there is an expectation that by 2012 these programs will reduce greenhouse gas intensity (per unit of output) by 12% relative to 2000.

There are opportunities to enhance carbon sequestration and storage through various forestry-related mechanisms. These include using biomass energy to substitute for fossil fuels, improving harvesting efficiency and lowering transportation costs by siting high-yield plantations closer to processing points, storing carbon in wood and paper products, storing carbon in belowground soil carbon pools through sustainable plantation management, and substituting wood products for other building materials that are less energy efficient.

Working with the AF&PA Forest Science and Technology Committee and the NCASI Biometrics Work Group, the forest inventory and analysis program was examined to determine if it could be used as the basis to report carbon sequestration volumes on forest land in the U.S. In addition, five model projects were developed to determine the possibility of increasing carbon volumes on forest lands in the U.S. Projects included a) nitrogen fertilization improvements; b) streamside management zones; c) afforestation; d) extended rotations; and e) productivity improvements. Results are still being compiled and analyzed, but there appear to be good opportunities to enhance carbon stocks or reduce emissions through some of these practices.

During 2003-2004, the Department of Energy, in cooperation with the U.S. Department of Agriculture, is expected to propose revisions to the 1605(b) voluntary greenhouse gas reporting guidelines established under the 1990 Energy Policy Act. The USDA Forest Service is developing a comprehensive accounting system for estimating carbon sequestration on forest land by developing default estimates of carbon storage by tree species by region and estimates of carbon storage in wood products by end-use. Uncertainty remains as to whether the guidelines will allow corporate entities to report individual projects, or require that they report on a comprehensive, entity-wide basis.

Global climate change remains a very polarizing and contentious issue in Washington DC. While numerous pieces of federal legislation have been introduced, ranging from more research funding to voluntary commitments, mandatory reporting, mandatory reductions, or combinations of these, there does not now appear to be majority support for imposing mandatory reductions. At the same time, many state legislatures are enacting greenhouse gas emissions inventory programs, encouraging reductions in greenhouse gases, and examining ways in which forestry can contribute to greenhouse gas reductions.

11.2 What Do We Know and What Do We Need to Learn?

We know that North American forest ecosystems play major roles in the terrestrial carbon cycle. These roles include carbon exchange with the atmosphere; carbon sequestration in soils, vegetation, and forest products; and production of renewable raw materials and biofuels that reduce aggregate demand for fossil fuels.

What do we need to learn?

- How can we improve existing carbon cycle impact models to provide better estimates of the net effects of forest management and wood processing systems on the global carbon cycle?
- What are the current and potential effects on the terrestrial carbon cycle of intensive forestry practices, and how will future improvements in forest management and wood processing technology impact the capacity of managed forest ecosystems to sequester, store, and provide biofuels for offsetting fossil fuel use?
- What are the most sustainable and cost-effective forest management options for enhancing carbon sequestration and/or biomass energy production through active forest management?
- What are the current and potential effects of rising CO_2 and climate change on forest health and productivity?

12.0 MYTH AND REALITY OF FOREST LAND USE IN THE UNITED STATES

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12.1 Introduction

Policy makers have expressed growing concern with the rate at which forested lands are being converted to urban and industrial uses. These conversions are concentrated along the East Coast, the Southeast, and parts of the West Coast. However, conversions from other land covers to forest are also taking place (primarily from marginal pasture and crop lands). These conversions to forest cover are concentrated in the upper Midwest and parts of the South. Changes in forest land reflect complexity that has made it difficult to explain and predict these shifts. Attention to facts and a broader theoretical framework will enhance our capacity to anticipate and manage changes in land use resulting in gains or losses in forest cover.

The USDA Natural Resources Conservation Service (2000) conducted a 1997 National Resources Inventory and reported a net increase in total forest land area of 800,000 acres between 1982 and 1997, reflecting growth of somewhat less than 1% over this 15-year period. Roughly 25 million acres of forest land was converted to other cover types between 1982 and 1997, and a little over 25 million acres of land was converted from other cover types to forest. About 4% of the 1982 forest land base was lost to other uses by 1997. Conversion of pasture land, rangeland, cropland, and other rural land contributed 25 million acres of forest cover between 1982 and 1997. Between 1982 and 1997, urban, industrial, and infrastructure development claimed less than half of the forest land converted to other uses (11.7 million acres, or 2.9% of the area forested in 1982).

The USDA Forest Service's 2000 RPA [Resource Planning Act] Assessment of Forest and Range Lands (2000) used the NCRS inventory data to note a significant improvement in forest conditions over the 20th Century. The RPA assessment also relied on MacCleery (1992), who showed progress over the century from a situation where there was extensive "cutover," no reforestation, and harvests greatly exceeded growth to a situation today where reforestation is required to follow harvests and growth far exceed harvests.

12.2 Scientific Language and Land Use

We need a more comprehensive theoretical framework to better understand the dynamic nature of forest land use, especially in regions where conversion of forest land is a growing concern. Most current discussions of forest land use embody economic or ecological principles. The language of economics focuses on using an understanding of market processes to model land use conversions. While it is important to understand land markets, they often operate within a cultural and biological context. In recent years, the biological context has been discussed in a language focusing on ecological imperatives such as protecting unique natural features or endangered species. The latter may constitute constraints on market transactions, but do not reflect the relative productivity of land for an array of alternative uses. The cultural context has been largely ignored in discussing forest land use, from both economic and ecological perspectives. A more encompassing language is needed to improve our capacity to explain and predict changes in land use.

Natural resource sociologists have been developing such an inclusive language for over 60 years. The work of Walter Firey (1960) represents perhaps the most systematic attempt to integrate economic, ecological, and cultural processes affecting land uses. According to Firey, a stable (today we would say "sustainable') relationship between human resource use and the environment requires that resource practices meet three independent conditions. They must be a) biologically possible (nature must be capable of producing resources and/or accommodating management actions without losing its productive capacity and ecological resilience); b) individually gainful (provide an acceptable rate of return on investment of capital and labor); and c) socially acceptable (involve conformity to the cultural norms of a group or community). So far, this formulation resembles the "triple bottom line" used to describe sustainability.

Firey, however, goes further by demonstrating how conservation (or sustainability) is only possible by additionally requiring that current consumption be reduced so that further options are preserved. Individuals are motivated to undertake resource practices that are not maximally gainful because they are expected to do so by members of their community. Since other individuals also conform to these expectations, voluntary conformity becomes highly likely, and individuals can predict the behavior of their associates. Voluntary conformity is generally reinforced by democratically established legal sanctions, or at least the threat thereof.

The tension between rational (calculation of private gainfulness) and non-rational (non-gainful conformity to group expectations) resource practices is the basis for conservation behavior (sustainable practices). When historical events create physical and/or cultural instability, they give rise to loosened social expectations and personal insecurity. Under these conditions, individuals can no longer predict the future based on what had been likely in the past. Willing conformity to group expectations is replaced by the "calculating opportunism" of rational individuals, with each seeking to maximize his or her private advantage or gain. As a result, sustainable resource practices are only as stable as the social order within which they developed. Historic shifts in social order or the cultural meaning of forests and forest land provide the conditions for a release of calculating opportunism—an opportunism that can sometimes give rise to new "resources" and social expectations essential for perpetuating the new resources.

The sudden shift in the cultural meaning of "old-growth forests" from 1985 to 1995 is a prime example of how long-established resources (old-growth trees as commodities) were transformed into new resources (old-growth trees as sacred objects). Social expectations regarding sustained yield were supplanted by an emerging set of social expectations generally referred to as "sustainable forestry" or "ecosystem management." The calculating opportunism of political entrepreneurs seeking to eliminate timber harvesting of federal lands undermined the old expectations and is actively developing new expectations to accompany the new resources associated with maintaining "ecological capital."

12.3 Explaining and Predicting Changes in Forest Land Use

Walter Firey's work is relevant today because he reminds us that economic and ecological values are influenced by the cultural context within which they exist. We live in society that, by historical standards, is subject to relatively rapid shifts in social arrangements and cultural meanings. Therefore, we will be better able to explain and predict changes in land use by identifying the cultural context within which people make decisions that alter the use of land. The cultural context will tell us about the nature of social expectations and/or calculating opportunism that provides the context for decisions.

Current concern with the conversion of forest land to residential and industrial uses reflects social consensus favoring provision of opportunities for dispersed settlement. Somewhat ironically, the "back to the land" movement that started in the 1960s is closely associated with the popularization of romantic sentiments toward the natural world. An image of a sublime life on the urban fringe or countryside has replaced attachments to urban living. People are fleeing the stress, crime, and congestion of urban life in places like New York City, Miami, and Atlanta to seek refuge in places like the forested hills and hollows of the Appalachian Mountains. Without taking into account this shift in cultural meanings, economic models could not predict these geographic shifts and the sharp rise in rural land values in communities historically plagued with severe poverty. Moral appeals to ecological imperatives have been relatively ineffective in stemming the spread of residential development into forested regions because the values people seek in such moves are to consume a beautiful and secure private natural environment. In short, dispersed forest conversion is driven by a contagion of private "environmental opportunism." Social expectations to protect forests from changes inflicted by logging are far more developed than expectations to protect forests from residential use.

A case study of historic shifts in cultural meaning was conducted in the Dungeness watershed encompassing Sequim, Washington. Jennings-Eckert (1998) identified and mapped six distinct cultural meanings assigned to public and private forests over the last 150 years: a) timber mining (economic opportunism governed by few social expectations); b) forests as a nuisance to farming (shared expectations of trees as weeds); c) public forests reserved for future uses (stewardship era of federal land management); d) sustained-yield wood production (expectations of long-term balance of harvest and growth, coupled with protection of water, fish, and wildlife); e) forests as residential environments; and f) preservation (opportunistic creation of new biological resources) of public forests. This analysis revealed several important conclusions. The cultural meaning of forests was far more dynamic than the biological states of forests with which they were associated. What was considered economically "gainful" changed with the cultural meaning of the forest. Finally, social expectations associated with the use of treatment of forests varied with the cultural meanings assigned to forests. Hence, an economic analysis of ecological assessment could not be useful for explanation or prediction without taking into account the cultural/historical context.

12.4 Remaining Questions

Research on conversions in forest land use could be more effective in explaining and predicting change by addressing the following questions:

- Is change in forest land use predictable only within cultural frames?

- Is cultural change predictable?
- Can the ecological system be sustained when cultural and economic processes are more dynamic?
- Given national and regional shifts in the cultural meanings assigned for forested lands, where should long-term commitments such as timber production be located?

A focus of attention on these questions would help overcome the misunderstandings that arise from the pursuit of mythical *independent* economic drivers or ecological imperatives. Economic, ecological, and social/cultural can only be isolated in the minds of researchers or advocates. They do not exist independently in the real world.

12.5 References

Firey, W. 1960. *Man, mind, and land: A theory of resource use.* Glencoe, IL: The Free Press.

Jennings-Eckert, P. 1998. The social construction of a watershed: Changing rights and changing land. Ph.D. diss., University of Washington-Seattle.

MacCleery, D.W. 1992. *American forests: A history of resiliency and recovery*. FS-540. Washington, DC: United States Department of Agriculture Forest Service.

United States Department of Agriculture Forest Service (USDA FS). 2000. *2000 RPA assessment of forest and range lands*. Washington, DC: United States Department of Agriculture Forest Service.

United States Department of Agriculture Natural Resources Conservation Service. 2000. *Summary report—1997 National Resources Inventory* (revised December 2000). Washington, DC: United States Department of Agriculture Natural Resources Conservation Service.

APPENDIX A

REFERENCES BY SECTION

1.0 CLEARCUTTING

Beschta, R.L. et al. 1995. *Cumulative effects of forest practices in Oregon*. Salem, OR: Oregon Department of Forestry.

Blackburn, W.H., Wood, J.C., and DeHaven, M.G. 1986. Storm flow and sediment losses from site-prepared forestland in East Texas. *Water Resources Research* 22(5):776-784.

Helms, J.A. [ed.]. 1998. *A dictionary of forestry*. Bethesda, MD: Society of American Foresters.

Ice, G.G., Megahan, W.F., McBroom, M.W., and Williams, T.M. (2003). Opportunities to assess past, current, and future impacts from forest management. In *Proceedings of the Second Conference on Watershed Management to Meet Emerging TMDL Environmental Regulations*. St. Joseph, MI: American Society of Agricultural Engineers.

Mitchell, J.G., and Essick, P. 1996. Our polluted runoff. *National Geographic* 189(2):106-126.

Society of American Foresters (SAF). 2003. *Clearcutting: A position of the Society of American Foresters*. http://www.safnet.org/policyandpress/psst/clearcut1202.cfm (September 11, 2003).

2.0 FORESTRY AND WATER QUALITY

Bates, D., Willis, K., Swanson, F., Glasmann, J.R., Halemeier, D., and Wujcik, H. 1998. North Santiam River turbidity study, 1996-1997. *Watershed Management Council Newsletter* Fall 1998:1-17.

Bisson, P.A., Ice, G.G., Perrin, C.J., and Bilby, R.E. 1992. Effects of forest fertilization on water quality and aquatic resources in the Douglas-fir region. 179-193 in Chappell, H.N., Weetman, G.F., and Miller, R.E. (eds.). *Forest fertilization: Sustaining and improving nutrition and growth of western forests*. Seattle: University of Washington, Institute of Forest Resources.

Beschta, R.L., Pyles, M.R., Skaugset, A.E., and Surfleet, C.G. 2000. Peakflow responses to forest practices in the western Cascades of Oregon, USA. *Journal of Hydrology* 233:102-120.

Bonn, B.A., Hinkle, S.R., Wentz, D.A., and Uhrich, M.A. 1995. *Analysis of nutrient and ancillary water-quality data for surface and ground water of the Willamette Basin, Oregon, 1980-90*. Water Resources Investigations Report 95-4036. Portland, OR: U.S. Geological Survey.

Brett, J.R. 1956. Some principles in the thermal requirements of fishes. *Quarterly Review of Biology* 31:75-87.

Brown, G.W. 1988. *Forestry and water quality*. Corvallis: Oregon State University Bookstores, Inc. 142 pp.

Cafferata, P.H., and Spittler, T.E. 1998. Logging impacts of the 1970s vs. the 1990s in the Caspar Creek Watershed. 103-15 in Ziemer, R.R. (technical coordinator). *Proceedings from the Conference on Coastal Watersheds: The Caspar Creek Story, May 8, 1998, Ukiah, CA*. General Technical Report PSW GTR-168. Albany, CA: USDA Forest Service, Pacific Southwest Research Station.

Duncan, S.H. and S.W. Ward. 1985. The influence of watershed geology and forest roads on the composition of salmon spawning gravel. *Northwest Science* 59(3):204-212.

Fredriksen, R.L., Moore, D., and Norris, L. 1975. The impact of timber harvest, fertilization, and herbicide treatment on streamwater quality in western Oregon and Washington. 283-313 in Bernier, B., and Winger, C. (eds.). *Forest soils and land management*. Quebec: Laval University Press.

Hagans, D.K., and Weaver, W.E. 1987. Magnitude, cause and basin response to fluvial erosion, Redwood Creek basin, northern California. 419-428 in *Erosion and Sedimentation in the Pacific Rim*. IAHS Publication 165. Washington, DC: International Association of Hydrological Sciences.

Ice, G., and Binkley, D. 2002. Forest streamwater concentrations of nitrogen and phosphorus: A comparison with EPA's proposed water quality criteria. *Journal of Forestry* 101(1):21-28.

Ice, G., Dent, L., Robben, J., Cafferata, P., Light, J., Sugden, B., and Cundy, T. (2004). Programs assessing implementation and effectiveness of state forest practice rules and BMPs in the West. *Water, Air and Soil Pollution: Focus* 4(1):143-169.

Ice, G.G., Light, J., and Reiter, M. (in press). Use of natural temperature patterns to identify achievable stream temperature criteria for forest streams. *Western Journal of Applied Forestry*.

Ice, G., and Sugden, B. 2003. Summer dissolved oxygen concentrations in forested streams of northern Louisiana. *Southern Journal of Applied Forestry* 27(2):92-99.

Independent Science Review Panel (ISRP). 2003. *Phase II Report: Independent Science Review Panel on Sediment Impairment and Effects on Beneficial Uses of the Elk River and Stitz, Bear, Jordan and Freshwater Creeks*. Santa Rosa, CA: North Coast Water Quality Control Board.

Jackson, C.R., Sturm, C.A., and Ward, J.M. 2001. Timber harvest impacts on small headwater stream channels in the Coast Ranges of Washington. *Journal of the American Water Resources Association* 37(6):1533-1549.

Jones, J.A., and Grant, G.E. 1996. Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon. *Water Resources Research* 32(4):959-974.

Lewis, J., Mori, S.R., Keppeler, E.T., and Ziemer, R.R. 2001. Impacts of logging on storm peak flows, flow volumes and suspended sediment loads in Caspar Creek, California. 85-125 in Wigmosta, M.S., and Burges, S.J. (eds.). *Land use and watersheds: Human influence on hydrology and geomorphology in urban and forest areas. Water science and application Volume 2*. Washington, DC: American Geophysical Union.

MacDonald, L.H., Coe, D., and Litschert, S. 2003. Assessing cumulative watershed effects in the central Sierra Nevada: Hillslope measurement and catchment-scale modeling. Fort Collins: Colorado State University, Department of Forest, Range, and Watershed Stewardship.

Marco, A., and Blaustein, A. 1999. The effect of nitrite on behavior and metamorphosis in Cascades frogs (*Rana cascadae*). *Environmental Toxicology and Chemistry* 18(5):946-949.

McNabb, D.H., and Swanson, F.J. 1990. The effects of fire on soil erosion. 159-176 in Walstad, J.D., and Radosevich, S.R. (eds.). *Natural and prescribed fire in Pacific Northwest forests*. Corvallis: Oregon State University Press.

Megahan, W.F., Potyondy, J.P., and Seyedbagheri, K.A. 1992. Best management practices and cumulative effects from sedimentation in the South Fork Salmon River: An Idaho case study. 401-414 in *Watershed management: Balancing sustainability and environmental change*. Naiman, R.J. (ed.). New York: Springer-Verlag.

Moring, J.R. 1975. *The Alsea Watershed Study: Effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part II.-Changes in environmental conditions*. Res. Rep. 9. Corvallis: Oregon Department of Fish and Wildlife.

Oregon Forest Resources Institute (OFIC). Nd. *Drinking water & forestry: How a healthy forest ecosystem helps keep streams clean and water quality high*. Portland: Oregon Forest Resources Institute.

Reiter, M, Baitis, K, and Stark, J. 1996. The effects of forest fertilization on water quality in Calapooya Creek. Weyerhaeuser Company Research and Development Technical Report. 12 pp.

Salminen, E.M., and Beschta, R.L. 1991. *Phosphorus and forest streams: The effects of environmental conditions and management activities*. Corvallis: Oregon State University, Department of Forest Engineering. 185 pp.

Smith, R.A., Alexander, R.B., and Schwartz, G.E. 2003. Natural background concentrations of nutrients in streams and rivers of the conterminous United States. *Environmental Science and Technology* 37(14):3039-3047.

Society of American Foresters (SAF) and National Association of State Foresters (NASF). 2000. *A review of waterbodies listed as impaired by silvicultural operations*. Bethesda, MD: Society of American Foresters.

Stark, J., and Reiter, M. 2000. Water quality effects of forest fertilization on potential aquatic amphibian habitat. Weyerhaeuser Company Technical Report. Proprietary.

Stednick, J.D. 1991. *Wildland water quality sampling and analysis*. San Diego, CA: Academic Press.

Sullivan, K., Lisle, T.E., Dolloff, C.A., Grant, G.E., and Reid, L.M. 1987. Stream channels: The link between forests and fishes. 39-97 in Salo, E.O., and Cundy, T.W. (eds.). *Proceedings of the symposium on streamside management: Forestry fisheries interactions*. Contribution 57. Seattle, WA: University of Washington, Institute of Forest Resources.

Swanson, F.J., Benda, L.E., Duncan, S.H., Grant, G.E., Megahan, W.F., Reid, L.M., and Ziemer, R.R. 1987. Mass failures and other processes of sediment production in the Pacific Northwest forest landscape. 9-38 in Salo, E.O., and Cundy, T.W. (eds.). *Proceedings of the symposium on streamside management: Forestry fisheries interactions*. Contribution 57. Seattle, WA: University of Washington, Institute of Forest Resources.

Swanson, F.J. and Jones, J.A. 2002. Geomorphology and hydrology of the H.J. Andrews Experimental Forest, Blue River, Oregon. In *Field Guide to Geologic Processes in Cascadia*. Special Paper 36. Salem: Oregon Department of Geology and Mineral Industries.

Thomas, R.B., and Megahan, W.F. 1998. Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon: A second opinion. *Water Resources Research* 34(12):3393-3403.

Williams, T.M., Hook, D.D., Lipscomb, D.J., Zeng, X., and Albiston, J.W. 1999. Effectiveness of best management practices to protect water quality in the South Carolina Piedmont. 271-277 in *Proceedings of the Tenth Biennial Southern Silvicultural Research Conference*. General Technical Report SRS-30. Asheville, NC: USDA Forest Service, Southern Research Station.

Ziemer, R.R. (technical coordinator). 1998. *Proceedings of the Conference on Coastal Watersheds: The Caspar Creek Story, May 6, 1998, Ukiah, CA*. General Technical Report PSW GTR-168. USDA Forest Service, Pacific Southwest Research Station. 149 pp. http://www.rsl.psw.fs.us/projects/water/caspubs.html (March 18, 2003).

3.0 FOREST CHEMICALS

Alsea Citizens Monitoring Team. 2000. *Herbicide concentrations in stream runoff after rain events in the Alsea River Basin*. Salem: Oregon Watershed Enhancement Board.

Brown, G.W. 1980. *Forestry and water quality*. Corvallis: Oregon State University Book Store.

Carruthers, R.I. 2003. Invasive species research in the United States Department of Agriculture-Agricultural Research Service. *Pest Management Science* 59(6-7):827-834.

Dent, L., and Robben, J. 2000. *Oregon Department of Forestry: Aerial pesticide application monitoring final report*. Technical Report No. 7. Salem: Oregon Department of Forestry, Forest Practices Monitoring Program.

Ice, G.G., Schmedding, D.W., and Shepard, J.P. 1998. State restrictions and initiatives to restrict the use of silvicultural chemicals: What we know and need to know. 303-325 in *Proceedings of the 1998 NCASI Northeast Regional Meeting*. Research Triangle Park, NC: National Council for Air and Stream Improvement, Inc.

Kearney, P.C. 1987. In summary. 135-137 in *Fate of pesticides in the environment*. Publication 3320. Oakland: University of California, Agricultural Experiment Station, Division of Agriculture and Natural Resources.

Munn, M.D., and Gruber, S.J. 1997. The relationship between land use and organochlorine compounds in streambed sediment and fish tissue in the central Columbia Plateau, Washington and Idaho, USA. *Environmental Toxicology and Chemistry* 16(9):1877-1887.

National Forest Products Association (NFPA). 1979. *Forest Chemical News* 1(2):1.

Newton, M., and Norgren, J.A. 1977. *Silvicultural chemicals and protection of water quality*. Seattle, WA: United States Environmental Protection Agency, Region X.

Rashin, E., and Graber, C. 1993. *Effectiveness of best management practices for aerial application of forest pesticides.* TFW-WQ1-93-001. Olympia: Washington Department of Ecology.

Simard, S., and Heineman, J. 1996. *Nine-year response of Douglas-fir and the mixed hardwood-shrub complex to chemical and manual release treatments on an ICHmw2 site near Salmon Arm*. FRDA Report No. 257. Victoria, BC: Canadian Forest Service and British Columbia Ministry of Forestry.

Scholz, N.L., Truelove, N.K., French, B.L., Berejikian, B.A., Quinn, T.P., Casilla, E., and Collier, T.K. 2000. Diazinon disrupts antipredator and homing behavior in Chinook salmon (*Oncorhynchus tshawytscha*). *Canadian Journal of Fisheries and Aquatic Science* 57:1911-1918.

Teske, M.E., Bird, S.L., Esterly, D.M., Curbishley, T.B., Ray, S.L. and Perry, S.G. 2000. AgDRIFT: A model for estimating near-field spray drift from aerial applications. *Environmental Toxicology and Chemistry* 21:659-71.

Teske, M.E., and Ice, G.G. 2002. A one-dimensional model for aerial spray assessment in forest streams. *Journal of Forestry* 100(3):40-45.

United States Environmental Protection Agency (USEPA). 1979. *Report on assessment of a field investigation of six-year spontaneous abortion rates in three Oregon areas in relation to forest 2,4,5-T spray practices*. Washington, DC: United States Environmental Protection Agency.

Wentz, D.A., Bonn, B.A., Carpenter, K.D., Hinkle, S.R., Janet, M.L., Rinella, F.A., Uhrich, M.A., Waite, I.R., Laenen, A., and Bencala, K.E. 1998. *Water quality in the Willamette River Basin, Oregon, 1991-1995*. Circular 1161. Reston, VA: United States Department of Interior, United States Geological Survey.

4.0 FOREST HEALTH AND WILDFIRE

Quigley, T.M., and Cole, H.B. 1997. *Highlighted scientific findings of the Interior Columbia Basin Ecosystem Management Project*. General Technical Report PNW-GTR-404. Portland, OR: USDA Forest Service, Pacific Northwest Research Station and USDI Bureau of Land Management.

Schmidt, K.M., Menakis, J., Hardy, C., Hann, W., and Bunnell, D. 2002. *Development of coarse-scale data for wildland fire and fuel management*. General Technical Report RMRS-GTR-87. Ogden, UT: USDA Forest service, Rocky Mountain Research Station.

U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration-National Marine Fisheries Service (NOAA-Fisheries). 1998. *Endangered species act consultation handbook: Procedures for conducting Section 7 consultations and conferences*. http://www.nv.blm.gov/t&e/documents/s7book.pdf (June7, 2004).

5.0 SALMON AND FORESTS

Everest, F.H., Beschta, R.L., Scrivener, J.C., Koski, K.V., Sedell, J.R., and Cederholm, C.J. 1987. Fine sediment and salmonid production: A paradox. 98-142 in Salo, E.O., and Cundy, T.W. (eds.). *Streamside management: Forestry and fishery interactions*. Contribution Number 57. Seattle: University of Washington, Institute of Forest Resources.

Hall, J.D., Brown, G.W., and Lantz, R.L. 1987. The Alsea Watershed Study: A retrospective. 399-416 in Salo, E.O., and Cundy, T.W. (eds.). *Streamside management: Forestry and fishery interactions*. Contribution Number 57. Seattle: University of Washington, Institute of Forest Resources.

Pess, G.R., Montgomery, D.R., Steel, E.A., Bilby, R.E., Feist, B.E., and Greenberg, H.M. 2002. Landscape characteristics, land use, can coho salmon (*Oncorhynchus kisutch*) abundance, Snohomish River, Wash., U.S.A. *Canadian Journal of Fisheries and Aquatic Sciences* 59:613-623.

6.0 HEADWATER STREAMS

Alverts, B., Danehy, B., Dambacher, J., Dent, L., Hafele, R., Ice, G., Moore, K., Reiter, M., Roberts, K., and Russell, K. 2001. *Headwater Research Cooperative: Workshop summary*. Oregon Department of Forestry Technical Report #16. http://www.odf.state.or.us/FP/fpmp/TechReport.htm (August 7, 2003).

Andrus, C.W., and Froehlich, H.A. 1988. Riparian forest development after logging or fire in Oregon Coast Range: Wildlife habitat and timber value. In *Symposium on streamside management: Riparian wildlife and forestry interactions*. Seattle: University of Washington.

Beasley, S., Chang, M., Ice, G.G., Gowan, B., and McBroom, M. 2001. A study of intensive forest management for small southern watersheds (Alto Watershed Project). 54-59 in *Forest Resources Institute 2001 annual report*. Nacogdoches, TX: Stephen F. Austin State University, Arthur Temple College of Forestry.

Bilby, R.E., and Ward, J.W. 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. *Transactions of the American Fisheries Society* 118:368-378.

Black, J. 2001. Summer temperatures in small stream sources on managed Olympic Peninsula timberlands. Master's thesis. Seattle: University of Washington.

Day, F. 2003. Letter to Donna Downing, U.S. Environmental Protection Agency, and Ted Rugiel, U.S. Army Corps of Engineers, on advanced notice of proposed rulemaking April 16, 2003. http://www/sws/org/regional/northcentral/SWS_ANPRM.html (August 8, 2003).

Dent, L., and Danehy, B. 2002. Little streams, big impact: Oregon Headwaters Research Cooperative. *Western Forester* 47(5):10-11.

Duncan, W.F.A., and Brusven, M.A. 1985. Benthic macroinvertebrates in logged and unlogged low-order southeast Alaskan streams. *Freshwater Invertebrate Biology* 4(3):125-133.

Forest Ecosystem Management Assessment Team (FEMAT). 1993. *Forest ecosystem management: An ecological, economic, and social assessment*. Portland, OR.

Gomi, T., Sidle, R.C., and Richardson, J.S. 2002. Understanding processes and downstream linkages of headwater streams. *BioScience* 52(10):905-916.

Goolsby, D.A. 1997. *Midcontinent Herbicide Initiative: Significant findings*. United States Geological Survey.

Hagan, J.M. 2000. Water temperature profile of a western Maine headwater stream with adjacent clearcuts. *Mosaic Science Notes #2000-1*. Brunswick, ME: Manomet Center for Conservation Science.

Hagan, J.M. 2002. *CFRU annual report: The effectiveness of different buffer widths for protecting riparian values on headwater streams*. Brunswick, ME: Manomet Center for Conservation Science.

Ice, G., and Schoenholtz, S. 2003. Understanding how extremes influence water quality: Experience from forest watersheds. *Hydrological Sciences and Technology* 19(1-4):99-108.

Ice, G., and Van Deusen, P. 1994. An analysis of alternative riparian protection requirements on land available for management and their cost to landowners. Paper presented at the 1994 NCASI

West Coast Regional Meeting. Available from the NCASI West Coast Regional Center, Corvallis, OR.

Johnson, S.L., and Jones, J.A. 2000. Stream temperature responses to forest harvest and debris flows in western Cascades, Oregon. *Canadian Journal of Fisheries and Aquatic Sciences* 57(Suppl. 2):30-39.

Kahl, S. 1996. *A review of the effects of forest practices on water quality in Maine*. Augusta: Maine Department of Environmental Quality, Bureau of Land and Water Quality Control.

Macdonald, J.S., Macisaac, E.A., Herunter, H., and Beaudry, P.G. 2002. The effects of variable retention riparian buffers on discharge, temperature, and suspended sediment in small headwater streams in the northern interior of British Columbia. Abstract in *Symposium on small streams channels and their riparian zone: Their form, function and ecological importance in a watershed context*. Vancouver, BC.

Moore, R.D., Mellina, E., Story, A., and Sutherland, P. 2003. Headwater stream temperature response to forest harvesting as a hydrologic problem. In *Headwater stream ecology research forum*. Oregon Headwaters Research Cooperative. http://www.headwatersresearch.org.

Natural Resources Defense Council. 2003. Press backgrounder-Limiting Clean Water Act protection could contaminate drinking water. http://www.nrdc.org/media/pressreleases/030611a.asp (August 28, 2003).

Ohio Environmental Protection Agency (OEPA). 2003. Ohio primary headwater habitat streams. http://www.epa.state.oh.us/dsw/wqs/headwaters/ (January 15, 2003).

Oregon Department of Forestry (ODF) and Oregon Department of Environmental Quality (ODEQ). 2002. *Oregon Department of Forestry and Department of Environmental Quality sufficiency analysis: A statewide evaluation of FPA effectiveness in protecting water quality*. Salem: Oregon Department of Forestry.

Rashin, E., and Graber, C. 1993. *Effectiveness of best management practices for aerial application of forest pesticides*. Timber, Fish, and Wildlife Report TFW-WQ1-93-001. Olympia: Washington State Department of Ecology.

Shepard, J. 2002. Synthesis of BMP research needs. *2001 Forest Best Management Practices Research Symposium*, April 2002, Atlanta, GA.

Teske, M.E., and Ice, G.G. 2002. A one-dimensional model for aerial spray assessment in forest streams. *Journal of Forestry* 100(3):40-45.

Zwieniecki, M.A., and Newton, M. 1999. Influence of streamside cover and stream features on temperature trends in forested streams of western Oregon. *Western Journal of Applied Forestry* 14(2):106-113.

7.0 THE SPOTTED OWL AND ENDANGERED SPECIES

Agee, J.K., and Edmonds, R.L. 1992. Forest protection guidelines for the northern spotted owl. 181-244 in *USDI Recovery plan for the northern spotted owl—final draft*. Vol. 2. Washington, DC: U.S. Government Printing Office.

Anthony, R.G., Olson, G., Forsman, E., Reid, J., Loschl, P., Ripple, W., Glenn, E., and Harkins, K. 2000. *Predicting abundance and demographic performance of northern spotted owls from* *vegetative characteristics. Report on Phase I: Evaluation of different methods for habitat mapping*. Corvallis: Oregon State University, Oregon Cooperative Wildlife Research Unit. 100 pp.

Bart, J., and Forsman, E.D. 1992. Dependence of northern spotted owls (*Strix occidentalis caurina*) on old-growth forests in the western USA. *Biology Conservation* 62:95-100.

Bingham, B.B., and Noon, B.R. 1997. Mitigation of habitat "take"; application to habitat conservation planning. *Conservation Biology* 11:127-139.

Boyce, M.S., Meyer, J.S., and Irwin, L.L. 1994. Habitat-based PVA for the northern spotted owl. 63-85 in Fletcher, D.J., and Manly, B.F.J. (eds.). *Statistics in ecology and environmental monitoring*. Otago Conference Series 2. Dunedin, NZ: University of Otago.

Buchanan, J.B., Irwin, L.L., and McCutchen, E.L. 1995. Within-stand nest site selection by spotted owls in the eastern Washington Cascades. *Journal of Wildlife Management* 59:301-310.

Buchanan, J.B., Irwin, L.L., and McCutchen, E.L. 1993. Characteristics of spotted owl nest trees in the Wenatchee National Forest. *Journal of Raptor Research* 27:1-7.

Burnham, K.P., Anderson, D.R., and White, G.C. 1996. Meta-analysis of vital rates of the northern spotted owl. *Studies in Avian Biology* 17:92-101.

Carey, A.B., and Peeler, K.C. 1995. Spotted owls: Resource and space use in mosaic landscapes. *Journal of Raptor Research* 29:223-239.

Covington, W.W., Everett, R.L., Steele, R., Irwin, L.L., Daer, T.A., and Auclair, A.N.D. 1994. Historical and anticipated changes in forest ecosystems of the inland west of the United States. *Journal of Sustainable Forestry* 2:13-63.

DeBell, D.S., Curtis, R.O., Harrington, C.A., and Tappeiner, J.C. 1997. Shaping stand development through silvicultural practices. 41-164 in Kohm, K.A., and Franklin, J.A. (eds.). *Creating a forestry for the 21st century*. Washington, DC: Island Press.

Everett, R.L., Schellhaas, R., Keenum, D., Spurbeck, D., and Ohlson, P. 2000. Fire history in the ponderosa/Douglas-fir forests on the east slope of the Washington Cascades. *Forest Ecology Management* 129:207-225.

Forest Ecosystem Management and Assessment Team (FEMAT). 1993. *Forest ecosystem management: An ecological, economic and social assessment*. Portland, OR: USDA Forest Service, USDC National Oceanic and Atmospheric Administration, USDC National Marine Fisheries Service, USDI Bureau of Land Management, USDI Fish and Wildlife Service, and USDI Environmental Protection Agency. 1004 pp.

Forsman, E.D., Meslow, E.C., and Wight, H.M. 1984. Distribution and biology of the spotted owl in Oregon. *Wildlife Monographs* No. 87.

Franklin, A.B., Anderson, D.R., Gutiérrez, R.J., and Burnham, K.P. 2000. Climate, habitat quality and fitness in northern spotted owl populations in northwestern California. *Ecology Monographs* 70:539-590.

Franklin, A.B., Burnham, K.P., White, G.C., Anthony, R.J., Forsman, E.D., Schwartz, C., Nichols, J.D., and Hines, J. 1999. *Range wide status and trends in northern spotted owl populations*. Ft. Collins, CO: USDA Geological Survey, Colorado Cooperative Fish and Wildlife Research Unit. 72 pp.

Hayes, J.P., Chan, S.S., Emmingham, W.H., Tappeiner, J.C., Kellogg, L.D., and Bailery, J.D. 1997. Wildlife response to thinning young forest in the Pacific Northwest. *Journal of Forestry* 95:28-33.

Irwin, L.L. 1994. A process for improving wildlife habitat models for assessing forest ecosystem health. *Journal of Sustainable Forestry* 2:293-306.

Irwin, L.L., Fleming, T.L., and Beebe, J. (in press). Are spotted owl populations sustainable in fire-prone forests? *Journal of Sustainable Forestry*.

Irwin, L.L, Rock, D.F., and Miller, G.P. 2000. Stand structures used by northern spotted owls in managed forests. *Journal of Raptor Research* 34:175-186.

Irwin, L.L., and Wigley, T.B. 1993. Toward an experimental basis for protecting forest wildlife. *Ecological Applications* 3:213-217.

Meyer, J.S., Irwin, L.L., and Boyce, M.S. 1998. Influence of habitat abundance and fragmentation on northern spotted owls in western Oregon. *Wildlife Monographs* No. 139. 51 pp.

Paton, P.W.C. 1994. The effect of edge on avian nest success: How strong is the evidence? *Conservation Biology* 8:17-26.

Paton, P.W.C., Zabel, C.J., Neal, D.L., Steger, G.N., Tilghman, N.G., and Noon, B.R. 1991. Effects of radio tags on spotted owls. *Journal of Wildlife Management* 55:617-622.

Ransome, D.B., and Sullivan, T.P. 2002. Short-term population dynamics of *Glaucomy sabrinus* and *Tamiasciurus douglasii* in commercially thinned and unthinned stands of coastal coniferous forests. *Canadian Journal of Forest Research* 32:2043-2050.

Suzuki, N., and Hayes, J.P. 2003. Effects of thinning on small mammals in Oregon coastal forests. *Journal of Wildlife Management* 67:352-371.

Swindle, K.A., Ripple, W.J., Meslow, E.C., and Shafer, D. 1999. Old-forest distribution around spotted owl nests in the central Cascade Mountains, Oregon. *Journal of Wildlife Management* 63:1212-1221.

Thomas, J.W., Forsman, E.D., Lint, J.B., Meslow, E.C., Noon, B.R., and Verner, J. 1990. *A conservation strategy for the northern spotted owl*. Report of the Interagency Scientific Committee to address the conservation of the northern spotted owl. Portland, OR: USDA Forest Service. Washington, DC: U.S. Government Printing Office. 458 pp.

Thomas, J.W., et al. 1993. *Forest ecosystem management: An ecological, economic, and social assessment*. Doc. 1999-793-071. Report of the Forest Ecosystem Management Assessment Team. Washington, DC: U.S. Government Printing Office.

USDA/USDI. 1994. Final supplemental environmental impact statement on management of habitat for late successional and old-growth forest related species within the range of the northern spotted owl.

Zabel, C.J., Roberts, L.M., Mulder, B.S., Stouffer, H.B., Dunk, J.R., Wolcott, K., Solis, D., Gertsch, M., Woodbridge, B., Wright, A., Goldsmith, G., and Keckler, C. 2003. A collaborative approach in adaptive management at a large-landscape scale. Chap. 19 in Scott, J.M., Heglund, P.J., Morrison, M.L., Haufler, J.B., Raphael, M.G., Wall, W.A., and Samson, F.B. (eds.). *Predicting species occurrences: Issues of scale and accuracy*. Covelo, CA: Island Press. 840 pp.

8.0 BIODIVERSITY

American Forest and Paper Association (AF&PA). 2002. 2002-2004 Edition Sustainable Forestry Initiative (SFI) Program. Washington, DC: Sustainable Forestry Initiative Sustainable Forestry Board and the American Forest & Paper Association.

Brown, N.R., Noss, R.F., Diamond, D.D., and Myers, M.N. 2001. Conservation biology and forest conservation: Working together toward ecological sustainability. *Journal of Forestry* 99(8):18-25.

Connell, J.H. 1978. Diversity in tropical rain forests and coral reefs. *Science* 199:1302-1310.

Haufler, J.B., Mehl, C.A., and Roloff, G.J. 1996. Using a coarse-filter approach with species assessment for ecosystem management. *Wildlife Society Bulletin* 24(2):200-208.

Huston, M.A. 1999. Forest productivity and diversity: Using ecological theory and landscape models to guide sustainable forest management. 329-341 in Aguirre-Bravo, C., and Franco, C.R. (comps.). *North American Science Symposium: Toward a unified framework for inventorying and monitoring forest ecosystem resources*. USDA Forest Service Proceedings RMRS-P-12.

Noss, R.F. 1991. From endangered species to biodiversity. 227-246 in Kohm, K.A. (ed.). *Balancing on the brink of extinction: The Endangered Species Act and lessons for the future*. Washington, DC: Island Press.

Rosenzweig, M.L. 1995. *Species diversity in space and time*. Cambridge: Cambridge University Press.

Tappe, P.A., Thill, R.E., Melchiors, M.A., and Wigley, T.B. 2004. Breeding bird communities on four watersheds under different management scenarios in the Ouachita Mountains of Arkansas. In *A symposium on ecosystem management research in the Ouachita and Ozark Mountains*, J.M. Guldin (tech. comp.), 154-163. General Technical Report SRS-74. Asheville, NC: USDA Forest Service.

Wigley, T.B., Baughman, W.M., Dorcas, M.E., Gerwin, J.A., Gibbons, J.W., Guynn, D.C. Jr., Lancia, R.A., Leiden, Y.A., Mitchell, M.S., and Russell, K.R. 2000. Contributions of intensively managed forests to the sustainability of wildlife communities in the South. In *Sustaining southern forests: The science of forest assessment*. USDA Forest Service, Southern Forest Resource Assessment. http://www.srs.fs.fed.us/sustain/conf/abs/wigley.htm

Wilson, E.O. 1988. The current state of biodiversity. 3-18 in Wilson, E.O., and Peter, F.M. (eds.). *Biodiversity*. Washington, DC: National Academy Press. 521 pp.

9.0 RELATIONS BETWEEN FORESTRY AND BIG GAME: DOES IT MATTER ANYMORE?

Black, H., Jr., Scherzinger, R., and Thomas, J.W. 1976. Relationships of Rocky Mountain elk and Rocky Mountain mule deer to timber management in the Blue Mountains of Oregon and Washington. 11-13 in *Elk-logging-roads: Proceedings of a symposium*. Hieb, S.R. (ed.). Moscow: University of Idaho, Forest, Wildlife, and Range Experiment Station.

Edge, W.D., Olson-Edge, S.L., and Irwin, L.L. 1990. Planning for wildlife in National Forests: Elk and mule deer habitats as an example. *Wildlife Society Bulletin* 18:87-88.

Giles, R.H., Jr. 1962. Timber-wildlife coordination concepts for large eastern forests. *Transactions of the North American Wildlife and Natural Resources Conference* 27:402-412.

Hobbs, N.T., and Hanley, T.A. 1990. Habitat evaluation: Do use/availability data reflect carrying capacity? *Journal of Wildlife Management* 49:814-822.

Morrison, M.L. 2001. A proposed research emphasis to overcome the limits of wildlife-habitat relationship studies. *Journal of Wildlife Management* 65:613-623.

10.0 NCASI'S BIG GAME PROGRAM: HIGHLIGHTS OF A DECADE OF RESEARCH

Bender, L.C., Fowler, P.E., Bernatowicz, J.A., Musser, J.L., and Stream, L.E. 2002. Effects of open-entry spike bull, limited-entry branched bull harvesting on elk composition in Washington. *Wildlife Society Bulletin* 30:1078-1084.

Cook, J.G. 2002. Nutrition and food. 259-349 in Toweill, D.E., and Thomas, J.W. (eds.). *North American elk: Ecology and management*. Washington, DC: Smithsonian Institution Press.

Cook, J.G., Cook, R.C., Bender, L.C., Hall, B., and Irwin, L.L. 2003**.** Nutritional influences on northwestern elk herds: Wild elk capture and nutritional condition assessment. Progress Report. La Grande, OR: National Council for Air and Stream Improvement, Inc.

Cook, J.G., Irwin, L.L., Bryant, L.D., Riggs, R.A., and Thomas, J.W. 1998. Relations of forest cover and condition of elk: A test of the thermal cover hypothesis in summer and winter. *Wildlife Monographs* 141.

Cook, J.G., Johnson, B.K., Cook, R.C., Riggs, R.A., Delcurto, T., Bryant, L.D., and Irwin, L.L. (2004). Effects of summer-autumn nutrition and parturition date on reproduction and survival of elk. *Wildlife Monographs* 155:1-61.

Cook, J.G., Quinlan, L.J., Irwin, L.L., Bryant, L.D., Riggs, R.A., and Thomas, J.W. 1996. Nutrition-growth relations of elk calves during late summer and fall. *Journal of Wildlife Management* 60:528-541.

Cook, R.C., Cook, J.G., Garrott, R.A., Irwin, L.L., and Monfort, S.L. 2002. Effects of diet and body condition on fecal progestagen excretion in elk. *Journal of Wildlife Diseases* 38:558-565.

Cook, R.C., Cook, J.G., and Irwin, L.L. 2003. Estimating elk body mass using chest-girth circumference. *Wildlife Society Bulletin* 31:536-543.

Cook, R.C., Cook, J.G., Murray, D.L., Zager, P., Johnson, B.K., and Gratson, M.W. 2001a. Development of predictive models of nutritional condition for Rocky Mountain elk. *Journal of Wildlife Management* 65:973-987.

Cook, R.C., Cook, J.G., Murray, D.L., Zager, P., Johnson, B.K., and Gratson, M.W. 2001b. Nutritional condition models for elk: Which are the most sensitive, accurate, and precise? *Journal of Wildlife Management* 65:988-997.

Cook, R.C., Murray, D.L., Cook, J.G., Zager, P., and Gratson, M.W. 2001c. Nutritional influences on breeding dynamics in elk. *Canadian Journal of Zoology* 79:845-853.

Smith, F.W., and Long, J.N. 1987. Elk hiding and thermal cover guidelines in the context of lodgepole pine stand density. *Western Journal of Applied Forestry* 2:6-10.

12.0 MYTH AND REALITY OF FOREST LAND USE IN THE UNITED STATES

Firey, W. 1960. *Man, mind, and land: A theory of resource use.* Glencoe, IL: The Free Press.

Jennings-Eckert, P. 1998. The social construction of a watershed: Changing rights and changing land. Ph.D. diss., University of Washington-Seattle.

MacCleery, D.W. 1992. *American forests: A history of resiliency and recovery*. FS-540. Washington, DC: United States Department of Agriculture Forest Service.

United States Department of Agriculture Forest Service (USDA FS). 2000. *2000 RPA assessment of forest and range lands*. Washington, DC: United States Department of Agriculture Forest Service.

United States Department of Agriculture Natural Resources Conservation Service. 2000. *Summary report—1997 National Resources Inventory* (revised December 2000). Washington, DC: United States Department of Agriculture Natural Resources Conservation Service.