Literature Review on Innovative Silviculture and Management Practices Supportive of Conservation Values

March 2009

Mark Swanson

Hiroo Imaki

and

Bruce Lippke

Working Paper 10

Rural Technology Initiative
College of Forest
Resources
University of Washington
Box 352100
Seattle, WA 98195-2100
www.ruraltech.org

Olympic Natural Resources
Center (ONRC)
College of Forest Resources
University of Washington
PO Box 1628
Forks, WA 98331
www.onrc.washington.edu

Literature Review on Innovative Silviculture and Management Practices Supportive of Conservation Values

March 2009

Mark Swanson

Hiroo Imaki

and

Bruce Lippke

Working Paper 10

Rural Technology Initiative
College of Forest Resources
University of Washington
Box 352100
Seattle, WA 98195-2100
www.ruraltech.org

Olympic Natural Resources Center (ONRC)
College of Forest Resources
University of Washington
PO Box 1628
Forks, WA 98331
www.onrc.washington.edu

Acknowledgements

This report was made possible by a grant from the Olympic Natural Resources Center with financial support from the U.S.F.S. Pacific Northwest Experiment Station. An early version of the literature review was funded by the Washington State Department of Natural Resources. The findings in the report hopefully mirror the results of the many pioneering research studies referenced in the literature review. Any opinions, findings, conclusions or recommendations in this report are those of the authors and do not necessarily reflect the views of contributing entities.

Abstract

In this literature review we identified over 700 articles following the Washington Forest Landscape Management Project, (WFLMP), which provided one of the early attempts to understand the implications of innovative silviculture and landscape management on conservation values. We enumerate many of the alternative treatments and important elements starting with the WFLMP while noting the several research pathways that developed from that work. We do not attempt to highlight the impact of each referenced article but follow the several directions research has taken and rely on the emphasis provided through several publications and conferences that have attempted to provide a comprehensive summary and review of the literature.

Keywords: Landscape management; biodiversity; habitat suitability; wildlife models; innovative silviculture; spatial forest planning; endangered species protection; harvest scheduling; optimization; meta-heuristic; spatial and temporal landscape patterns; spatial explicit wildlife model; multi-species approach; GIS.

Table of Contents **Page**

Background and Introduction

In June 1988, with intensifying public debate about forest management and ecosystem protection, Brian Boyle, Commissioner of Public Lands, established the Commission on Old Growth Alternatives for Washington's Forest Trust Lands. The Commission brought together 32 diverse "stakeholder group" representatives. Their mission was to develop consensus recommendations for the Washington Department of Natural Resources (DNR) on how to balance the goals of providing revenue for education, protecting the biological diversity of the forest environment, and supporting local timber-dependent communities. Commission recommendations included the establishment of the 264,000-acre Olympic Experimental State Forest (OESF) on the western portion of the Olympic Peninsula as a commercial forest within which there would be a special opportunity to research harvest and regeneration methods to enhance habitat characteristics and commodities production. To focus and coordinate the long-term research program for the OESF, the Commission recommended creation of the Olympic Natural Resources Center, or ONRC (Commission on Old Growth Alternatives 1989). These investments in experimental research capacity reflected a broader trend in the field of forest management, in which the desirability of maintaining the inherent complexity and array of functions of natural forest ecosystems is recognized. Prominent Washington forest scientists offered papers suggesting that modifications to commercial forest management could achieve ecological benefits and accelerate development of desired old forest habitat structures while generating forest products and economic returns (Franklin 1989, Oliver 1992).

In 1993, the Washington Forest Landscape Management Project (WFLMP), funded by the U.S. Congress and facilitated by the DNR (Carey *et al.* 1996), created for the first time a broad multi-disciplinary research group with the objective of determining the advantages of simultaneously managing forests for multiple species of threatened, endangered, and sensitive wildlife over large landscapes and across different ownerships including economic considerations. It was hoped that innovative approaches to forest management could integrate species habitat enhancement with harvest of forest resources to maximize environmental benefits and reduce the costs of species conservation on society. Many ideas about the impacts of changing forest structures on species conservation were discussed and evaluated by the study team. The WFLMP provided the first interdisciplinary opportunity to evaluate the potential costs and benefits of intentionally managing forest stands to restore old forest functionality following harvests and other anthropogenic disturbance. The management treatment strategies developed by the WFLMP scientific team became known as biodiversity pathways, or 'biopathways', designed to intentionally produce old forest habitat conditions through active management at a much lower cost than no-action or passive alternatives. From a literature review perspective, the project considered 150 then-current publications such that projects after 1996 generally had the benefit of the integrative work provided by the project. The project produced many publications (e.g., Carey, Eliot *et al.* 1996, Carey, Thysell *et al.*1996, 1999; Lippke *et al.* 1996) and began a decade of additional scientific research into the effectiveness of biopathway treatment regimes as compared to no-harvest reserves and commercial or longer than commercial rotations.

In this literature review we identified over 700 articles following the WFLMP with implications for innovative silviculture and landscape management. We enumerate many of the alternative treatments and important elements starting with the WFLMP while noting the several research pathways that developed from that work. We do not attempt to highlight the impact of each referenced article, as this approach would be too long for a useable synthesis. Rather, we follow the several directions silvicultural and forest landscape research has taken, and we rely on the emphasis provided through several publications and conferences that have attempted to provide a comprehensive summary and review of the literature.

Biodiversity Management and Protection Pathways

The distinguishing features of "biodiversity pathways" developed in the WFLMP included retention of biological legacies at harvest, plantation and natural regeneration for mixed species forests, pre-commercial thinning to quickly bypass the stage of competitive exclusion in dense young stands, thinning at variable densities in maturing stands, extending final harvest rotation lengths through multiple entry thinning, and creation of snags and downed woody debris. The range of options examined has been largely oriented toward thinning earlier or later while retaining less or more trees over time with consideration for retention of legacy trees, stumps and debris. Riparian buffer management incorporated similar thinning treatments with extra attention to stream bank stability, sufficient vegetative and overstory retention for shade, and recruitment of large woody debris (LWD). Direct measures of forest ecosystem health were largely related to the capacity to support vertebrate diversity, forest floor function for mammals, ecological productivity based on the abundance of arboreal rodents as a critical element of the food chain and production of large vertebrates. These functions/proxies were developed as indices to estimate the ecological impacts of alternative management approaches.

The biodiversity pathways approach emphasizes changes in forest structure based on growth model simulations, which were analyzed statistically and spatially. The structural composition changes were shown to restore forest stand structure distributions more like those present before European settlement, albeit at a cost to landowners.

The spatial patterns were less revealing since the size of treatment areas was dictated by prior treatments and stand boundaries and regulatory or operational limits on the treatment scale. While biodiversity pathways on the entire landscape produced what were considered to be better spatial distributions for late seral forests, there were few interior species that would benefit. The spotted owl was believed to be more negatively affected by aggregated cuttings than dispersed (Carey *et al.* 1992, Carey and Peeler 1995). Other studies found no effects from interior forest management alterations and further concluded that no species of concern were "associated" with (benefited from) "competitive exclusion" of dense closed-canopy structures (Hansen *et al.* 1993). The conclusion that no species benefited from competitive exclusion structure, with most species negatively affected, has provided strong motivation for biopathway thinning in forests with a legacy of commercial management. The dominant forest structure class associated with commercial rotations (or no-action alternatives in previously-harvested forests) following regeneration strategies is competitive exclusion. This forest condition can potentially last for much more than a century following full stocking regeneration if stem densities are not reduced by thinning treatments or disturbance. As a result, many studies have emphasized the need to reduce stem densities and avoid or reduce the prevalence of closed-canopy competitive exclusion as important to achievement of biodiversity goals and old forest habitat objectives (Oliver 1992, Poage 2000, Poage and Tappeiner 2002, Acker *et al.* 1998, Agee 1991, Carey *et al.* 1999, Hayes *et al.* 1997, Garman *et al.* 2003, Tappeiner *et al.* 1997, Bailey and Tappeiner 1998).

Functional equivalents of the biopathways approach have been developed for forests in other regions, such as the broadleaf forests of New England. At a spatial scale of the individual stand, the use of rotated-sigmoid diameter distributions in combination with specific strategies to enhance structural richness (e.g., snag creation, crown release of vigorous trees, etc.) can further contribute to these objectives (Keeton 2006, Kenefic and Nyland 2000). Lindenmayer and McCarthy (2002) propose similar alterations to intensive forest management in southeastern Australia to conserve fauna dependent on old, hollow trees and intact forest landscapes. Application of these recommendations in landscapes will validate degrees of effectiveness over the long time scales necessary to conduct research in forested landscapes.

Measuring the Biological and Economic Success of Pathways

Development of quantifiable and statistically robust measures of ecosystem health with which to assess the comparative success of alternative management treatments has been a challenge for researchers. Early studies were constrained by limited empirical stand data and with limited statistical analysis enriched by expert opinion. Gehringer (2006) developed a non-parametric statistical target of old forest conditions by analyzing actual old and previously not harvested forest inventory data and determining the attributes that most reliably discriminate those stands from all others. Following this analysis Gehringer was able to create management targets to test for development of old forest characteristics within a confidence interval representative of an old forest range of variability for Western Washington. Gehringer found that trees per acre, diameter and height were the dominant metrics of interest that differentiated old forest characteristics. When simulated treatments and growth for forest stands are modeled forward in time then the point at which stand characteristics resemble those of the target older forests can be identified. Two important performance metrics for assessing comparative old forest treatment options emerge: which treatments create desired conditions soonest and which treatment regimes most successfully extend the duration of time in the old forest target. Other variables thought to be important to habitat such as coarse woody debris (CWD) were characterized by such large variance that they did not provide a discriminating function for old forests. However, CWD may be a discriminator of better habitat for some critical species (Bunnell *et al.* 1999), and can be used as a fine filter discriminator to identify selected species habitats within the broader class of old forests (Zobrist and Gehringer 2004). Other metrics include an index of old growth (Acker *et al.* 1998), which has been used to quantify the rate of structural development in unmanaged Douglas-fir stands (Larson *et al.* 2008). Stand-level diameter distributions are also useful for quantifying differences between structurally simple young stands and complex, multi-cohort late-successional stands (Zenner 2005), especially under chronic disturbance regimes (D'Amato *et al.* 2008).

Simulated treatment activities such as thinning harvests can be used to forecast potential log yields and economic returns. Old forest structure targets and simulated economic returns provide a means for identifying least-cost pathways for achievement of biological forest targets. Similar methodologies for statistical discrimination between forest conditions have been explored by Lundquist (Lundquist & Beatty 1998, Lundquist & Lidner 2000).

Zobrist *et al.* (2005a) used the Gehringer procedure to determine the most economic pathways to reach old forest structure targets. The method was to inform forest management options within riparian zones in the PNW Douglas-fir zone as well as to aid development of legacy structures in the U.S. Southeast, a project supported by the National Commission on Science for Sustainable Forestry, NCSSF (Zobrist *et al.* 2005b). A similar approach was used to investigate management options for old forests and spotted owl habitat on the DNR Olympic Experimental State Forest (Lippke, *et al.* 2007). The performance metrics for a zone-specific target of old forests with their discriminating structural differences were used in all these studies to identify which treatments most successfully reach the structural target objective at the lowest economic costs.

Habitat Suitability Models

Other forest structure research efforts have targeted the development of various habitat suitability measures for individual species, which are logically more sensitive to detailed segmentation of forest structure classes. The U.S. Fish and Wildlife Service developed a habitat evaluation procedure (HEP) (USDI 1980) based on characterizing the forest in a number of discrete conditions in order to provide the inputs for habitat suitability models. These methods were automated for a study in Western Washington that used a stand-level simulation model to conduct habitat suitability tests, demonstrating repeatability in evaluation methods (Ceder *et al.* 2002a, Marzluff *et al.* 2002).

Johnson and O'Neil (2001) developed a wildlife-habitat model that covers entire vertebrate communities in Washington and Oregon. This habitat model recognizes three factors: wildlife habitats = wildlife cover type(s) plus structural condition(s) plus habitat element(s). Wildlife cover types refer to vegetation classifications that were determined based on similarity of wildlife use. Structural conditions describe the forest structure at the stand level. There are a total of 26 structural conditions defined by tree size, percent canopy cover, and the number of canopy layers. Finer scale habitat features are habitat elements such as downed logs and snags. The resulting Johnson and O'Neil wildlife-habitat matrix associates species types with 26 habitat structural conditions further defined by three habitat qualities: closely-associated, generally-associated, and present. Although habitat elements are considered important components in habitat models, elements are too variable and species-specific to generalize in the Johnson and O'Neil's wildlife-habitat model although potentially important at the site or forest type level.

Habitat suitability measures are useful tools for analysis but currently lack sufficient data to be as statistically robust as the Gehringer approach. As more data is collected on species-specific habitats, statistical links between habitat suitability and forest structure class will logically improve. However, another problem with classification systems is that habitat definitions tend to be limited to "in or out" rather than probabilistic gradients and consequently can exhibit knife-edge properties relative to management simulations obscuring performance at the margin (University of Washington College of Forest Resources 2007).

Models integrating a non-binary perspective on habitat utilization are more likely to offer insights into landscape and stand influence on vertebrates (Marzluff et *al.* 2004, Folliard *et al.* 2000). The former focus in landscape ecology on the patch-mosaic model of landscape structure is being enriched by an understanding that many phenomena occur as gradients in landscapes (McGarigal and Cushman 2005). This is reflected by the use of logistic regression models parameterized at multiple scales to assess the importance of landscape context (including the abundance of various structural classes of forest) in determining organism abundance or viability (e.g., White *et al.* 2005, Daw and DeStefano 2001). These models can then be used to create maps of probability gradients, assess actual landscapes for areas of high-quality habitat, or plan restoration treatments that will create appropriate combinations of landscape elements.

Variable Densities and Variable Retention

Research on the ecological impacts of biopathways silvicultural interventions is still in formative stages. Individual tree growth in variable density units tends to vary as a function of proximity to gaps and whether the tree is in the thinned matrix of the unit (Roberts and Harrington 2008). While variable densities were considered important in the early biodiversity pathway work (Carey *et al.* 1996), natural variation as well as variation induced from equipment impacts made it difficult to establish useful measures of density within otherwise uniform stand structures. Thinning clearly favors the development of shade-tolerant trees in the understory of stands in the competitive exclusion/biomass accumulation stages (Chan *et al.* 2006). Underplanting may have to be employed to accelerate this process, especially when seed sources for shade-tolerant conifers are distant (Beach and Halpern 2001). A meta-analysis of thinning impacts on understory vegetation (Wilson and Puettmann 2007) found that variable-density thinning increased spatial variability in understory communities, but effects on richness varied from case study to case study, often as a function of past site management. Concerns regarding potential for wind damage related to larger openings associated with variable-density thinning were allayed by Roberts *et al.* (2007), who found no difference between unthinned controls and treatment plots. Certain taxa may benefit from variable-density thinning, such as litter invertebrates (Schowalter *et al.* 2003). Many of these results await confirmation over longer time scales and application in other forest types, but the results of current research favor the concept that spatially variable thinning is an effective, ecologically-based method for enhancing complexity and diversity in young forest stands.

Disturbance in forest ecosystems, by definition, kill or remove trees and other organisms (Pickett and White 1985). Most natural disturbance processes, however, tend to leave a variety of living or dead structures as biological legacies (Franklin *et al.* 2000). These legacies promote ecosystem recovery (e.g., Keeton 2000) and the persistence of a wide variety of organisms at multiple spatial scales. It has been proposed that retaining structures at harvest can capture some of the functional benefits of biological legacies within the context of the managed forest environment (Franklin *et al.* 1997, Mitchell and Beese 2002). Variable retention has been shown to be effective for the conservation of understory plant communities (Nelson and Halpern 2005), water quality (MacDonald *et al.* 2003), lichen communities (Esseen *et al.* 1996), and other values. Ectomycorrhizal fungi have been found to be more abundant in the vicinity of retained individual trees (Cline *et al.* 2005), with proximity to patches is relatively more important than the size of the patch itself (Jones *et al.* 2008). A meta-analysis of research on green tree retention (variable retention) demonstrated the utility of the approach for maintaining organisms from several important functional groups, such as dispersal-limited lichens, birds, and ectomycorrhizal fungi (Rosenvald and Lohmus 2008).

Survival and growth of retained trees is a major concern when applying variable retention harvest strategies. Survival is often influenced by tree wounding during the harvest or proximity to skid trails (Thorpe *et al.* 2008), and wind firmness is a major consideration when selecting trees for retention. Healthy, uninjured trees (even in older age classes), however, typically respond well to the release provided by a variable retention harvest event (Latham and Tappeiner 2002, Bebber *et al.* 2004). Experience in wet sclerophyll forests of Tasmania demonstrates that variable retention may aid in regeneration of species-rich forest communities by reducing dispersal distances (Tabor *et al.* 2007), and that while windthrow may damage retained trees, old-growth individuals tend to be relatively windfirm (Neyland 2004). Additionally, the retention of undisturbed forest aggregates in Tasmanian forest has been shown to favor amphibians (Lauck *et al.* 2008) and beetles (Baker *et al.* 2007).

Experimental On-the-Ground Treatments

Most early work on innovative silviculture to promote conservation values relied on simulations as the historical data on past treatments was generally lacking. This prompted a series of experimental studies, collectively known as the Capitol Forest Study, to apply different treatments on the ground in sample plots to estimate cost and environmental benefit over time (Curtis *et al.* 2004). Located on public land in Washington State, this is an exemplary experimental effort aimed at clarifying the impacts of various silvicultural treatments on the structure and composition of Douglas-fir stands in the competitive exclusion stage. These studies, unlike many from the ecological literature, provide useful operational cost information; however, the impacts on ecological measures are only now beginning to have enough maturation time to be indicative of the future. Future monitoring will help to determine comparative environmental effectiveness.

Silvicultural research to assess the efficacy of different timber harvest regimes in maintaining habitat values or ecosystem processes have shown the value of various modifications of traditional timber harvesting. The DEMO study (Aubry *et al.* 2004) has produced a number of studies on stand-level response to various forms of variable retention, some of which have been discussed in the section on variable retention.

Silvicultural experimentation has not been limited to the creation of later-successional structural conditions, however. An excellent example may be found in the oak forests of the Puget Sound region in western Washington, where partial and full crown release prescriptions have been shown to be effective in restoring vigor to overgrown Oregon white oak (Devine and Harrington 2006).

At Fort Lewis in Western Washington, Churchill (2005) showed that on dry-sites Douglas-fir can grow in the understory and maintain its release potential for at least 20 years under moderate overstory stocking levels (30-55% full stocking). His results indicate that by combining elements of shelterwood, group selection, and single tree selection systems, multi-cohort, structurally complex stands can be created and maintained in a shifting mosaic of patches while also producing significant wood volume over time.

Historic stand conditions cannot be duplicated rapidly following either stand replacement fires or high volume timber harvests.

Dry pine forests present a further set of restoration challenges, since these forest types have experienced exploitative timber extraction, fire suppression, and agricultural conversion. Everett *et al.* (2007) provide a unique analysis of history based on stand reconstructions over 150 years. They concluded that in pre-settlement forests landscapes varied greatly with many structural stand types reflecting different stages of recovery from multiple disturbances of varying intensity and frequency but had a well-represented tree-understory with very few dead and down fuels. Following euro settlement, decreased fire effects allowed existing understory to continue development, which increased stand density and the proportion of shade tolerant species. Under fire suppression, landscape diversity of forest structure has been lost with a decline in early succession stages and an increase in old forest structure (Everett *et al.* 2008). Stands are currently transitioning from high post fire suppression tree densities to less dense stands as insect and pathogens thin stands from above and below. This stand thinning process has increased amounts of dead and down wood, previously maintained at low levels by frequent surface fires. Although the dry forest landscape has always operated under a mixed fire regime, the proportion of landscape subject to high severity fires has increased over the last several decades reflecting unsustainable conditions (see also Hessburg *et al.* 2005). Both forest structure and disturbance regimes are evolving. Restored landscape and forest structures will need to be sustainable under disturbance regimes that differ significantly from euro settlement conditions. Restoration objectives that include thinning and prescribed fire to emulate the inherent disturbance regimes of the area will also need to reflect post settlement socio-economic expectations.

Research in the forests of the Southeast has shown that it is possible to restore old-growth longleaf and loblolly stands through modified group selection and single-tree selection, the application of prescribed fire, and the introduction of spatial heterogeneity (Bragg *et al.* 2008, Brockway *et al.* 2002). Experimental silviculture in the Ouachita Mountains of Arkansas has focused on restoring shortleaf pine stands formerly maintained by fire (Guldin 2004). Research in ponderosa pine ecosystems in the Black Hills (Shepperd and Battaglia 2002), the interior Pacific Northwest (Youngblood *et al.* 2006), and the Southwest (Allen *et al.* 2002) indicate that restoration of coarse woody debris, retention of large-diameter pines, reintroduction of fire, and creation of spatial complexity (gaps, clusters of trees, and randomness at various spatial scales) are important elements that diverge from traditional tenets of silvicultural practice. Arno and Fiedler (2005) examine long research histories from a number of western forest types where carefully applied silvicultural treatments and the resumption of historic fire regimes lead to a host of ecological, economic, and social benefits.

Temperate systems from around the world offer similar experiences. For example, silvicultural trials at Warra, Tasmania, in eucalyptus-dominated stands show benefits to creation of ecological complexity within stands and restoration of elements of natural disturbance regimes (Neyland 2004).

Stand Variability Over Greater Spatial Scales

Lindenmayer and Franklin (2002) focused on enhancing biodiversity with the perspective that the scale requirements can not be met by partitioning off some lands as reserves while other lands are used for intensive timber production. They characterized a checklist for achievement of forest biodiversity conservation across a landscape based upon a matrix of conditions needed. A number of cases studies were summarized to highlight the contribution of a variety of landscape characteristics.

Important areas: The Lindenmayer and Franklin checklist begins by identifying important areas that need to be protected. Important areas include aquatic systems such as stream networks and wetlands, wildlife corridors, specialized habitats such as cave and thermal protection, biological hotspots, and remnants of late successional and disturbance refugia such as forest areas with no prior history of harvest.

Culturally and socially important areas are identified for protection as well. These areas are mid-spatial scale and are to be given special consideration before making a forest management plan.

Aquatic ecosystems: Protecting aquatic ecosystems are given special attention as uniquely important to biodiversity in a forested landscape (Naiman *et al.* 1993, Naiman *et al.* 2000, Brinson and Verhoeven 1999, Calhoun 1999). Sixty percent of 480 wildlife species were observed in riparian forest in Washington State (Raedeke 1988). Important roles of riparian forests are 1) light and water temperature control, 2) organic matter inputs, 3) bank protection, and 4) source of large woody debris.

Selection of the appropriate widths and lengths for streamside corridors should be based on the objectives of the buffer and the spatial pattern of relevant influences (Lindenmayer and Franklin 2002). Recruitment of large woody debris is a good example. Relatively narrow buffers (e.g. 10 meters or less) have generally not been considered adequate to address the biological and physical interactions between riparian forests and streams. The Forest Ecosystem Management Team (FEMAT 1993) created one standard that uses a site-potential tree height to define protection areas (the more productive the site; the wider the buffer). Two tree heights for fish-bearing streams and one tree height for other small streams were used as standards for federal lands in the northwestern United States. However, these standards were arbitrary, based upon expert opinion, and not derived from effectiveness studies. Effectiveness studies (Cross 2002, Ice 2000, NCASI 2000) tend to show the vast majority of the LWD, shade and particulate matter available to streams are concentrated in the first ten meters. Microclimatic impacts, however, may not be attenuated with narrower buffers (Brosofske *et al.* 1997). The length of protection along the stream is also an issue since low order streams are more common and have been difficult to identify (University of Washington College of Forest Resources 2007, DP7). A final issue is related to management on migratory floodplains, since buffers established adjacent to the current channel position will be insufficient to accommodate fluvial shifts in the channel (Naiman *et al.* 2000).

Lakes, ponds, and other wetlands are considered important elements within aquatic ecosystem that are afforded special protection when landscape management plans are developed. The Northwest Forest Plan (USDA Forest Service and USDI Bureau of Land Management 1994a, b) assigned two site-potential tree heights to protect forests around lakes and natural ponds and one site potential tree height for other wetlands.

One provocative discussion that grew out of the WFLMP was that not all riparian protection steps are equally productive such that consistent width buffers are much lower in effectiveness than more site-specific criteria could be (Reeves and Benda 1995, Reeves *et al.* 2004). In particular, low gradient pools for salmon rearing and the LWD important to their formation were considered of high importance. Only certain elevation profiles, streams banks and stream configurations likely to contribute LWD are critical in the formation of these pools. Greater protection from urban influences was thought to be more important than needed for rural areas. While these and other elements were considered of high priority and could potentially support more effective criteria for management, there does not appear to be a direct body of research quantifying such relative priorities as a part of management planning.

Road networks: Because road networks can heavily influence sediments and organic materials supply to wetlands, road location and construction in order to minimize sediment is another important forest management consideration (Lindenmayer and Franklin 2002). While there exists a substantial body of literature on sediment management it is generally beyond the scope of this review.

Skid roads in thinning units may contribute to spatial variability in stand structure, as well as sites for establishment of shade-tolerant trees (Nyland 2002). For example, bats may utilize roads and trails for travel between feeding (Hayes and Loeb 2007). Additionally, demographic processes such as post-harvest tree mortality (a source process for snag/downed wood) may be influenced by the proximity of skid trails (Thorpe *et al.* 2008).

Wildlife corridors: Wildlife corridors have been assumed by some scientists to be an important element for landscape management (Noss 1987); however, the research evidence has not always supported this assumption. For example, the hypothesis that corridor structure facilitates northern spotted owl dispersal was rejected (Thomas *et al.* 1990, Murphy and Noon 1992). Conversely, however, Verboom and Huitema (1997) reported that population densities of some bats were positively correlated to the existence of wildlife corridors. Instead of supporting animal movement, migration, and dispersal, there is some evidence that corridor-like linear strips of forests serve as residential habitat instead of migration or dispersal habitat (Bennett 1998). For some species, riparian forest buffers may work as wildlife corridors. The difficulty in proving the usefulness of wildlife corridors originates partly in the difficulty of defining wildlife corridors in a landscape. Therefore, the effectiveness of wildlife corridors in forest planning may need to be considered on a species-by-species basis with better-developed spatial arrangements. Bailey (2007) notes that organisms of intermediate dispersal ability benefit most from this type of connectivity, and calls for further empirical work into the utility of corridors for the conservation of biological diversity.

Geologic features: Specialized habitats such as cliffs, caves, thermal habitats, meadows, and vernal pools were identified as needing special attention. Calving sites for ungulates, high-quality spawning habitat for fish, foraging sites with rare but essential food resources, overwintering habitat areas were also to be considered for special attention (Lindenmayer and Franklin 2002).

Harvesting and natural disturbances: Spatial and temporal arrangement of harvest units were identified as important in landscape-level forest management. The size of harvest units, levels of structural complexity retained within units, and time interval between rotations and temporal arrangement of harvest units and their management prescriptions were all identified as important considerations (Lindenmayer and Franklin 2002) and are covered in considerable depth under the spatial management sections of this review.

While young stands do not develop features associated with old forest species such as the spotted owl, heavy thinnings at 50 and 80 years were considered more effective than not thinning (Andrews and Perkins 2005). In effect long rotations without thinnings are less effective both economically and for producing old forest-like conditions. Multiple treatment approaches may also help to mimic the variability of natural disturbance regimes. Lindenmayer and Franklin (2002) summarize stand-level management methods by including biodiversity pathways, dispersed retention, aggregated retention, variable retention harvest systems, variable-density thinning, and snag creation.

Longer rotations have been linked to greater biological diversity (Lindenmayer and Franklin 2002, Oliver 1992, Carey *et al.* 1999). However, extended rotations result in losses of economic return that, without compensation, will limit acceptability. A range of rotation periods instead of a single rotation period has been proposed. Multiple rotation ages better mimic the variability in frequency of natural disturbance regimes (Seymour and Hunter 1999), and short rotations on certain sites may enhance certain structures that benefit biodiversity (e.g., aspen stands, Arno and Fiedler 2005).

A useful frame of reference that has been used by researchers is natural disturbance history. Disturbance regimes have been developed to imitate landscape patterns caused by natural processes. Natural disturbance regimes are divided into two classes, 1) intense episodic disturbance regimes and 2) chronic disturbance regimes. Intense episodic disturbance regimes are defined by catastrophic stand-replacing disturbances such as forest fire and floods. However, the scale of size and time of episodic disturbance regimes are usually much larger than can be implemented on the ground. Therefore, only a few cases have employed intense episodic disturbance regimes (Cissel *et al.* 1998, 1999). Events associated with many chronic disturbance regimes occur at smaller spatial scales than those associated with episodic disturbance regimes, and are common in landscapes with frequent wind disturbances or insect/disease patches (Deal and Tappeiner 2002). Gap based timber harvesting or group selection may mimic the spatial effects of many chronic disturbance regimes (Lindenmayer and Franklin 2002). Silviculture based on chronic disturbance regimes is intended to create spatially complex landscape structures through the use of relatively small harvesting units. The current management plan for federal lands throughout the Sierra Nevada provides one example of a project emulating a chronic disturbance regime (USDA Forest Service 2001).

In the New England landscape, agricultural clearing and subsequent abandonment of farmlands and imposition of patch clearcutting timber harvest regimes have resulted in substantial, measurable changes to forest landscape patch size distribution, stand composition, and structures such as woody debris (Seymour *et al.* 2002, Howard *et al.* 2005). Seymour *et al.* (2002) emphasize the shift from intermediate-scale clearcutting to a within-stand, gap-based cutting system to regenerate the species composition and structure of historic stands in addition to restoring the large, chronically disturbed landscape patches of historic New England. Such approaches are being investigated for other parts of the world, such as the true-fir/European beech forests of southeastern Europe (e.g., Nagel and Svoboda 2008) and the southern beech forests of southern Argentina and Chile (e.g., Martínez-Pastur *et al.* 2000).

The many reports on thinning cited earlier are largely focused on achieving outcomes similar to the impact of disturbances (Bailey and Tappeiner 1998, Carey 1998, Tappeiner *et al.* 1997). Bailey and Tappeiner (1998) noted substantial structural differences by different thinning treatments contributing to diversity and complexity but that there were greater differences in response across sites than across stand types suggesting stand locations are very resilient in restoring prior growth and structural conditions after disturbances.

The dispersed management model that spatially distributes harvest units across a landscape has been applied by many government agencies. The dispersed management model is appealing since it creates heterogeneity across the landscape. However, there are disadvantages as well, including negative impacts on biodiversity (Franklin and Forman, 1987), average patch size and interior habitat reduction, edge habitat increase, and increase in wind susceptibility (Sinton *et al.* 2000). Many of these issues are related to lack of congruence with the spatial characteristics of the natural disturbance regime. Lindenmayer and Franklin (2002) recommend diversifying landscape-level approaches by imitating natural disturbance regimes as much as possible in harvest planning.

Internal structural complexity can be enhanced through live tree retention and partial cutting. The retention harvesting approaches and partial cutting can result in increased capacity to sustain biodiversity, increased structural complexity, and reduced edge impacts (Lindenmayer and Franklin 2002). Many different partial cutting and patch cut regimes have been proposed (Curtis *et al.* 2004). Beese and Bryant (1999) reported species richness and abundance greater just 3 years after a shelterwood harvest, but with different levels of canopy retention potentially having “drastic” effects on breeding birds. A comparison of clearcuts, mature forest, and shelterwoods in northern New Hampshire showed that shelterwood units had higher bird species richness and diversity than either clearcuts or mature forest (King and Degraaf 2000). Understory re-seeding was reported to improve plant diversity over natural regeneration (Adams and Zuo 1998), and the underplanting of conifers in managed riparian zones may also accelerate the development of structurally complex riparian forest (Beach and Halpern 2001). Since this was believed to be a response to broader access to seed species variation, it may be become more important with climate change as it would likely speed-up the prevalence of more resilient species.

Harvest unit size and shape are considered important in landscape-level forest management. The size of interior habitat required for target species and edge/interior ratio can provide one index (Hof and Joyce 1992, 1993; Bevers and Hof 1999; Ducheyne *et al.* 2006; Wei and Hoganson 2006). Bayne and Hobson (1997) did not find fragmentation contributed to predation and that forest patch harvesting may not be a serious problem. In other studies (1998) they reported the impact of fragmentation to be largely species specific with some doing better and others worse with the impact of total habitat the more dominant predictor. They noted many species did better outside of isolated patches of dense older forests. The conclusion that a variety of stand types is needed to meet the needs of all species is frequently noted (Chambers and McComb 1999, Oliver 1992, Daw and DeStefano 2001). Spatial connections between different habitat types are also noted in the literature; for example, Mladenoff *et al.* (1993) noted that connectivity between riparian forest and upland old growth has been disrupted in managed vs. unmanaged forest landscapes by timber harvest regimes that spatially differ from the natural disturbance regime. The early work on biodiversity pathways concluded that while sequencing different treatments had some impact on creating diversity in structures across the landscape, regulations and guidelines limiting the size of harvests or other treatments were more important in determining ultimate outcomes (Carey *et al.* 1996).

A meta-analysis on the impact of patch sizes (Bender and Contreras 1998) concluded that generalist species were sensitive to total habitat, not configuration; interior species experienced somewhat greater loss than others from fragmentation while edge species experience somewhat less loss; and migrating species less loss than resident species. McGarigal and McComb (1995) found that bird abundance for several common forest birds in western Oregon increased in relatively fragmented landscapes. Fragmentation would appear to be most important to just a few species for management planning. Boutin and Hebert (2002) believe that landscape structure (fragmentation) has been overemphasized for some landscapes and that threshold effects that can be better detected by spatial modeling comparisons to natural disturbance regimes will become more important. For some organisms and processes, fragmentation is a serious concern, but it must be carefully disentangled from co-occurring processes such as simple habitat loss in order to design effective conservation strategies (Fahrig 2002, Lindenmayer and Fishcher 2006).

Consideration of disturbance processes operative at landscape scales is also critical to the success of forest management. The enhanced contiguity of forest stands vulnerable to fire, disease, and insect infestation in the inland Northwest is a result of prolonged fire suppression in a system once characterized by short fire return intervals (Hessburg *et al.* 2000, Hessburg *et al.* 2005). Recommended silvicultural treatments would focus on restoring the spatial interspersion of patch types, reducing density in pine and Douglas-fir stands, and conserving late-successional, complex forest at points in the landscape where the biophysical environment would have historically favored them (Camp *et al.* 1997).

Many of the advances in conceptual and empirical understanding discussed here reflect a trend towards recognizing that management imperatives are derived from considerations at multiple spatial scales. Hummel and Barbour (2005) employ the term “landscape silviculture” to demonstrate coordination of silvicultural activities across multiple spatial scales to achieve objectives. This is an important trend that diverts focus from standard operational scales of focus such as the production area and harvest units.

Effectiveness measures

While there would appear to be some support in the literature for the concepts of biodiversity enhancement as described above, the depth of research studies that include effectiveness is limited, long-term conclusions potentially premature, and many of the concepts would be difficult to implement technically as well as economically. Such approaches are natural outgrowths of efforts to preserve or restore naturally found conditions rather than to characterize effectiveness measures for integrated management. One difficulty with characterizing the effectiveness across such large scales is how to measure the benefits. Statistical measures across large scales reveal the substantial variation associated with habitat and old forest functionality. While this validates conceptually the idea that substantial variation in forest conditions across the landscape has been the historic precedent, it is still difficult to determine what treatment to apply where for what result. Spatial analysis has emerged over the last two decades as a means of quantifying more directly the impact of any given set of treatment strategies. A substantial body of the literature has attempted to assimilate the latest landscape-level forest management studies that focus on the effects of spatial and temporal forest stand management arrangements on ecological as well as economic outcomes.

Spatial and Temporal Forest Stand Management Modeling

Recent spatial forest planning studies that provide methods to optimize both economic and ecological outcomes through managing forests are summarized in this section. After "new forestry" was proposed by Franklin (1989), various forest management approaches that consider landscape-level parameters into account have evolved under the general topic area of spatial modeling. Early approaches often dealt with treatments at the stand or multi-stand level. Difficulties in developing landscape-level forest management methodologies originated from the need to consider both large scale and diverse parameters. Parameters that need to be considered in landscape-level management include stand shape, size, location, juxtaposition, timing of harvesting and thinning, stand level treatments, and other economic and ecological constraints. It is difficult to set up landscape size silvicultural experiments and set aside the area for a period of time long enough to collect sufficient data. Therefore, simulation studies became an alternative way to explore landscape-level forest management.

Multi-Stand-Level Approaches

Franklin and Forman (1987) and Li *et al.* (1993) explored the possibility of implementing landscape objectives such as patch size, edge length, and patch configurations into a forest management plan. They examined only clear-cutting patterns in a static landscape. To make their simplistic approaches more applicable in real situations, Baskent and Jordan (1996) and Baskent (1999) developed the management design model LANDMAN and a landscape pattern analysis model, PATREC. LANDMAN was developed to explore forest landscape design under different management strategies. In their approach, general landscape management strategies such as scatter harvesting, cluster harvesting, edge progressive harvesting, and nuclei progressive harvesting are pre-defined, while spatial objective variables and intervention strategies can be developed. Li *et al.* (2000) integrated their landscape model, LEEMATH, with a habitat suitability model to aid in management decisions. However, their approaches did not have the capability to optimize both economic and ecological goals through a mathematical optimization process. Aside from the forest landscape management approaches, landscape considerations in harvest scheduling have been developed in operational research studies. Spatial components within a harvest scheduling process started in 1990 and optimization studies for timber revenue or volume with wildlife habitat objectives have also increased (Bettinger and Chung 2004). Since the goal of forest landscape management and optimization studies with wildlife habitat constraints have common objectives, both ideas can be integrated into spatial forest planning.

Spatial Forest Planning

Spatial forest planning accommodates spatial requirements as well as multiple, often conflicting, management objectives over a landscape (Baskent and Keles 2005). It uses a mathematical optimization approach such as linear programming, simulation, or heuristics to achieve conflicting goals in an optimal manner. Spatial requirements often relate to size, shape, juxtaposition, and distribution of management units, minimum and maximum harvest block size limits, adjacency restrictions, connectivity and proximity, and interior and edge habitat availabilities. Spatial forest planning focuses on forest management activities and the specific tools used to develop, implement, and evaluate spatial forest plans and alternative policies (Bettinger and Sessions 2003a). In spatially managed forests, each stand is treated as an individual component and its relative location to other stands is considered. Spatial forest-planning problems are often solved through optimization calculations in order to achieve all management goals in an efficient manner. Outputs from optimization can be graphically presented using geographic information systems (GIS), and utilized in planning processes as well as communication with interest groups.

Bettinger and Session (2003b) pointed out several reasons to adopt spatial forest management approaches over other traditional non-spatial approaches. First, some public agencies charged with managing resources for the public good operate under a wide variety of regulations that include landscape considerations such as limiting the size of clearcuts and maintaining core area requirements for wildlife (Oregon Secretary of State 2002). Second, voluntary programs such as the Sustainable Forestry Initiative program (Wallinger 2003) and habitat conservation plans (HCP) may require landscape-level forest management for indigenous flora and fauna. Third, in order to maintain and develop environmental resources to meet various objectives including economic ones, an efficient use of the landscape is necessary (Nalle *et al.* 2002). For example, when adjacency restrictions which require the arrangement of harvests over space and time are required, spatial forest planning can evaluate the problem mathematically before activities are implemented on the ground. Fourth, forest landscape planning efforts require a broad perspective looking across ownership boundaries, and spatial forest planning can help evaluate potential activities that are likely compatible across multiple ownerships. Fifth, the ability to graphically display the results of alternative forest plans on maps using GIS may greatly help an organization's forest planning. Sixth, when biodiversity is a stated objective, forest management ideally emulates the natural disturbance regime with respect to size and frequency of disturbance patches. This tends to perpetuate the biophysical environment in which native forest fauna and flora evolved (North and Keeton 2008). Spatial planning is necessary to ensure that the size and frequency distributions associated with silvicultural activities do not deviate excessively from the natural disturbance regime (e.g., Seymour *et al.* 2002). Finally, spatial forest planning may help build trust among interest groups and organizations (Bettinger and Session 2003b). This is because a systematic and organized planning process that recognizes and accounts for spatial concerns and displays the results graphically may ensure that the resulting forest plans can withstand rigorous evaluation (Bettinger and Session 2003b).

Spatial forest planning offers a very quantitative framework to implement forest management plans seamlessly from long-term and wide scale strategic plans to ground level operational plans. However, stand-level forest planning has also played a significant role in the implementation of diverse management goals into forest planning (Li *et al.* 1993; Marzluff *et al.* 2002). A stand-level approach is especially well suited for strategic level planning (Murray and Church 1995, Bettinger *et al.* 2004b). However, stand-level forest planning requires the additional step to translate the strategy into operational planning (Van Raffe 2000, Bettinger *et al.* 2004b). In operational planning, the execution of ground-level detailed operational activities is planned on a yearly or seasonal basis (Baskent and Keles 2005). Additionally, stand-level trade-off analysis may not guarantee whether a proposed plan can achieve all management goals in an optimal fashion. Therefore spatial forest planning that includes both spatial pattern considerations and harvest schedule optimization in one place may be the better approach for forest management planning. The difficulty with spatial models has largely been with the complexity of spatial criteria and computational difficulty associated with problem size. It may not be computationally practical to consider complex spatial criteria in large problems.

Management Objectives

Spatial forest planning is especially useful for wildlife conservation in working forests. Since landscape ecology and meta-population theory are integrated in wildlife and habitat conservation, spatial and temporal landscape configurations are a critical component of wildlife conservation. Meta-population theory suggests that habitat fragmentation results in a lower possibility of species persistence in a landscape (Lande 1993). Since forest treatments both directly and indirectly manipulate landscape structure and composition, forest management and planning also should be considered spatially. This is especially true when a manager needs to consider wildlife species that are sensitive to landscape changes through stand treatments. Concern for wildlife habitat has been one of the main topics in many spatial forest planning studies (Bettinger *et al.* 1997, Bettinger *et al.* 1999a).

Objective functions modeled in spatial forest planning are diverse. Spatial requirements such as harvest unit or habitat patch size, shape and distribution (Cox and Sullivan 1994; Baskent and Jordan 1995, 2002; Başkent 1997, Gustafson *et al.* 2006; Hurme *et al.* 2007, Hof and Raphael 1997; Holzkamper *et al.* 2006; Kurttila 2001; Rempel and Kaufmann 2003; Kurttila *et al.* 2002; Authaud and Rose 1996; Bettinger *et al.* 2003, Bettinger *et al.* 1997), adjacency restrictions (Jones *et al.* 1991; Weintraub *et al.* 1994; Yoshimoto and Brodie 1994; Murray and Church 1995, 1996; Snyder and Revelle 1997; Hoganson and Borges 2000; McDill and Braze 2000, 2001; Nalle *et al.* 2005), connectivity and proximity (Nelson and Finn 1991; Sessions 1992; Hof and Joyce 1993; Church *et al.* 1998; Williams 1998; Lu and Eriksson 2000, Weintraub *et al.* 2000; Richards and Gunn 2000, 2003), interior and edge habitat (Hof and Joyce 1992, 1993; Bevers and Hof 1999; Ducheyne *et al.* 2006; Wei and Hoganson 2006), habitat attributes (Rohweder *et al.* 2000), habitat effectiveness (HEI, Bettinger *et al.* 1999a), and wildlife populations (Moore *et al.* 2000; Spring *et al.* 2001; Calkin *et al.* 2002; Juutinen *et al.* 2004; Nalle *et al.* 2004; Polasky *et al.* 2005; Loehle *et al.* 2006) were taken into account with economic goals.

Wildlife Habitat as a Management Objective

Spatial forest planning studies that chose wildlife habitat as an objective function were more common in our references. Bettinger *et al.* (1997) developed a tabu search algorithm to find efficient harvest schedule subject to even-flow of timber volume harvested, adjacency constraints, and spatial wildlife habitat quality (distribution and amount of foraging and thermal habitat for elk) goals. Bettinger and Boston (1999a) developed a method to integrate a Habitat Effectiveness Index (HEI) for Roosevelt elk into the objective function in an optimization process. They set a commodity production goal with the HEI objective and adopted a tabu search algorithm to find efficient relationships between those two conflicting objectives. Boston and Bettinger (2001) set similar management goals with red-cocked woodpeckers and used linear programming and heuristic techniques to solve their problems. The hybrid two-stage approach was also used in Boston and Bettinger (2002) to solve four problems with spatial constraints such as maximum opening size and maximum average opening size. Bettinger and Boston (1999b) also integrated different management objectives such as even-flow and adjacency considerations into an optimization process. The goal in their study was to achieve the highest, and most even, flow of timber volume over a certain time period with an adjacency harvest restriction rule.

Bettinger *et al.* (1996) set five management goals, such as stream temperature for fish habitat, habitat effectiveness index (HEI) for elk, habitat corridors, old seral stage stands, and an even flow of timber, and tested three riparian management strategies and two forest road construction scenarios. The objectives of Bettinger *et al.* (2003a) was to develop a process where the amount of habitat for northern spotted owl could be maintained within a certain radius of an owl nest location, while using thinning and group selection harvests to assist in the development of mid- to late-successional forest conditions. They reported that when nesting, roosting, and foraging (NRF) habitat levels were constrained to a minimum level of 40 %, net present value declined by almost 24%, while average NRF value increased 11% over a 100-year time horizon. When NRF habitat levels were constrained to a minimum level of 80%, NPV declined almost 70%, while average NRF increased 29%. Although Kurttila *et al.* (2002) did not include an economic evaluation of different management decisions; they evaluated spatial forest patterns for flying squirrel and moose that show conflicting habitat demands. They used habitat suitability indices (HSI) to evaluate the amount of habitat availability for both species. They calculated the proportion of a specified type of stand boundary to the total boundary length, spatial autocorrelation of HSI and a weighted mean of the stand-level HSI to evaluate the distribution of different habitat types. They evaluated results from an optimization process in terms of available habitat areas, spatial patterns and habitat connectivity. Hurme *et al.* (2007) set timber production and available suitable habitat for the Siberian flying squirrel as management objectives. They developed an empirical site-specific habitat model and integrated it into their optimization framework. They created five alternative forest plans under different combination of objective levels. They concluded that the formation of flying squirrel habitat in the landscape was enhanced, and did not always incur severe reductions in harvestable timber volume.

Wildlife Populations as a Management Objective

There were few studies that modeled wildlife populations or communities in their optimization processes. Hof *et al.* (1994) combined wildlife growth and dispersal as a dynamic process in their mixed integer linear programming approach. Hof and Raphael (1997) used a method in Hof *et al.* (1994) and developed an optimization procedure that can analyze habitat layouts for northern spotted owl. Calkin *et al.* (2002) integrated a wildlife model into their optimization process. Simulated annealing was used to solve for harvest schedules that maximized the net present value of timber harvest subject to a target value for likelihood of species over a 100-year planning period. Nalle *et al.* (2004) developed a method that used two heuristic algorithms and spatially explicit wildlife population models for the common porcupine and the great horned owl to evaluate the tradeoff between ecological and economic outputs with various harvest schedules. Polaksy *et al.* (2005) developed an optimal land allocation algorithm for working forests, agricultural lands, and reserve sites. They created a spatially explicit model for analyzing the consequences of alternative land use patterns on the persistence of various species and on market-oriented economic returns. Through an optimization process, they found that the degree of conflict between conservation and economic returns appears much less using their joint biological and economic modeling approach than using a reserve-site selection approach. Lindenmayer and Possingham (1996) used a population viability model to predict persistence of the Leadbetear's possum in Australian mountain ash forests under a number of different timber harvest scenarios.

Optimization Techniques

Spatial forest planning relies on optimization techniques to solve problems that often include conflicting ecological and economic management goals. Among many optimization approaches, meta-heuristic such as simulated annealing, tabu-search, and genetic algorithms have been used for wildlife studies. This is because heuristics are an effective approach when the size of a problem is large, such as landscape-level forest management with wildlife objectives. Meta-heuristics provide alternative approaches for spatial forest planning studies. Meta-heuristics cannot guarantee optimality in the solutions (such as reaching a global optimum), however, and often integer programming cannot be applied to wildlife problems for this reason. However, they can deal with non-linear, complex, and large size problems. Therefore, meta-heuristics are becoming more mainstream in recent spatial forest planning studies (Bettinger and Chung 2004). Bettinger *et al.* (2002) tested 8 different heuristic techniques (random search, simulated annealing, great deluge, threshold accepting, tabu search with 1-opt moves, tabu search with 1-opt and 2-opt moves, genetic algorithms and hybrid tabu search / genetic algorithm search) and reported that simulated annealing, threshold accepting, great deluge, tabu search with 1-opt and 2-opt moves and tabu search / genetic algorithm performed better than other methods in their testing environment. Boston and Bettinger (1999) conducted a similar study to compare Monte Carlo integer programming, simulated annealing, and tabu search and reported that simulated annealing found the highest solution value for three of the four planning problems. Studies that used heuristics were listed. Simulated annealing was adopted by Baskent and Jordan (2002), Calkin *et al.* (2002), Chen and Von Gadow (2002), Nalle *et al.* (2004). Tabu search and its variations were used by Bettinger *et al.* (1997, 2007), Boston and Bettinger (2002), Caro *et al.* (2003), Nalle *et al.* (2004). Threshold accepting was used in Bettinger *et al.* (2003a).

Hof and Joyce (1992) conducted one of the original studies that introduced an optimization technique to maximize wildlife habitat availability and stand allocations. They used non-linear integer programming to solve optimal stand allocation for the amount of edge and interior habitat as well as connectivity. In order to improve several shortcomings such as the non-convex nature of spatial models and limitations in the solving ability of their method, Hof and Joyce (1993) proposed a mixed-integer linear programming approach for wildlife and harvest schedule problems and showed that their method could solve more complex constraints such as accessibility and larger size problems. However, both integer and mixed-integer programming have critical limitations for solving real forest management problems such as the large problem size and difficulty in formulating problems. Mixed-integer programming was used in Hof and Joyce (1992, 1993), Hof and Bevers (1994), Bevers and Hof (1999) and Boston and Bettinger (1999). Boston and Bettinger (2001) combined linear programming and a tabu search / genetic algorithm technique and claimed that their two-stage approach was superior to the one-stage approach that only used a tabu search / genetic algorithm technique. Limitations of integer and mixed-integer programming to wildlife habitat optimization were detailed in Baskent and Keles (2005).

Recent spatial forest management studies that focused on wildlife habitat suggested that finding optimal relationships between conflicting ecological and economic management objectives create more cost efficient management solutions compared with traditional approaches (Juutinen *et al.* 2004, Nalle *et al.* 2004). Other research also suggested that a large fraction of conservation objectives could be achieved at little cost to economics through spatial forest planning (Nalle *et al.* 2004, Polasky *et al.* 2005, Hurme *et al.* 2007).

Spatial forest planning can include and test complex forest stand treatments such as biodiversity pathways. Imaki *et al.* (2007) adopted a biodiversity pathway in their study and constructed production possibility frontiers (PPF) to examine trade-offs between habitat conservation levels and opportunity costs for an interior and edge bird species. This study showed that the trade-off was not linear and spatial dependencies from stand arrangements and stand treatment allocations influenced the shape of the PPF. Ecological traits of species such as dispersal distance, home range size, and habitat preference also significantly changed the optimal forest management plans.

Complexity and Limitations

Spatial forest planning concepts and techniques have been developed for two decades; however, there are still practical limitations to the application of spatial forest planning to real forest management problems such as including more complex and diverse management objectives and personnel who can develop complex optimization processes and GIS analysis. Spatial forest management can provide the capability to test and implement conceptual landscape management approaches on the ground. Too much complexity, however, can work against developing a common understanding of what was learned and how to implement a practical program on the ground given many more specific details than could be handled in an optimization program. "The devil is in the details", to quote an old adage. Furthermore, spatial forest management methods do not eliminate stand-level considerations as the impacts of treatments at the stand-level generate the metrics that can be used and assessed spatially.

Salient Messages

What are the salient messages from these many studies?

The process starts with understanding the impact of treatments at the stand level although managing a few stands will not be sufficient to meet most objectives since there are many different desired conditions across a large area (i.e. *no one treatment fits all*).

Since overly dense stands (stem exclusion structure) are in surplus relative to natural history yet provide the least habitat, a range of thinning treatments in dense stands will likely be necessary to reach a range of habitat objectives and they might best emulate disturbance history even though that does not by itself guarantee functionality. Thinnings are essential for restoration of an understory and greater biological complexity from managed forests.

If the objective is largely focused on old forest species for which the supply has undoubtedly been reduced the most, dispersed treatments may be more important than protecting interiors. Moving mosaics of dispersed treatments generally allow better results across conflicting objectives such as economic impact vs. old forest habitat.

One can target and manage for future conditions, however natural old forest conditions were very variable so that any target needs to include variation, and protecting certain critical legacies may be the best way to provide for some specific future conditions. However, in the long term, legacies may not be protectable from all disturbances and some of the more mature stands may need to be managed for legacy restoration.

There are many tradeoffs in meeting different ecological and economic objectives and learning how to be effective is important. Many modeling efforts, from simulation to spatial optimization, have been examined but have not greatly simplified the complexity inherent in meeting a range of future conditions across a broad landscape as the objective. Situations are different and local objectives will most likely determine best local treatments although that does not guarantee fulfilling all important criteria across a broad landscape. There are tradeoffs both within ecological objectives and between ecological and economic objectives that can be displayed. Establishing hard criteria that weight these objectives to produce best or optimum results is rarely practiced except by optimization programs where any one objective can be optimized while the others are characterized as constraints. Achieving multiple objectives can be approximated by iteratively relaxing or tightening constraints.

Authors that have attempted to summarize management opportunities to maintain biodiversity tend to consider one of two approaches, the coarse filter approach or the fine filter approach (Loehle ,Wegley *et al.* 2005). The coarse filter approach assumes that maintaining a range of forest patterns and successional stages that are similar to the historic natural landscapes is sufficient to maintain a degree of biodiversity. The fine filter approach tries to meet the functional needs of specific species even if based on empirical comparisons of structural conditions as a proxy for function. Some features may be good for a broad range of species while others appear to be necessary only for a few species.

What are the more effective treatments characterized in these studies?

A 2006 conference on managing for wildlife habitat in west side production forests resulted in many papers (PNW-GTR-695 March 2007) endorsing and customizing the biodiversity pathway concepts originating a decade earlier (Carey *et al.* 1995). Some of the papers focused on structural features as targets (large trees, dead wood and snags, structural diversity including floristic (understory) diversity). Diversity was considered necessary if not sufficient for fungi, lichens, mosses, terrestrial and aquatic invertebrates and the process supportive of these organisms that are important to wildlife (Hagar 2007).

A key theme running through much of the recent literature is that maintenance of structural and compositional richness in each developmental stage is critical to support most species and processes in forested landscapes (Lindenmayer and Franklin 2002). Traditional silvicultural methods, which are relatively agricultural in nature and not tightly modeled on natural disturbance regimes, do not tend to function in this way (Puettman *et al.* 2009). These methods may, however, be modified to produce desired values (O'Hara 2001). Primary elements of silvicultural systems that recognize processes in natural ecosystems include: extended rotations (Curtis 1997, Lindenmayer *et al.* 2006), variable retention at harvest (Franklin *et al.* 2007), and intermediate operations to enhance complexity during a rotation (essentially the biopathways approach). Much research remains to be done to assess the effectiveness of combinations of these principle elements, and modeling efforts should continue to receive the initial focus while field trials are conducted at longer time scales.

What constitutes the relevant range of treatments for a modeling exercise?

A range of biodiversity pathways and commercial alternatives that focus on the production of a range of structural features found to be important to habitat and economic returns are needed as the primary input to the modeling exercise. While one should not focus on a single or even just a few species, there is ample evidence that the habitat in shortest supply is best described as being characterized by old forest structures. The structures in greatest surplus are overly dense stem exclusion structures. Studies focused on commercially managed forests have generally found adequate levels of most species except those preferring old forest structures. In contrast the lack of management on federal lands and perhaps some state lands including no clearcuts or thinnings is resulting in no open areas except those that may result from natural disturbance. Disturbance patterns have however been substantially reduced by human interventions such as fire suppressions and patterns of land management.

The most successful economic prescription on industry lands relies heavily on pre and post regeneration vegetation control. The rapid growth of young conifer does not eliminate a short period with open structures but very quickly produces very dense albeit young stands, a less than desirable structure for most habitats (University of Washington College of Forest Resources 2007).

As the purpose of a modeling exercise is to explore ranges of innovative treatments while pushing the boundaries of current practices to better understand ecological/economic tradeoffs, a wide range of treatments needs to be considered. Similarly a wide range of ecological metrics will need to be analyzed. Metrics of greatest interest will logically focus on older forest structures but should not do so exclusively.

What metrics for ecological sufficiency are highlighted in the literature?

- *Non-parametric statistical tests of the goodness of a sample treatment replicating old forest samples* (i.e. time in the desired old forest structure described earlier (Gehringer 2006).
- *Meeting defined habitat thresholds such as structural conditions specific to owl nest sites or structural definitions for nesting-roosting-foraging habitat* (e.g. WAC definitions of nesting roosting foraging habitat).
- *The Old-Growth Habitat Index (OGHI) developed to define old-growth forests. The OGHI integrates five stand structure parameters and successional status into a single measure by the Old-Growth Definition Committee in 2004* (Washington Department of Natural Resources 2005). Those five parameters are:
    1. Large trees (number of trees per hectare > 100 cm dbh)
    2. Large snags (number of standing dead trees per hectare > 50 cm dbh and > 15 m tall)
    3. Volume of down woody debris (cubic meters per hectare)
    4. Tree size diversity
    5. Stand age (years)

  Each of the five elements making up the OGHI is scored on a scale of 0 to 100. There are three forms of the OGHI for western Washington. The standard OGHI is simply the average of the five scores. A modified OGHI excludes stand age from the calculation and emphasizes stand structures. A weighted OGHI uses the same 4 elements as a modified OGHI but weights each parameter to emphasize the density of large trees in a stand. The density of large snags was highly variable and the least informative in the weighted OGHI. Thresholds in the indices to define old growth forest were subjectively selected based on the experience of the ecologists. An index score of 60 (the standard OGHI) was generally corresponded to stands whose dominant overstory Douglas-firs were > 200 years old (Washington Department of Natural Resources 2005).

  Assessment of stands in the relatively drier forests in the east Cascades requires the integration of structural differences in these stands from more mesic forests (Franklin *et al.* 2007, Everett *et al.* 2007). These include fewer large trees per acre, fewer standing dead trees, lower volumes of downed wood, a patchier distribution of regenerating trees, and simpler canopy structure in general.

- *A lower threshold such as the amount of a late seral forest structure class* (Oliver 1981, Franklin et al. 2002). This metric is often based on a coarse filter approach to forest diversity and hence somewhat easier to measure testing for presence of all of about 5 broadly defined structure classes.
- *Finer filter objectives such as downed wood, snags, canopy closure while not good discriminators of old forests in general, they may still be important for some habitat such as woodpeckers and owls*. Finer filter objectives can provide better or more critical habitat within the broader class of old forest structures. These structural elements tend to indicate ecological complexity and function during all developmental phases (including naturally disturbed stands in early succession). The importance of variable densities imposes statistical problems since characterization at the stand level requires breaking a stand into sub-parts in order to measure the variation. There is substantial natural and managed variation in stand metrics caused by natural conditions (rocks, disease patches, and wind disturbance) as well as management impacts (thinning trails, thinning densities).
- *Habitat Suitability Indices that depend on the segmentation of stand structures into a large array of forest conditions that can be linked to use by different species*. Early efforts may evolve over time as more data is collected and the link between suitability and structure class is developed by more thorough statistical testing. Gradations from one condition to another tend to produce knife edge measures of suitability rather than a more continuous transition.
- *Economic "forest value" for different treatments i.e. the discounted present market value net of discounted costs.* Soil expectation value (SEV) (after harvest removal) is the most representative value for perpetually sustained forest management. For dry forests with a stand-replacing fire risk, the economics of avoided suppression costs may play an increasingly important role in the decision to thin or not (e.g., Snider *et al.* 2006).
- *Fire risk/severity measures* (e.g., Hummel and Barbour 2007, Hessburg *et al.* 2005). This is especially relevant for dry forest types where fire suppression has resulted in greater contiguity of fuels and the potential for stand-replacing fire.
- *Landscape patch-size distribution characteristic of historic landscapes* (e.g., Seymour *et al.* 2002). Other landscape-scale metrics may also be useful.

The National Commission on Science for Sustainable Forestry (NCSSF) sponsored many studies with a focus on sustainability of biodiversity among critical attributes. They recognized the importance of characterizing biodiversity locally. They published a guidebook aimed at helping interested parties determine how to identify and maintain biodiversity within the sustainability context (NCSSF 2007). They suggest using condition indicators, pressure indicators and policy response indicators. Condition indicators include metrics like the percent of area in a mature condition by forest type, large tree density, and mature forest reserves. Pressure indicators include negative counter parts like the percentage of acres not yet mature, as well as positive indicators like the percentage managed for some degree of forest retention. NCSSF policy indicators incorporated process motivation such as a written conservation policy and the application of incentives recognizing the non-market aspects of sustaining biodiversity. Collectively this process integrates many of the indicators provided in the literature.

What range of silvicultural treatment alternatives are considered?

Variables such as initial density, rotation length, and internal variation in treatments may be modified to fit landscape-specific conditions in research at the OESF and elsewhere.

1. Commercial rotations (e.g. 45 years or optimal economic rotation for a medium site class in the Pacific Northwest, with optional thinning for dense stands). Commercial rotations provide a baseline for economic comparisons in order to determine the opportunity cost (net revenue or present value loss) to provide alternatives with increased conservation values.

2. No action (no harvest within planning interval after stocking, although not necessarily replicating natural development).
3. No action areas restricted to important legacy "biodiversity hotspots".
4. Long rotations (e.g., 60-100 years with medium density and high density alternatives) with longer rotations or periodic restoration thinnings when old forest retention objectives are critical.
5. Short rotation intensive (35 years), with pre-commercial thinning [PCT] if needed.
6. Biopathway with multiple thinnings and a long rotation clearcut i.e. only green tree retention with no retention of the largest trees in the overstory (approximate trees per acre each treatment = 300, 150, 60, green tree). Thinning operations may be omitted for lower density stands.
7. Biopathway on extended rotation but no retention at harvest.
8. Fast biopathway (accelerated thinning schedule) with no retention at harvest.
9. Biopathway with retention of 15 to 30 large overstory trees for RMZ (PCT, single thin low density, 2 thin higher density, overstory retention/harvest).
10. Group selection of variable-size compartments with retention of CWD. This system may be tested for functional similarity to the windthrow regime common to many forest types (e.g., western Olympic lowlands or southern beech).

Finer filter refinements

11. Manage #5 and/or #6 for narrower range in canopy closure (more thinning entries throughout rotation).
12. Manage #5 and /or #6 for recruiting more logs/snags.
13. Manage #8 for recruiting more CWD.

Summary of Trends and Challenges In Silvicultural and Forest Management Research

Innovative silviculture modeling over range of treatments noted in the literature applied across landscapes based on the ecological sufficiency metrics noted in the literature provide instructive alternatives serving a range of objectives from economic to ecological restoration. Gaps in ecological metrics will be noted. The modeling generally starts by simulations of various treatments at the stand level and progresses to simulated spatial applications across example landscapes. The outputs provide a quantitative assessment of comparative impacts across treatment alternatives and ecological sufficiency metrics. The lack of retrospective studies on the impacts of earlier treatments limits the degree of validity testing between simulations and outcomes. More long term monitoring of treatments will be needed but will be slow in coming.

Although there is much that remains to be done in terms of empirical research, this review clearly documents encouraging advances in knowledge and practice in temperate forests in the Pacific Northwest and around the world. Improvements in the spatial modeling (and concurrent advances in remote sensing and computational power) will allow managers to best approach complex, multiple-output resource management scenarios. Silvicultural methodology is beginning to draw inputs from multiple spatial scales, instead of the single forest stand alone, and the heterogeneity of any forested landscape is increasingly addressed in planning. Elements of natural disturbance regimes are emulated, from single-tree gap creation to the incorporation of biological legacies into large harvest units and inclusion of mesoscale reserves in managed landscapes. Traditional silvicultural systems are increasingly modified for site-specific circumstances, much like the originators of those systems intended. And the rigor and sophistication with which ecological functionality is quantified continues to expand in concert with a deeper understanding of both managed and natural forest ecosystems.

The OESF and numerous similar management situations in temperate forests around the world represent key opportunities to perform research at stand and landscape scales at a time when natural resource managers around the world are recognizing that traditional models of silviculture may not recognize the full range of disturbances, developmental pathways, and landscape patterns represented in functional forest ecosystems. Evolving silvicultural systems still recognize the importance of producing wood and other forest products, but have expanded their recognition of serving biological diversity and complexity objectives as well.

How to properly assess the economic value of achieving conservation objectives relative to the measureable cost of production or protection, while not the focus of this review, was generally not very evident but is receiving increased attention in the growing literature on ecosystem services.

Reference List

Topic Areas:

1. Landscape management for biodiversity and wildlife responses

Abbott, R. S., J. D. White, et al. (1999). "The Benefits and Challenges of Large-scale Silvicultural Experiments: Perspectives from Forest Managers on the Demonstration of Ecosystem Management Options(DEMO) Study." Northwest Science 73: 118-125.

Acker, S. A., T. E. Sabin, et al. (1998). "Development of old-growth structure and timber volume growth trends in maturing Douglas-fir stands." Forest Ecology and Management 104(1): 265-280.

Adams, W. T., S. Hobbs, et al. (2005). "Intensively managed forest plantations in the Pacific Northwest: Introduction." Journal of Forestry: 59.

Adams, W. T., J. Zuo, et al. (1998). "Impact of alternative regeneration methods on genetic diversity in coastal Douglas-fir." Forest Science 44(3): 390-396.

Agee, J. K. (1991). "Fire history of Douglas-fir forests in the Pacific Northwest." Wildlife and vegetation of unmanaged Douglas-fir forests. USDA Forest Service, Pacific Northwest Research Station, Gen. Tech. Report PNW-GTR-285: 25-33.

Agee, J. K. (1996). Fire Ecology of Pacific Northwest Forests, Island Press.

Allen, A. W., W. Energy, et al. (1983). Habitat Suitability Index Models: Southern Red-backed Vole (western United States), Western Energy and Land Use Team, Division of Biological Services, Research and Development, Fish and Wildlife Service, US Dept. of the Interior.

Allen, C.D., Savage, M., Falk, D.A., Suckling, K.F., Swetnam, T.W., Schulke, T., Stacey, P.B., Morgan, P., Hoffman, M., Klingel, J.T., 2002. "Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective. " Ecological applications 12, 1418-1433.

Amaranthus, M. P., D. DeBell, et al. (1993). Demonstration of Ecosystem Management Options (D.E.M.O.): A cooperative effort between NFS and research in the Pacific Northwest. SE-GTR 88 USDA Forest Service Southern Experiment Station.

Anderson, P.D., 2007. "Understory vegetation responses to initial thinning of Douglas-fir plantations undergoing conversion to uneven-age management" In: Deal, R.L. (Ed.), Integrated restoration of forested ecosystems to achieve multiresource benefits: proceedings of the 2007 national silviculture workshop. USDA Forest Service, Pacific Northwest Research Station Gen. Tech. Rep. PNW-GTR-733, Ketchikan, AK.

Andren, H. (1992). "Corvid Density and Nest Predation in Relation to Forest Fragmentation: A Landscape Perspective." Ecology 73(3): 794-804.

Andren, H. (1994). "Effects of Habitat Fragmentation on Birds and Mammals in Landscapes with Different Proportions of Suitable Habitat: A Review." Oikos 71(3): 355-366.

Andren, H. (1996). "Population Responses to Habitat Fragmentation: Statistical Power and the Random Sample Hypothesis." Oikos 76(2): 235-242.

Andren, H. (1999). "Habitat Fragmentation, the Random Sample Hypothesis and Critical Thresholds." Oikos 84(2): 306-308.

Andrén, H. (1997). "Habitat fragmentation and changes in biodiversity." Ecological Bulletins 46: 171-181.

Andren, H. and P. Angelstam (1988). "Elevated Predation Rates as an Edge Effect in Habitat Islands: Experimental Evidence." Ecology 69(2): 544-547.

Andren, H. and A. Delin (1994). "Habitat Selection in the Eurasian Red Squirrel, Sciurus vulgaris, in Relation to Forest Fragmentation." Oikos 70(1): 43-48.

Andrews, L. S. and J. P. Perkins (2005). "Silvicultural approaches to develop northern spotted owl nesting sites, Central Coast ranges, Oregon." Western Journal of Applied Forestry 20(1): 13-27.

Arno, S.F., Fiedler, C.E., 2005 Mimicking Nature's fire: restoring fire-prone forests in the West. Island Press, Washington, D.C.

Askins, R. A. and M. J. Philbrick (1987). "Effect of changes in regional forest abundance on the decline and recovery of a forest bird community." Wilson Bulletin 99(1): 7-21.

Askins, R. A., M. J. Philbrick, et al. (1987). "Relationship between the regional abundance of forest and the composition of forest bird communities." Biological Conservation 39(2): 129-152.

Aubry, K. B. (2007). "Changing Perceptions of the Role of Managed Forests as Wildlife Habitat in the Pacific Northwest." USDA Forest Service General Technical Report PNW 695: 3.

Aubry, K. B., M. P. Amaranthus, et al. (1999). "Evaluating the Effects of Varying Levels and Patterns of Green-tree Retention: Experimental Design of the DEMO Study." Northwest Science 73: 12-26.

Aubry, K. B., C. B. Halpern, et al. (2004). "Ecological effects of variable-retention harvests in the northwestern United States: the DEMO study." Forest Snow and Landscape Research 78(1/2): 119-137.

Bailey, J. D., C. Mayrsohn, et al. (1998). "Understory Vegetation In Old And Young Douglas-R Forests Of Western Oregon." Forest Ecology and Management 112, 289-302.

Bailey, J. D. and J. C. Tappeiner (1998). "Effects Of Thinning On Structural Development In 40-To 100-Year-Old Douglas-Fir Stands In Western Oregon." Forest Ecology and Management 108, 99-113.

Bailey, S. (2007). "Increasing connectivity in fragmented landscapes: an investigation of evidence for biodiversity gain in woodlands. " Forest Ecology and Management 238, 7-23.

Baker, P. J. and J. S. Wilson (2000). "A quantitative technique for the identification of canopy stratification in tropical and temperate forests." Forest Ecology and Management 127(1-3): 77-86.

Baker, S.C., Barmuta, L.A., McQuillan, P.B., Richardson, A.M.M., (2007). "Estimating edge effects on ground-dwelling beetles at clearfelled non-riparian stand edges in Tasmanian wet eucalypt forest. " Forest Ecology and Management 239, 92-101.

Barbour, R. J., S. Johnston, et al. (1997). "Simulated stand characteristics and wood product yields from Douglas-fir plantations managed for ecosystem objectives. " Forest Ecology and Management 91(2): 205-219.

Barg, A. K. and D. P. Hanley (2001). Silvicultural Alternatives: Variable Retention Harvests in Forest Ecosystems of Western Washington: a Guide for Forest Landowners, Cooperative Extension, Washington State University.

Battaglia, M.A., Mou, P., Palik, B., Mitchell, R.J. (2002). "The effect of spatially variable overstory on the understory light environment of an open-canopied longleaf pine forest". Canadian Journal of Forest Research 32, 1-8.

Bayne, E. M. and K. A. Hobson (1997). "Comparing the Effects of Landscape Fragmentation by Forestry and Agriculture on Predation of Artificial Nests." Conservation Biology 11(6): 1418-1429.

Bayne, E. M. and K. A. Hobson (1998). "The effects of habitat fragmentation by forestry and agriculture on the abundance of small mammals in the southern boreal mixedwood forest." Can. J. Zool 76(1): 62–69.

Bebber, D. P., S. C. Thomas, W. G. Cole, and D. Balsillie. 2004. "Diameter increment in mature eastern white pine Pinus strobus L. following partial harvest of old-growth stands in Ontario", Canada. Trees 18:29–34.

Beese, W. J. and A. A. Bryant (1999). "Effect of alternative silvicultural systems on vegetation and bird communities in coastal montane forests of British Columbia, Canada." Forest Ecology and Management 115(2): 231-242.

Beggs, L. R., K. J. Puettmann, et al. (2005). "Vegetation Response to Alternative Thinning Treatments in Young Douglas-fir Stands." USDA Forest Service General Technical Report PNW 635: 243.

Begon, M., C. R. Townsend, et al. (2003). Ecology: individuals, populations and communities, Blackwell Science.

Bender, D. J., T. A. Contreras, et al. (1998). "Habitat Loss and Population Decline: A Meta-Analysis of the Patch Size Effect." Ecology 79(2): 517-533.

Berg, D. R., T. K. Brown, et al. (1996). "Silvicultural systems design with emphasis on the forest canopy." Northwest Science 70: 31-36.

Berryman, S. D., R. T. Fahey, et al. (2005). "Characterizing understory vegetation response to variable density thinnings in young Dougls-fir forests of western Oregon." Balancing Ecosystem Values: Innovative Experiments for Sustainable Forestry, Portland, OR. available at: http://ocid. nacse. org/nbii/density/pdfFiles/PosterA_Characterizing_understory _veg_response. pdf.

Bevers, M. and J. Hof (1999). "Spatially optimizing wildlife habitat edge effects in forest management linear and mixed-integer programs." Forest science 45(2): 249-258.

Bible, K. J. (2001). Long-term patterns of Douglas-fir and western hemlock mortality in the western Cascade Mountains of Washington and Oregon, University of Washington.

Bladon, K. D., V. J. Lieffers, U. Silins, S. M. Lanhausser, and P. V. Blenis. (2008). "Elevated mortality of residual trees following structural retention harvesting in boreal mixedwoods. " Forestry Chronicle 84:70–75.

Bond, B. J. and J. F. Franklin (2002). "Aging in Pacific Northwest forests: a selection of recent research." Tree Physiology 22(2): 73-76.

Bormann, F. H. and G. E. Likens (1994). Pattern and Process in a Forested Ecosystem: Disturbance, Development and the Steady State Based on the Hubbard Brook Ecosystem Study, Springer-Verlag.

Bottorff, J. (2007). "Wildlife habitat management practices on private non-industrial forestlands." USDA Forest Service General Technical Report PNW 695: 62-64.

Boulinier, T., J. D. Nichols, et al. (2001). "Forest Fragmentation and Bird Community Dynamics: Inference at Regional Scales." Ecology 82(4): 1159-1169.

Boutin, S. and D. Hebert (2002). "Landscape Ecology and Forest Management: Developing an Effective Partnership." Ecological Applications 12(2): 390-397.

Bragg, D.C., Shelton, M.G., Guldin, J.M., (2008). "Restoring old-growth southern pine ecosystems: strategic lessons from long-term silvicultural research. " In: Deal, R.L. (Ed.), Integrated restoration of forested ecosystems to achieve multiresource benefits: proceedings of the 2007 National Silviculture Workshop. PNW-GTR-733. United States Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland, OR.

Brandeis, T. J., M. Newton, et al. (2001). "Underplanted conifer seedling survival and growth in thinned Douglas-fir stands." Can. J. For. Res 31: 302-312.

Brockway, D.G., Outcalt, K.W., Guldin, J.M., Boyer, W.D., Walker, J.L., Rudolph, D.C., Rummer, R.B., Barnett, J.P., Jose, S., Nowak, J., (2002). "Uneven-aged management of longleaf pine forests: a scientist and manager dialogue. " USDA Forest Service General Technical Report SRS-78, Southern Research Station, Asheville, NC.

Brodie, A., M. Bowering, et al. (2007). "Combining management goals of wildlife habitat conservation and revenue on Washington state trusts." USDA Forest Service General Technical Report PNW 695: 67-80.

Brosofske, K.D., Chen, J., Naiman, R.J., Franklin, J.F., (1997). "Harvesting effects of microclimatic gradients from small streams to uplands in western Washington. " Ecological applications 7, 1188-1200.

Bull, E.L., Blumton, A.K., (1999). "Effect of fuels reduction on American martens and their prey. " In. USDA Forest Service, Pacific Northwest Research Station. PNW-RN-539, Portland, OR.

Bull, E.L., Clark, A.A., Shepherd, J.F., 2005. "Short-term effects of fuel reduction on pileated woodpeckers in northeastern Oregon- a pilot study".. In. USDA Forest Service, Pacific Northwest Research Station Res. Pap. PNW-RP-564. Portland, OR.

Bunnell, F. L. and L. L. Kremsater (1990). "Sustaining wildlife in managed forests." Northwest Environmental Journal 6(2): 243-269.

Bunnell, F. L., L. L. Kremsater, et al. (1999). "Managing to sustain vertebrate richness in forests of the Pacific Northwest: relationships within stands." Environmental Reviews 7(3): 97-146.

Burkey, T. V. (1989). "Extinction in Nature Reserves: The Effect of Fragmentation and the Importance of Migration between Reserve Fragments." Oikos 55(1): 75-81.

Busing, R. T. and S. L. Garman (2002). "Promoting old-growth characteristics and long-term wood production in Douglas-fir forests." Forest Ecology and Management 160(1): 161-175.

Carey, A. B. (1995). "Sciurids in Pacific Northwest Managed and Old-Growth Forests." Ecological Applications 5(3): 648-661.

Carey, A. B. (1996). "Interactions of northwest forest canopies and arboreal mammals." Northwest Science 70: 72-79.

Carey, A. B. (1998). "Ecological Foundations of Biodiversity: Lessons from Natural and Managed Forests of the Pacific Northwest." Northwest Science 72(2): 127-133.

Carey, A. B. (1999). Ecological Scale and Forest Development: Squirrels, Dietary Fungi, and Vascular Plants in Managed and Unmanaged Forests, Wildlife Society.

Carey, A. B. (2000). "Effects of New Forest Management Strategies on Squirrel Populations." Ecological Applications 10(1): 248-257.

Carey, A. B. (2003). "Restoration of landscape function: reserves or active management?" Forestry 76(2): 221.

Carey, A.B., (2003). "Biocomplexity and restoration of biodiversity in temperate coniferous forest: inducing spatial heterogeneity with variable-density thinning. " Forestry 76, 127-136.

Carey, A. B. and R. O. Curtis (1996). "Conservation of Biodiversity: A Useful Paradigm for Forest Ecosystem Management." Wildlife Society Bulletin 24(4): 610-620.

Carey, A. B. and W. Dept. of Fish and (1996). Washington Forest Landscape Management Project: A Pragmatic, Ecological Approach to Small-landscape Management: Report No. 2, Washington State Dept. of Natural Resources, Washington Forest Landscape Management Project.

Carey, A. B. and J. D. Gill (1983). "Direct habitat improvements—some recent advances." Snag Habitat Management: Proceedings of a Symposium. General Technical Report RM-99. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO; 80–87.

Carey, A. B., S. P. Horton, et al. (1992). "Northern Spotted Owls: Influence of Prey Base and Landscape Character." Ecological Monographs 62(2): 223-250.

Carey, A. B. and M. L. Johnson (1995). "Small Mammals in Managed, Naturally Young, and Old-Growth Forests." Ecological Applications 5(2): 336-352.

Carey, A. B., B. R. Lippke, et al. (1999). "Intentional systems management: managing forests for biodiversity." Journal of Sustainable Forestry 9(3/4): 83-125.

Carey, A. B. and H. R. Sanderson (1981). "Routing to Accelerate Tree-Cavity Formation." Wildlife Society Bulletin 9(1): 14-21.

Carey, A. B., D. R. Thysell, et al. (1999). The Forest Ecosystem Study Background, Rationale, Implementation, Baseline Conditions, and Silvicultural Assessment, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Carey, A. B. and S. M. Wilson (2001). "Induced Spatial Heterogeneity in Forest Canopies: Responses of Small Mammals." The Journal of Wildlife Management 65(4): 1014-1027.

Ceder, K. R. (2002). Using Silviculture to Sustain Wildlife Habitat: Assessing Changes and Trade-offs in Forest Habitats Using a Habitat Evaluation Procedure within the Landscape Management System. College of Forest Resources. Master of Science: 76. Seattle, WA, University of Washington.

Ceder, K. R. and J. M. Marzluff (2002). Linking tools of forest and wildlife managers: Wildlife habitat evaluation using the Landscape Management System. Forest Vegetation Simulator (FVS) Conference, Fort Collins, CO, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Chambers, C. L., R. Carrigan, et al. (1997). "Use of artificially created Douglas-fir snags by cavity-nesting birds. West." J. Appl. For 12: 93-97.

Chambers, C. L., W. C. McComb, et al. (1999). "Breeding Bird Responses to Three Silvicultural Treatments in the Oregon Coast Range." Ecological Applications 9(1): 171-185.

Chan, S.S., Larson, D.J., Maas-Hebner, K.G., Emmingham, W.H., Johnston, S.R., Mikowski, D.A., (2006). "Overstory and understory development in thinned and underplanted Oregon Coast Range Douglas-fir stands. " Canadian Journal of Forest Research 36, 2696-2711.

Chapin, T. G., D. J. Harrison, et al. (1998). "Influence of Landscape Pattern on Habitat Use by American Marten in an Industrial Forest." Conservation Biology 12(6): 1327-1337.

Chen, J. (1991). Edge effects: microclimatic pattern and biological responses in old-growth Douglas-fir forests, University of Washington.

Chen, J., J. F. Franklin, et al. (1996). "Comparison of Abiotic and Structurally Defined Patch Patterns in a Hypothetical Forest Landscape." Conservation Biology 10(3): 854-862.

Chen, J., J. F. Franklin, et al. (1990). "Microclimatic pattern and basic biological responses at the clearcut edges of old-growth Douglas-fir stands." Northwest Environmental Journal 6: 424-425.

Chen, J., J. F. Franklin, et al. (1992). "Vegetation Responses to Edge Environments in Old-Growth Douglas-Fir Forests." Ecological Applications 2(4): 387-396.

Churchill, D. J. (2005). Factors Influencing Understory Douglas-fir Vigor in Multi-Cohort Prairie Colonization Stands at Fort Lewis, Washington. College of Forest Resources. Master of Science: 62. Seattle, WA, University of Washington.

Cissel, J. H., J. S. Frederick, G. E. Grant, D. H. Olson, S. V. Gregory, S. L. Garman, L. R. Ashkenas, M. G. Hunter, J. A. JKertis, J. H. Mayo, M. D. McSwain, S. G. Swetland, K. A. Swindle and D. O. Wallin (1998). A Landscape Plan Based on Historical Fire Regimes for a Managed Forest Ecosystem: The Augusta Creek Study. General Technical Report PNW-GTR-422, USDA Forest Service, Pacific Northwest Research Station.

Cissel, J. H., F. J. Swanson and P. J. Weisberg (1999). "Landscape management using historical fire regimes: Blue River, Oregon." Ecological Applications 9: 1217-1231.

Cline, E.T., Ammirati, J.F., Edmonds, R.F., (2005). "Does proximity to mature trees influence ectomycorrhizal fungus communities of Douglas-fir seedlings? " New Phytologist 166, 993-1009.

Collingham, Y. C. and B. Huntley (2000). "Impacts of Habitat Fragmentation and Patch Size upon Migration Rates." Ecological Applications 10(1): 131-144.

Commission on Old Growth Alternatives. (1989). Final Report submitted to the Washington Department of Natural Resources. Olympia, WA. 40pp. plus appendices.

Conner, R. N., D. C. Rudolph, et al. (1996). "Red-cockaded woodpecker nesting success, forest structure, and southern flying squirrels in Texas." Wilson Bulletin 108(4): 697-711.

Conner, R. N., D. Saenz, et al. (1998). "Red-cockaded woodpecker nest-cavity selection: Relationships with cavity age and resin production." Auk 115(2): 447-454.

Copeyon, C. K. (1990). "A Technique for Constructing Cavities for the Red-Cockaded Woodpecker." Wildlife Society Bulletin 18(3): 303-311.

Curtis, R. O. (1982). "A Simple Index of Stand Density for Douglas-fir." Forest Science 28(1): 92-94.

Curtis, R. O. (1997). "The role of extended rotations." Creating a Forestry for the 21st Century. Island Press, Washington, DC: 165–170.

Curtis, R. O. (1998). "" Selective Cutting" in Douglas-Fir: History Revisited." Journal of Forestry 96(7): 40-46.

Curtis, R. O. and A. B. Carey (1996). "Timber supply in the Pacific Northwest: managing for economic and ecological values in Douglas-fir forests." Journal of Forestry 94(9): 4-7.

Curtis, R. O., D. S. DeBell, et al. (1998). "Silviculture for multiple objectives in the Douglas-fir region. " USDA Forest Service Gen. Tech. Rep. PNW-GTR-435 123.

Curtis, R. O., D. S. DeBell, et al. (2007). "Silvicultural research and the evolution of forest practices in the Douglas-fir region. " USDA Forest Service PNW GTR 696. Pacific Northwest Research Station. Portland, OR.

Curtis, R. O., D. D. Marshall, et al. (1997). "LOGS: A Pioneering Example of Silvicultural Research in Coast Douglas-Fir." Journal of Forestry 95(7): 19-25.

Curtis, R. O., D. D. Marshall, et al. (2004). "Silvicultural options for young-growth Douglas-fir forests: the Capitol Forest study-establishment and first results." General Technical Report-Pacific Northwest Research Station, USDA Forest Service(PNW-GTR-598): xi+110pp.

Curtis, R. O. and S. Or Pacific Northwest Research (1994). Some Simulation Estimates of Mean Annual Increment of Douglas-fir Results, Limitations, and Implications for Management, USDA Forest Service, Pacific Northwest Research Station.

Curtis, R. O. and S. Or Pacific Northwest Research (1995). Extended Rotations and Culmination Age of Coast Douglas-fir Old Studies Speak to Current Issues, USDA Forest Service, Pacific Northwest Research Station.

Curtis, R. O. and S. Or Pacific Northwest Research (1998). Silviculture for Multiple Objectives in the Douglas-fir Region, USDA Forest Service, Pacific Northwest Research Station.

Davis, F. W. and D. Roberts (2000). "Stand structure in terrestrial ecosystems." Methods in Ecosystem Science, edited by OE Sala, RB Jackson, HA Mooney and RW Howard (Berlin: Springer), part 1(4): 7–30.

Daw, S.K., DeStefano, S., (2001). Forest characteristics of northern goshawk nest stands and post-fledging areas in Oregon. Journal of Wildlife Management 65, 59-65.

Deal, R. L. and J. C. Tappeiner (2002). "The effects of partial cutting on stand structure and growth of western hemlock-Sitka spruce stands in southeast Alaska." Forest Ecology and Management 159(3): 173-186.

Deal, R. L., J. C. Tappeiner, et al. (2002). "Developing silvicultural systems based on partial cutting in western hemlock-Sitka spruce stands of southeast Alaska." Forestry 75(4): 425.

Deans, A. M., J. R. Malcolm, S. M. Smith, and M. I. Bellocq. (2005). "Edge effects and the responses of aerial insect assemblages to structural-retention harvesting in Canadian boreal peatland forests. " Forest Ecology and Management 204:249–266.

DeBell, D. S. and R. O. Curtis (1993). "Silviculture and New Forestry in the Pacific Northwest." Journal of Forestry 91(12): 25-30.

DeBell, D. S., R. O. Curtis, et al. (1997). "Shaping stand development through silvicultural practices." Creating a forestry for the 21st century. Edited by KA Kohm and JF Franklin. Island Press, Washington, DC: 141–149.

Debinski, D. M. and R. D. Holt (2000). "A Survey and Overview of Habitat Fragmentation Experiments." Conservation Biology 14(2): 342-355.

DeGraaf, R. M. and A. L. Shigo (1985). Managing Cavity Trees for Wildlife in the Northeast, USDA Forest Service, Northeastern Forest Experiment Station.

Delin, A. E. and H. Andrén (1999). "Effects of habitat fragmentation on Eurasian red squirrel (Sciurus vulgaris) in a forest landscape." Landscape Ecology 14(1): 67-72.

deMaynadier, P. G. and M. L. Hunter Jr (1995). "The relationship between forest management and amphibian ecology: a review of the North American literature." Environmental Reviews 3(3&4): 230-261.

Dick, M. R. (2007). "Proactive Management Considerations for Wildlife Habitat to Ensure Profitability." USDA Forest Service General Technical Report PNW 695: 117.

Dignan, P., King, M., Savaneh, A., Walters, M., (1998). "The regeneration of *Eucalyptus regnans* F. Muell. under retained overwood: seedling growth and density. " Forest Ecology and Management 102, 1-7.

Dooley Jr, J. L. and M. A. Bowers (1998). "Demographic Responses to Habitat Fragmentation: Experimental Tests at the Landscape and Patch Scale." Ecology 79(3): 969-980.

Douglas, R. (1993). Unfinished Business. Auckland, New Zealand, Random House New Zealand.

Dovciak, M., C. B. Halpern, J. R. Saracco, S. A. Evans, and D. A. Liguori. (2006). "Persistence of ground-layer bryophytes in a structural retention experiment: initial effects of level and pattern of overstory retention. " Canadian Journal of Forest Research 36:3039–3052.

Drew, T. J. and J. W. Flewelling (1979). "Stand density management: an alternative approach and its application to Douglas-fir plantations." For. Sci 25(3): 518-532.

Everest, F. H. and G. H. Reeves (2007). Riparian and aquatic habitats of the Pacific Northwest and southeast Alaska: ecology, management history, and potential management strategies. Gen. Tech. Rep. PNW-GTR-692. Portland, OR, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Everett, R., D. Baumgartner, et al. (2007). "Development of current stand structure in dry fir-pine forests of eastern Washington." Journal-Torrey Botanical Society 134(2): 199.

Fahrig, L. (1992). "Relative importance of spatial and temporal scales in a patchy environment." Theoretical Population Biology 41(3): 300-314.

Fahrig, L. (1997). "Relative Effects of Habitat Loss and Fragmentation on Population Extinction." The Journal of Wildlife Management 61(3): 603-610.

Fahrig, L. (1998). "When does fragmentation of breeding habitat affect population survival?" Ecological Modelling 105(2): 273-292.

Fahrig, L. (1999). "Forest loss and fragmentation: which has the greater effect on persistence of forest-dwelling animals." Forest fragmentation: wildlife and management implications. Koninklijke Brill NV, Leiden, The Netherlands: 87–95.

Fahrig, L. (2002). "Effect of Habitat Fragmentation on the Extinction Threshold: A Synthesis." Ecological Applications 12(2): 346-353.

Fahrig, L. and G. Merriam (1994). "Conservation of Fragmented Populations." Conservation Biology 8(1): 50-59.

Fahrig, L. and J. Paloheimo (1988). "Effect of Spatial Arrangement of Habitat Patches on Local Population Size." Ecology 69(2): 468-475.

Finn, S. P., J. M. Marzluff, et al. (2002). "Effects of landscape and local habitat attributes on northern goshawk site occupancy in western Washington." Forest Science 48(2): 427-436.

Fischer, W. C. and B. R. McClelland (1983). "A cavity-nesting bird bibliography—including related titles on forest snags, fire, insects, disease, and decay. " USDA Forest Service Gen. Tech. Rep. INT-140, Intermtn. For. and Range Exp. Stn.

Folliard, L. B., K. P. Reese, and L. V. Diller. (2000). "Landscape characteristics of Northern Spotted Owl nest sites in managed forests of northwestern California. " Journal of Raptor Research 34:75–84.

Ford, E. D. (1999). "Using tong-term investigations to develop silvicultural theory for new forestry." Forestry Chronicle 75: 379-384.

Foster, D. R. (1998). "Landscape Patterns and Legacies Resulting from Large, Infrequent Forest Disturbances." Ecosystems 1(6): 497-510.

Franklin, A. B., D. R. Anderson, et al. (2000). "Climate, Habitat Quality, and Fitness in Northern Spotted Owl Populations in Northwestern California." Ecological Monographs 70(4): 539-590.

Franklin, J. (1989). "Toward a new forestry. (includes related information)." American Forests v95(11-12): p37(8).

Franklin, J., D. Perry, et al. (2000). "Simplified Forest Management to achieve watershed and forest health." National Wildlife Federation, Seattle, Washington. 46pp.

Franklin, J. F. (1990). "Biological Legacies: a Critical Management Concept from Mount St. Helens." North American Wildlife and Natural Resources Conference 55: 216-219.

Franklin, J. F. (1992). "Scientific basis for new perspectives in forests and streams." Watershed Management. Springer-Verlag, NY: 25-72.

Franklin, J. F. (1993). "Lessons from Old-Growth: Fueling Controversy and Providing Direction." Journal of Forestry 91(12): 10-13.

Franklin, J. F. (1993). "Preserving Biodiversity: Species, Ecosystems, or Landscapes?" Ecological Applications 3(2): 202-205.

Franklin, J. F. (1997). "Ecosystem management: an overview." Ecosystem Management: Applications for Sustainable Forest and Wildlife Resources: 21–53.

Franklin, J. F. (2004). "Old-growth forests, owls, and conservtion paradigms." Society of Conservation Biology Newsletter 11(3): 18-19.

Franklin, J. F., D. R. Berg, et al. (1997). "Alternative silvicultural approaches to timber harvesting: variable retention harvest systems." Creating a Forestry for the 21: 111-139.

Franklin, J. F. and R. T. T. Forman (1987). "Creating landscape patterns by forest cutting: Ecological consequences and principles." Landscape Ecology 1(1): 5-18.

Franklin, J. F., D. Lindenmayer, et al. (2000). "Threads of continuity." Conservation Biology in Practice 1(1): 8-16.

Franklin, J. F., L. A. Norris, et al. (1999). "The History of DEMO: An Experiment in Regeneration Harvest of Northwestern Forest Ecosystems." Northwest Science 73: 3-11.

Franklin, J. F., T. Spies, et al. (2005). Definition and inventory of old growth forests on DNR-Managed state lands. Department of Natural Resources.

Franklin, J. F. and T. A. Spies (1991). "Composition, function, and structure of old-growth Douglas-fir forests." Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: USDA Forest Service, Pacific Northwest Research Station: 71-77.

Franklin, J. F., T. A. Spies, et al. (2002). "Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example." Forest Ecology and Management 155(1-3): 399-423.

Franklin, J. F. and R. Van Pelt (2004). "Spatial aspects of structural complexity." Journal of Forestry 102: 22-27.

Franklin, J.F., Mitchell, R.J., Palik, B.J. (2007). Natural disturbance and stand development principles for ecological forestry. General Technical Report NRS-19. USDA Forest Service, Northern Research Station, Newtown Square, PA.

Freese, C. H. and D. L. Trauger (2000). "Wildlife markets and biodiversity conservation in North America." Wildlife Society Bulletin 28(1): 42-51.

Garman, S. L., J. Cissel, et al. (2003). Accelerating Development of Late-successional Conditions in Young Managed Douglas-fir Stands a Simulation Study, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Gehringer, K. R. (2006). "Structure-based nonparametric target definition and assessment procedures with an application to riparian forest management." Forest Ecology and Management 223(1): 125-138.

Gibbons, P. and D. B. Lindenmayer (1996). "A review of issues associated with the retention of trees with hollows in wood production forests." For. Ecol. Manage 83: 245-279.

Gibbons, P., D. B. Lindenmayer, et al. (1997). Conserving Hollow-dependent Fauna in Timber-production Forests, NSW National Parks and Wildlife Service.

Gilmore, A. M. (1990). "Plantation forestry: conservation impacts on terrestrial vertebrate fauna." Prospects for Australian Plantations. Centre for Resource and Environmental Studies, The Australian National University, Canberra: 377-388.

Gilpin, M. E. (1987). "Spatial structure and population vulnerability." Viable Populations for Conservation, Ed. Michael E. Soule, 125-140. Cambridge University Press.

Graham, R.T., A.E. Harvey, et al. (1994). Managing coarse woody debris in forests of the Rocky Mountains. Res. Pap, INT-RP-477. Ogden, UT: USDA Forest Service, Intermountain Research Station. 13 p.

Graham, R.T. and T.B. Jain (1998). "Silviculture's role in managing boreal forests." Conserv. Ecol. 2(2): 8.

Guldin, J.M., 2004. Overview of ecosystem management research in the Ouachita and Ozark Mountains: Phases I-III. In: Guldin, J.M. (Ed.), Ouachita and Ozark Mountains Symposium: Ecosystem Management Research. Gen. Tech. Rep. SRS-74. USDA Forest Service, Southern Research Station, Asheville, NC.

Gustafson, E. J. and R. H. Gardner (1996). "The Effect of Landscape Heterogeneity on the Probability of Patch Colonization." Ecology 77(1): 94-107.

Gustafson, E. J. and G. R. Parker (1992). "Relationships between landcover proportion and indices of landscape spatial pattern." Landscape Ecology 7(2): 101-110.

Hagar, J., S. Howlin, et al. (2004). "Short-term response of songbirds to experimental thinning of young Douglas-fir forests in the Oregon Cascades." Forest Ecology and Management 199(2/3): 333-347.

Hagar, J. C. (2007). "Key elements of stand structure for wildlife in production forests west of the Cascade Mountains." USDA Forest Service General Technical Report PNW(695): 35-48.

Hagar, J. C., W. C. McComb, et al. (1996). "Bird Communities in Commercially Thinned and Unthinned Douglas-Fir Stands of Western Oregon." Wildlife Society Bulletin 24(2): 353-366.

Haila, Y., I. K. Hanski, et al. (1994). "Forestry and the boreal fauna: Matching management with natural forest dynamics." Annales Zoologici Fennici[ANN. ZOOL. FENN.]. 31(1).

Halaj, J., Halpern, C.B., Yi, H., (2008). "Responses of litter-dwelling spiders and carabid beetles to varying levels and patterns of green-tree retention." Forest Ecology and Management 255, 887-900.

Haines-Young, R. and M. Chopping (1996). "Quantifying landscape structure: a review of landscape indices and their application to forested landscapes." Progress in physical geography 20(4): 418-445.

Halpern, C. B., S. A. Evans, et al. (1999). "Response of Forest Vegetation to Varying Levels and Patterns of Green-tree Retention: An Overview of a Long-term Experiment." Northwest Science 73: 27-44.

Halpern, C. B. and M. G. Raphael (1999). "Special issue on retention harvests in northwestern forest ecosystems: the Demonstration of Ecosystem Management Options (DEMO) study." Northwest Science 73: 1–2.

Halpern, C. B. and T. A. Spies (1995). "Plant Species Diversity in Natural and Managed Forests of the Pacific Northwest." Ecological Applications 5(4): 913-934.

Hann, W. J. and D. J. Strohm (2003). "Fire regime condition class and associated data for fire and fuels planning: methods and applications." Fire, fuel treatments and ecological restoration: conference proceedings Proceedings RMRS-P-29. Fort Collins,(CO): USDA Forest Service. p: 397–433.

Hansen, A. J., S. L. Garman, et al. (1995). "Alternative Silvicultural Regimes in the Pacific Northwest: Simulations of Ecological and Economic Effects." Ecological Applications 5(3): 535-554.

Hansen, A. J., W. C. McComb, et al. (1995). "Bird Habitat Relationships in Natural and Managed Forests in the West Cascades of Oregon." Ecological Applications 5(3): 555-569.

Hansen, A. J., T. A. Spies, et al. (1991). "Conserving Biodiversity in Managed Forests." BioScience 41(6): 382-392.

Hanski, I. (1994). "Patch-occupancy dynamics in fragmented landscapes." Trends in Ecology & Evolution 9(4): 131-135.

Hanski, I. (1994). "A Practical Model of Metapopulation Dynamics." The Journal of Animal Ecology 63(1): 151-162.

Hanski, I. (1998). "Metapopulation dynamics." Nature 396(6706): 41-49.

Hanski, I. (1999). "Habitat Connectivity, Habitat Continuity, and Metapopulations in Dynamic Landscapes." Oikos 87(2): 209-219.

Hanski, I. and M. Gilpin (1991). "Metapopulation dynamics: Brief history and conceptual domain." Biological Journal of the Linnean Society 42(1): 3-16.

Harcombe, P. A., S. E. Greene, et al. (2004). "The influence of fire and windthrow dynamics on a coastal spruce-hemlock forest in Oregon, USA, based on aerial photographs spanning 40 years." Forest Ecology and Management 194(1/3): 71-82.

Hargis, C.D., Bissonette, J.A., Turner, D.L., (1999). "The influence of forest fragmentation and landscape pattern on American martens. " Journal of Applied Ecology 36, 157-172.

Harmon, M. E., J. F. Franklin, et al. (1986). "Ecology of coarse woody debris in temperate ecosystems." Advances in Ecological Research 15: 133-302.

Harmon, M. E. and C. Hua (1991). "Coarse Woody Debris Dynamics in Two Old-Growth Ecosystems." BioScience 41(9): 604-610.

Harrington, C.A., DeVine, W.D., (2006). A practical guide to oak release. Gen. Tech. Rep. PNW-GTR-666. In. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Harrington, C. A., S. D. Roberts, et al. (2005). "Tree and Understory Responses to Variable-Density Thinning in Western Washington." USDA Forest Service General Technical Report PNW 635: 97.

Harrington, T. B. and J. C. Tappeiner (1997). "Growth responses of young Douglas-fir and tanoak 11 years after various levels of hardwood removal and understory suppression in southwestern Oregon, USA." Forest Ecology and Management 96(1): 1-11.

Harrington, T. B. and J. C. Tappeiner (2007). "Silvicultural Guidelines for Creating and Managing Wildlife Habitat in West-Side Production Forests." USDA Forest Service General Technical Report PNW 695: 49.

Harrington, T. B., J. C. Tappeiner, et al. (1991). "Predicting average growth and size distributions of Douglas-fir saplings competing with sprout clumps of tanoak or Pacific madrone." New Forests 5(2): 109-130.

Harris, L. D. (1984). The Fragmented Forest: Island Biogeography Theory and the Preservation of Biotic Diversity, University of Chicago Press.

Hartley, M. J. (2002). "Rationale and methods for conserving biodiversity in plantation forests." Forest Ecology and Management 155(1-3): 81-95.

Haveri, B. A. and A. B. Carey (2000). "Forest Management Strategy, Spatial Heterogeneity, and Winter Birds in Washington." Wildlife Society Bulletin 28(3): 643-652.

Hayes, J.P., Loeb, S.C., (2007). "Ch. 8. The influences of forest management on bats in North America. " In: Lacki, M.J., Hayes, J.P., Kurta, A. (Eds.), Bats in forests: conservation and management. JHU Press.

Hayes, J. P., S. S. Chan, et al. (1997). "Wildlife Response to Thinning Young Forests in the Pacific Northwest." Journal of Forestry 95(8): 28-33.

Hayes, J. P., S. H. Schoenholtz, et al. (2005). "Environmental consequences of intensively managed forest plantations in the Pacific Northwest." Journal of Forestry 103(2): 83-87.

Hayes, J. P., J. M. Weikel, et al. (2003). "Response of Birds to Thinning Young Douglas-Fir Forests." Ecological Applications 13(5): 1222-1232.

He, F. and H. J. Barclay (2000). "Long-term response of understory plant species to thinning and fertilization in a Douglas-fir plantation on southern Vancouver Island, British Columbia." Can. J. For. Res 30(4): 566-572.

Heithecker, T.D., Halpern, C.B., (2007). "Edge-related gradients in microclimate in forest aggregates following structural retention harvests in western Washington". Forest Ecology and Management 248, 163-173.

Helgerson, O. T., J. Bottorff, et al. (2003). Thinning Young Douglas-fir West of the Cacades for Timber and Wildlife, Washington State University Cooperative Extension; US Dept. of Agriculture.

Henderson, J. A. (1994). "The ecological consequences of long-rotation forestry." High quality forestry workshop: the idea of long rotations, JF Weigand, RW Haynes, and JL Mikowshi. University of Washington Center for International Trade in Forest Products, Seattle, WA: 4-26.

Hessburg, P.F., Agee, J.K., Franklin, J.F., (2005). "Dry forests and wildland fires of the inland Northwest USA: contrasting the landscape ecology of the pre-settlement and modern eras". Forest Ecology and Management 211, 117-139.

Hessburg, P.F., Salter, R.B., James, K.M., (2007). "Re-examining fire severity relations in pre-management era mixed-conifer forests: inferences from landscape patterns of forest structure. " Landscape Ecology 22, 5-24.

Holmberg, P. (2007). "Managing for wildlife habitat in westside production forests: A workshop synthesis." USDA Forest Service General Technical Report PNW 695: 123-134.

Holmberg, P. and Bob Aulds (2002). Developing Westside Sivicultural Prescriptions: An Inter-Active Self-Study and Reference Pamphlet (Draft). Washington State Department of Natural Resources.

Home, R. P., C. Home, et al. (2002). "Long-term patterns of diameter and basal area growth of old-growth Douglas-fir trees in western Oregon." Can. J. For. Res 32(7): 1232-1243.

Howard, L.F., Litvaitis, J.A., Lee, T.D., Ducey, M.J., (2005). Reconciling the effects of historic land use and disturbance on conservation of biodiversity in managed forests in the northeastern United States. Part 3- Northern Hardwoods. Report B1.1. National Commission on Science for Sustainable Forestry, Washington, D.C

Hunter, M. G. (1995). "Residual trees as biological legacies." Cascade Center for Ecosystem Management.

Hunter, M. G. (2001). "Management in young forests. Communique No. 3." Cascade Center for Ecosystem Management. Corvallis, OR http://www. fsl. orst. edu/ccem/pdg/Comque32. pdf.

Hunter, Malcolm. (1999). Maintaining Biodiversity in Forest Ecosystems. Cambridge University Press: 698.

Hunter, M. L. (1990). Wildlife, forests, and forestry: principles of managing forests for biological diversity, Englewood Cliffs, NJ (EUA). Prentice Hall Career & Technology.

Hyde, W. F. (1989). "Marginal Costs of Managing Endangered Species: The Case of the Red-Cockaded Woodpecker." Journal of Agricultural Economic Research 41(2): 12-19.

Ims, R. A., J. Rolstad, et al. (1993). "Predicting space use responses to habitat fragmentation: Can voles Microtus oeconomus serve as an experimental model system(EMS) for capercaillie grouse Tetrao urogallus in boreal forest?" Biological Conservation 63(3): 261-268.

Irland, L. C., A. E. Camp, et al. (2006). Long-term Silvicultural & Ecological Studies: Results for Science and Management. New Haven, School of Forestry & Environmental Studies, Yale University.

Ishii, H. T., S. Tanabe, et al. (2004). "Exploring the relationships among canopy structure, stand productivity, and biodiversity of temperate forest ecosystems." Forest Science 50(3): 342-355.

Janisch, J. E., M. E. Harmon, et al. (2005). "Decomposition of coarse woody debris originating by clearcutting of an old-growth conifer forest." Ecoscience 12(2): 151-160.

Jasienski, M., S. C. Thomas, et al. (1998). "Blaming the trees: a critique of research on forest responses to high CO2." Trends in Ecology and Evolution 13(10): 427-427.

Johnson, D. H. and T. A. O'Neil (2001). Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR, Oregon State University Press.

Johnson, K. N., J. F. Franklin, et al. (1991). "Alternatives for management of late-successional forests of the Pacific Northwest." A report to the Agriculture Committee and the Merchant Marine and Fisheries Committee US House of Representatives 59.

Jones, M.D., Twieg, B.D., Durall, D.M., Berch, S.M., (2008). "Location relative to a retention patch affects the ECM fungal community more than patch size in the first season after timber harvesting on Vancouver Island, British Columbia. " Forest Ecology and Management 255, 1342-1352.

Kavanagh, R. P. and G. A. Webb (1998). "Effects of variable-intensity logging on mammals, reptiles and amphibians at Waratah Creek, southeastern New South Wales." Pacific Conservation Biology 4: 326–347.

Keeton, W.S., (2006("Managing for late-successional/old-growth characteristics in northern hardwood-conifer forests." Forest Ecology and Management 235, 129-142.

Kelsey, K. A., S. D. West, et al. (1998). River Ecology and Management: Lessons From the Pacific Coastal Ecoregion, Springer-Verlag, New York.

Kimmins, J. P. (2007). "Forest ecosystem manament: miracle or mirage?" USDA Forest Service General Technical Report PNW 695: 19-31.

King, D.I., DeGraaf, R.M., (2000). "Bird species diversity and nesting success in mature, clearcut and shelterwood forest in northern New Hampshire, USA." Forest Ecology and Management 129, 227-235.

Kliskey, A. D., E. C. Lofroth, et al. (1999). "Simulating and evaluating alternative resource-use strategies using GIS-based habitat suitability indices." Landscape and Urban Planning 45(4): 163-175.

Kohm, K. A. and J. F. Franklin (1997). Creating a Forestry for the 21st Century: The Science of Ecosystem Management, Island Press.

Kramer, M. G., A. J. Hansen, et al. (2001). "Abiotic Controls on Long-Term Windthrow Disturbance and Temperate Rain Forest Dynamics in Southeast Alaska." Ecology 82(10): 2749-2768.

Kremsater, L. and F. L. Bunnell (1999). "Edge effects: theory, evidence and implications to management of western North American forests." Forest Fragmentation: Wildlife and Management Implications: 117–53.

Lahti, D. C. (2001). "The"edge effect on nest predation"hypothesis after twenty years." Biological Conservation 99(3): 365-374.

Lamberson, R. H., R. McKelvey, et al. (1992). "A Dynamic Analysis of Northern Spotted Owl Viability in a Fragmented Forest Landscape." Conservation Biology 6(4): 505-512.

Lamberson, R. H., B. R. Noon, et al. (1994). "Reserve Design for Territorial Species: The Effects of Patch Size and Spacing on the Viability of the Northern Spotted Owl." Conservation Biology 8(1): 185-195.

Lance, A. N., and M. Phinney. (2001). "Bird responses to partial retention timber harvesting in central interior British Columbia." Forest Ecology and Management 142:267–280.

Latham, P., and J. Tappeiner. (2002). "Response of old-growth conifers to reduction in stand density in western Oregon forests." Tree Physiology 22:137–146.

Latta, G. and C. A. Montgomery (2004). "Minimizing the cost of stand level management for older forest structure in western Oregon." Western Journal of Applied Forestry 19: 221-231.

Latta, G. and C. A. Montgomery (2007). "Economic considerations in managing for older-forest structure." USDA Forest Service General Technical Report PNW 695: 95-104.

Lauck, B., Swain, R., Bashford, R., (2008). "The response of the frog Crinia signifera to different silvicultural practices in southern Tasmania, Australia." Tasforests 17, 29-36.

Laurance, W. F. and E. Yensen (1991). "Predicting the impacts of edge effects in fragmented habitats." Biological Conservation 55(1): 77-92.

Lefkovitch, L. P. and L. Fahrig (1985). "Spatial characteristics of habitat patches and population survival." Ecological Modelling 30(3): 297-308.

Lehmkuhl, J. F., S. D. West, et al. (1999). "An Experiment for Assessing Vertebrate Response to Varying Levels and Patterns of Green-tree Retention." Northwest Science 73: 45-63.

Lemckert, F. and T. Brassil (2000). "Movements and habitat use of the endangered giant barred river frog (Mixophyes iteratus) and the implications for its conservation in timber production forests." Biological Conservation 96(2): 177-184.

Loehle, C., Wigley, T. et al. (2005). "Managed forest landscape structure and avian species richness in the southeastern US. " Forest Ecology and Management 214, 279-293.

Lewis, J. C. (1998). "Creating Snags and Wildlife Trees in Commercial Forest Landscapes." Western Journal of Applied Forestry 13(3): 97-101.

Li, H., J. F. Franklin, et al. (1993). "Developing alternative forest cutting patterns: A simulation approach." Landscape Ecology 8(1): 63-75.

Lidicker, W. Z. (1999). "Responses of mammals to habitat edges: an overview." Landscape Ecology 14(4): 333-343.

Lilieholm, R. J., W. B. Kessler, et al. (1993). "Stand density index applied to timber and goshawk habitat objectives in Douglas-fir." Environmental Management 17(6): 773-779.

Lindenmayer, D. B. (1994). "Timber harvesting impacts on wildlife: implications for ecologically sustainable forest use." Australian Journal of Environmental Management 1: 56-68.

Lindenmayer, D. B. and J. F. Franklin (1999). Managed unreserved land for biodiversity conservation: the imprtance of the matrix. Nature conservation 5: Nature conservation in production environments. Managing the matrix. J. L. Craig, N. Mitchell and D. A. Sanders. Chipping Norton, Australia, Surrey Beatty & Sons: 13-15.

Lindenmayer, D. B. and J. F. Franklin (2002). Conserving Forest Biodiversity: A Comprehensive Multiscaled Approach, Island Press.

Lindenmayer, D. B., J. F. Franklin, et al. (2006). "General management principles and a checklist of strategies to guide forest biodiversity conservation." Biological Conservation 131(3): 433-445.

Lindenmayer, D. B., C. R. Margules, et al. (2000). "Indicators of Biodiversity for Ecologically Sustainable Forest Management." Conservation Biology 14(4): 941-950.

Lindenmayer, D.B., McCarthy, M.A., 2002. “Congruence between natural and human forest disturbance: a case study from Australian montane ash forests.” Forest Ecology and Management 155, 319-335.

Lindenmayer, D. B. and T. W. Norton (1993). "The conservation of Leadbeater’s possum in south-eastern Australia and the Spotted Owl in the Pacific Northwest of the USA: management issues, strategies and lessons." Pacific Conserv. Biol 1: 13-19.

Lindenmayer, D. B. and H. P. Possingham (1996). "Modelling the inter-relationships between habitat patchiness, dispersal capability and metapopulation persistence of the endangered species, Leadbeater's possum, in south-eastern Australia." Landscape Ecology 11(2): 79-105.

Lindenmayer, D. B. and H. P. Possingham (1996). "Modelling the relationships between habitat connectivity, corridor design and wildlife conservation within intensively logged wood production forests of south-eastern Australia." Landscape Ecology 11: 79-105.

Lindh, B. C. and P. S. Muir (2004). "Understory vegetation in young Douglas-fir forests: does thinning help restore old-growth composition?" Forest Ecology and Management 192(2/3): 285-296.

Lippke, B. (1997). "The Role of Economics in Producing Non-Market Forest Amenities." The Uneven-Aged Management Symposium (IUFRO), Corvallis, OR, Oregon State University.

Lippke, B. and C. D. Oliver (1993). "How can management for wildlife habitat, biodiversity, and other values be most cost-effective." Journal of Forestry 91: 14-18.

Lippke, B. and C. D. Oliver (1993). "Managing for Multiple Values: A Proposal for the Pacific Northwest." Journal of Forestry 91(12): 14-18.

Lippke, B., K. W. Zobrist, et al. (2007). "Issues and alternatives associated with private forest wildlife and riparian habitat management." USDA Forest Service General Technical Report PNW 695: 81-94.

Lippke, B., K. W. Zobrist, et al. (2007). Templates for Forest Sustainability on the Olympic Experimental State Forest. RTI Working Paper #7. Seattle, WA, University of Washington: 61.

Lippke, B. R., J. Sessions, et al. (1996). Economic Analysis of Forest Landscape Management Alternatives, College of Forest Resources, University of Washington; USDA Forest Service, Pacific Northwest Research Station: Washington State, Dept. of Natural Resources.

Loomis, J. B. (2000). "Can environmental economic valuation techniques aid ecological economics and wildlife conservation?" Wildlife Society Bulletin 28(1): 52-60.

Lovett, G. (2005). Ecosystem Function in Heterogeneous Landscapes, Springer.

Lundquist, J. E. and J. S. Beatty (1999). "A Conceptual Model for Defining and Assessing Condition of Forest Stands." Environmental Management 23(4): 519-525.

Lundquist, J. E. and L. Lindner (2000). "Test of a Model to Assess the Condition of Lodgepole Pine Stands." Environmental Management 26(4): 421-426.

Macdonald, J.S., MacIsaac, E.A., Herunter, H.E. (2003). "The effect of variable-retention riparian buffer zones on water temperatures in small headwater streams in sub-boreal forest ecosystems of British Columbia. " Canadian Journal of Forest Research 33, 1371-1382.

MacLean, C. D., C. L. Bolsinger, et al. (1997). Urban Expansion in the Forests of the Puget Sound Region, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Maguire, D. A., S. Canavan, et al. (2005). "Fate of Taxa After Variable-Retention Harvesting in Douglas-fir Forests of the Northwestern United States." USDA Forest Service General Technical Report PNW 635: 271.

Maguire, D.A., Halpern, C.B., Phillips, D.L., (2007). "Changes in forest structure following variable-retention harvests in Douglas-fir dominated forests." Forest Ecology and Management 242, 708-726.

Marshall, D. D. and R. O. Curtis (2005). "Evaluation of Silvicultural Options for Harvesting Douglas-fir Young-Growth Production Forests." USDA Forest Service General Technical Report PNW 635: 119.

Martínez-Pastur, G., Cellini, J.M., Peri, P.L., Vukasovic, R.F., Fernández, M.C., (2000). "Timber production of *Nothofagus pumilio* forests by a shelterwood system in Tierra del Fuego (Argentina)." Forest Ecology and Management 134, 153-162.

Marzluff, J. M. and K. Ewing (2001). "Restoration of Fragmented Landscapes for the Conservation of Birds: a General Framework and Specific Recommendations for Urbanizing Landscapes." Restoration Ecology 9(3): 280-292.

Marzluff, J. M. and L. J. Lyon (1983). "Snags as indicators of habitat suitability for open nesting birds." Davis, JW, GA Goodwin, and RA Ockenfels, technical coordinators. Snag habitat management: Proceedings of the symposium. US Forest Service, General Technical Report RM-99: 140-146.

Marzluff, J. M., J. J. Millspaugh, et al. (2002). "Modeling changes in wildlife habitat and timber revenues in response to forest management." Forest Science 48(2): 191-202.

Marzluff, J. M., J. J. Millspaugh, et al. (2004). "Relating resources to a probabilistic measure of space use: Forest fragments and Steller's jays." Ecology 85(5): 1411-1427.

Marzluff, J. M., M. G. Raphael, et al. (2000). "Understanding the Effects of Forest Management on Avian Species." Wildlife Society Bulletin 28(4): 1132-1143.

Marzluff, J. M. and M. Restani (1999). "The effects of forest fragmentation on avian nest predation." Forest fragmentation: wildlife and management implications. Brill Academic Publishing, Leiden, The Netherlands: 155–169.

Mason, C. L., C. Ceder, et al. (2003). Investigation of Alternative Strategies for Design, Layout, and Administration of Fuel Removal Projects. Seattle, WA, Rural Technology Initiative, College of Forest Resources, University of Washington.

Matlack, G. R. and J. A. Litvaitis (1999). "Forest edges." Maintaining Biodiversity in Forest Ecosystems: 210–233.

McCarter, J. B., C. D. Oliver, et al. (2001). "The Landscape Management System (LMS) to attain, document and certify sustainable forest ecosystem management." Forest modelling for ecosystem management, forest certification and sustainable management: proceedings of the conference held in Vancouver, BC, Canada, August 12.

McCarter, J. B., J. S. Wilson, et al. (1998). "Landscape management through integration of existing tools and emerging technologies." Journal of Forestry 96(6): 17-23.

McClellan, M. H. and S. Or Pacific Northwest Research (2000). Alternatives to Clearcutting in the Old-growth Forests of Southeast Alaska Study Plan and Establishment Report, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

McClelland, B. R. and S. S. Frissell (1975). "Identifying forest snags useful for hole-nesting birds." J. For 73: 414-417.

McCollin, D. (1998). "Forest Edges and Habitat Selection in Birds: A Functional Approach." Ecography 21(3): 247-260.

McComb, W. C., T. A. Spies, et al. (1993). "Douglas-Fir Forests: Managing for Timber and Mature-Forest Habitat." Journal of Forestry 91(12): 31-42.

McGarigal, K. and S. A. Cushman (2002). "Comparative Evaluation of Experimental Approaches to the Study of Habitat Fragmentation Effects." Ecological Applications 12(2): 335-345.

McGarigal, K., Cushman, S. (2005). "Chapter 12. The gradient concept of landscape structure. " In: Wiens, J.A., Moss, M.R. (Eds.), Issues and perspectives in landscape ecology. Cambridge University Press, Cambridge, UK, pp. 112-119.

McGarigal, K. and W. C. McComb (1995). "Relationships Between Landscape Structure and Breeding Birds in the Oregon Coast Range." Ecological Monographs 65(3): 235-260.

McPherson, G. R. (1992). "Comparison of linear and non-linear overstory-understory models for ponderosa pine: a conceptual framework." Forest ecology and management 55(1-4): 31-34.

Mills, L. S. (1995). "Edge Effects and Isolation: Red-Backed Voles on Forest Remnants." Conservation Biology 9(2): 395-403.

Mills, L. S. and F. W. Allendorf (1996). "The One-Migrant-per-Generation Rule in Conservation and Management." Conservation Biology 10(6): 1509-1518.

Mitchell, S.J., Beese, W.J. (2002). "The retention system: reconciling variable retention with the principles of silvicultural systems." The Forestry Chronicle 78, 397-403.

Mladenoff, D. J., M. A. White, et al. (1994). "Applying Principles of Landscape Design and Management to Integrate Old-Growth Forest Enhancement and Commodity Use." Conservation Biology 8(3): 752-762.

Mladenoff, D. J., M. A. White, et al. (1993). "Comparing Spatial Pattern in Unaltered Old-Growth and Disturbed Forest Landscapes." Ecological Applications 3(2): 294-306.

Monkkonen, M. and P. Reunanen (1999). "On Critical Thresholds in Landscape Connectivity: A Management Perspective." Oikos 84(2): 302-305.

Moore, C. T., M. J. Conroy, et al. (2000). "Forest management decisions for wildlife objectives: system resolution and optimality." Computers and Electronics in Agriculture 27(1): 25-39.

Moore, S. E. and H. L. Allen (1999). "Plantation forestry." Maintaining biodiversity in forest ecosystems. Cambridge Univ. Press, New York, EE. UU: 400-433.

Muir, P. S., G. Survey, et al. (2002). Managing for Biodiversity in Young Douglas-fir Forests of Western Oregon, US Geological Survey, Forest and Rangeland Ecosystem Science Center.

Murcia, C. (1995). "Edge effects in fragmented forests: implications for conservation." Trends in Ecology and Evolution 10(2): 58-62.

Murphy, D. D. and B. R. Noon (1992). "Integrating Scientific Methods with Habitat Conservation Planning: Reserve Design for Northern Spotted Owls." Ecological Applications 2(1): 3-17.

Murphy, G. E., W. R. J. Sutton, et al. (2005). "Economics of intensively managed forest plantations in the Pacific Northwest." Journal of Forestry 103(2): 78-82.

Nadkarni, N. M., G. G. Parker, et al. (1996). "The international canopy network: A pathway for interdisciplinary exchange of scientific information on forest canopies." Northwest Science 70: 104-108.

Naiman, R. J., H. Decamps, et al. (1993). "The Role of Riparian Corridors in Maintaining Regional Biodiversity." Ecological Applications 3(2): 209-212.

Naiman, R. J., K. L. Fetherston, et al. (1998). "Riparian forests." River Ecology and Management: Lessons from the Pacific Coastal Ecoregion: 289–323.

National Council for Air and Stream Improvement, Inc. (NCASI) (2000). Riparian vegetation effectiveness. Technical Bulletin No. 799. Research Triangle Park, NC: National Council for Air and Stream Improvement, Inc.

North, M., J. Q. Chen, et al. (2004). "Forest stand structure and pattern of old-growth western hemlock/Douglas-fir and mixed-conifer forests." Forest Science 50(3): 299-311.

North, M. P., J. F. Franklin, et al. (1999). "Forest stand structure of the northern spotted owl's foraging habitat." Forest Science 45(4): 520-527.

North, M.P., Keeton, W.S. (2008). "Emulating natural disturbance regimes: an emerging approach for sustainable forest management. " Pages 341-372. In: Lafortezza, R., Sanesi, G., Chen, J., Crow, T.R. (Eds.), Patterns and processes in forest landscapes: multiple use and sustainable management. Springer Netherlands.

NCSSF, (2007). Conserving Biodiversity Through Sustainable Forestry: A Guide to Applying NCSSF Research. National Commission for Sustainable Forestry. Washington DC.173 pages

Nelson, P., Studyvin, C., (2007). "Silvicultural strategies for restoring Missouri Ozark ecosystems on the Mark Twain National Forest." In: Deal, R.L. (Ed.), Integrated restoration of forested ecosystems to achieve multiresource benefits: proceedings of the 2007 National Silviculture Workshop. USDA Forest Service, Gen. Tech. Rep. PNW-GTR-733, Ketchikan, Ak.

Neyland, M.G., (2004). "Selection, harvesting damage, burning damage and persistence of retained trees following dispersed retention harvesting in the Warra silvicultural systems trial in Tasmania." Tasforests 15, 55-66.

Noss, R. F. and A. Cooperrider (1994). Saving Nature's Legacy: Protecting and Restoring Biodiversity, Island Press.

Ohmann, J. L., W. C. McComb, et al. (1994). "Snag Abundance for Primary Cavity-Nesting Birds on Nonfederal Forest Lands in Oregon and Washington." Wildlife Society Bulletin 22(4): 607-620.

O'Hara, K.L., (2001). "The silviculture of transformation- a commentary." Forest Ecology and Management 151, 81-86.

Oliver, C. and B. C. Larson (1996). Forest Stand Dynamics: Update Edition, Wiley.

Oliver, C. D. (1992). "A landscape approach: achieving and maintaining biodiversity and economic productivity." Journal of Forestry 90(9): 20-25.

Pabst, R. J. and T. A. Spies (1999). "Structure and composition of unmanaged riparian forests in the coastal mountains of Oregon, USA." Can. J. For. Res 29: 1557-1573.

Parker, G. G. (1997). "Canopy structure and light environment of an old-growth Douglas-fir/Western Hemlock forest." Northwest Science 71(4): 261-270.

Parker, G. G. and M. J. Brown (2000). "Forest Canopy Stratification—Is It Useful?" The American Naturalist 155(4): 473-484.

Parker, G. G., M. E. Harmon, et al. (2004). "Three-dimensional Structure of an Old-growth Pseudotsuga-Tsuga Canopy and Its Implications for Radiation Balance, Microclimate, and Gas Exchange." Ecosystems 7(5): 440-453.

Parks, C. G. and D. C. Shaw (1996). "Death and decay: A vital part of living canopies." Northwest Science 70: 46-53.

Patel-Weynand, T. (2002). "Biodiversity and sustainable forestry: State of the science review." National Commission on Science for Sustainable Forestry. Washington DC.

Paton, P. W. C. (1994). "The Effect of Edge on Avian Nest Success: How Strong Is the Evidence?" Conservation Biology 8(1): 17-26.

Pearson, S. M., M. G. Turner, et al. (1996). "An organism-based perspective of habitat fragmentation." Biodiversity in managed landscapes: theory and practice. Oxford University Press, New York, New York, USA: 77–95.

Pelt, R. V. and J. F. Franklin (1999). "Response of Understory Trees to Experimental Gaps in Old-Growth Douglas-Fir Forests." Ecological Applications 9(2): 504-512.

Peterson, C. E. and D. A. Maguire (2005). Balancing Ecosystem Values: Innovative Experiments for Sustainable Forestry. USDA Forest Service, Pacific Northwest Research Station. PNW-GTR-635.

Poage, N. J. (1994). Comparison of stand development of a deciduous-dominated riparian forest and a coniferous-dominated riparian forest in the Oregon Coast Range, Oregon State University.

Poage, N. J. (2000). Structure and development of old-growth Douglas-fir in central western Oregon, Oregon State University.

Poage, N. J. and P. D. Anderson (2007). Large-scale silviculture experiments of western Oregon and Washington. GTR 7B USDA Forest Service PNW Experiment Station, Portland, OR.

Poage, N. J., D. D. Marshall, et al. (2007). "Maximum Stand-Density Index of 40 Western HemlockSitka Spruce Stands in Southeast Alaska." Western Journal of Applied Forestry 22(2): 99-104.

Poage, N. J. and T. A. Spies (1996). "A tale of two unmanaged riparian forests." COPE Report 9(1): 6-9.

Poage, N. J. and J. C. Tappeiner (2002). "Long-term patterns of diameter and basal area growth of old-growth Douglas-fir trees in western Oregon." Can. J. For. Res 32: 1232–1243.

Pressey, R. L. and R. M. Cowling (2001). "Reserve Selection Algorithms and the Real World." Conservation Biology 15(1): 275-277.

Puettmann, K. J. and C. A. Berger (2006). "Development of Tree and Understory Vegetation in Young Douglas-Fir Plantations in Western Oregon." Western Journal Of Applied Forestry 21(2): 94.

Puettmann, K.J., Coates, K.D., Messier, C. (2009). A critique of silviculture: managing for complexity. Island Press, Washington D.C.

Rambo, T. R. (2001). "Decaying Logs and Habitat Heterogeneity: Implications for Bryophyte Diversity in Western Oregon Forests." Northwest Science 75(3): 270-279.

Raphael, M. G., D. E. Mack, et al. (2002). "Effects of forest fragmentation on populations of the Marbled Murrelet." Studies in Avian Biology 25: 221-235.

Raphael, M. G. and M. White (1984). "Use of snags by cavity-nesting birds in the Sierra Nevada." Wildlife Monograph 86: 1-66

Rapp, V. (2002). "Restoring complexity: second-growth forests and habitat diversity." Science update.

Reeves, G. H., L. E. Benda, et al. (1995). "A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest." American Fisheries Society Symposium 17: 334-349.

Reeves, G. H., F. H. Everest and T. E. Nickelson (1989). Identification of Physical Habitats Limiting the Production of Coho Salmon in Western Oregon and Washington. Gen. Tech. Rep. PNW-GTR-245. Portland, OR, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Reeves, G. H., D. B. Hohler, D. P. Larsen, D. E. Busch, K. Kratz, K. Reynolds, K. F. Stein, T. Atzet, P. Hays and M. Tehan (2004). Effectiveness Monitoring for the Aquatic and Riparian Component of the Northwest Forest Plan: Conceptual Framework and Options. Gen. Tech. Rep. PNW-GTR-577. Portland, OR, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Reeves, G. H., J. E. Williams, K. M. Burnett and K. Gallo (2006). "The Aquatic Conservation Strategy of the Northwest Forest Plan." Conservation Biology 20(2): 319-329.

Reid, W. V. and K. R. Miller (1989). Keeping options alive: the scientific basis for conserving biodiversity. Washington DC, World Resource Institute.

Reineke, L. H. (1933). "Perfecting a Stand-density Index for Even-aged Forests."Journal of Agriculture Research 46(7): 627-638

Rempel, R. S., P. C. Elkie, et al. (1997). "Timber-Management and Natural-Disturbance Effects on Moose Habitat: Landscape Evaluation." The Journal of Wildlife Management 61(2): 517-524.

Ricketts, T. H. (2001). "The Matrix Matters: Effective Isolation in Fragmented Landscapes." The American Naturalist 158(1): 87-99.

Risenhoover, K. L. and B. S. Murden (2007). "Managing for wildlife habitat in intensively managed forests." USDA Forest Service General Technical Report PNW 695: 107-116.

Roberts, S.D., Harrington, C.A., Buermeyer, K.R. (2007). "Does variable-density thinning increase wind damage in conifer stands on the Olympic Peninsula." Western Journal of Applied Forestry 22, 285-296.

Roberts, S.D., Harrington, C.A. (2008). "Individual tree growth response to variable-density thinning in coastal Pacific Northwest forests." Forest Ecology and Management 255, 2771-2781.

Robinson, G. R., R. D. Holt, et al. (1992). "Diverse and Contrasting Effects of Habitat Fragmentation." Science 257(5069): 524.

Robinson, S. K., F. R. Thompson Iii, et al. (1995). "Regional Forest Fragmentation and the Nesting Success of Migratory Birds." Science 267(5206): 1987.

Rochelle, J. A., L. Lehmann, et al. (1999). Forest fragmentation, Brill.

Rohweder, M. R., C. W. McKetta, et al. (2000). "Economic and Biological Compatibility of Timber and Wildlife Production: An Illustrative Use of Production Possibilities Frontier." Wildlife Society Bulletin 28(2): 435-447.

Rogers, P. (1996). Disturbance ecology and forest management: a review of the literature. General Technical Report INT-GTR-336. Intermountain Research Station, Ogden, UT.

Rose, C. R. and P. S. Muir (1997). "Green-Tree Retention: Consequences for Timber Production in Forests of the Western Cascades, Oregon." Ecological Applications 7(1): 209-217.

Rosenwald, R., Lohmus, A. (2008). "For what, when, and where is green-tree retention better than clear-cutting? A review of the biodiversity aspects." Forest Ecology and Management 255, 1-15.

Rudnicky, T. C. and M. L. Hunter Jr (1993). "Avian Nest Predation in Clearcuts, Forests, and Edges in a Forest-Dominated Landscape." The Journal of Wildlife Management 57(2): 358-364.

Rudolph, D. C. and R. N. Conner (1996). "Red-Cockaded Woodpeckers and Silvicultural Practice: Is Uneven-Aged Silviculture Preferable to Even-Aged?" Wildlife Society Bulletin 24(2): 330-333.

Ruggiero, L. F., K. B. Aubry, et al. (1991). Wildlife and Vegetation of Unmanaged Douglas-fir Forests, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Sallabanks, R., E. B. Arnett, et al. (2000). "An Evaluation of Research on the Effects of Timber Harvest on Bird Populations." Wildlife Society Bulletin 28(4): 1144-1155.

Saunders, D. A., R. J. Hobbs, et al. (1991). "Biological Consequences of Ecosystem Fragmentation: A Review." Conservation Biology 5(1): 18-32.

Schowalter, T.D., Zhang, Y.L., Rykken, J.J. (2003). "Litter invertebrate responses to variable density thinning in western Washington forest." Ecological Applications 13, 1204-1211.

Schulte, P. J. (2006). "Water flow through junctions in Douglas-fir roots." Plant, Cell & Environment 29(1): 70-76.

Scott, R. E. and S. J. Mitchell (2005). "Empirical modelling of windthrow risk in partially harvested stands using tree, neighbourhood, and stand attributes." Forest Ecology and Management 218(1/3): 193-209.

Sessions, J., G. Reeves, et al. (1997). Implementing spatial planning in watersheds. Washington, D.C., Island Press.

Settings, M. (2007). "Biodiversity Management in Pacific Northwest Forests: Strategies and Opportunities.-Selected Papers from the conference on" Managing Biodiversity in Pacific Northwest Forests", Portland, Oregon, June 5-7, 2006." Forest Ecology and Management 246(1): 108-122.

Sharitz, R.R., Boring, L.R., Van Lear, D.H., Pinder, J.E.I. (1992). "Integrating ecological concepts with natural resource management of southern forests". Ecological applications 2, 226-237.

Sharpe, F. (1996). "The biologically significant attributes of forest canopies to small birds." Northwest Science 70: 86-93.

Shaw, D. C. and K. Bible (1996). "An overview of forest canopy ecosystem functions with reference to urban and riparian systems." Northwest Science 70: 1-6.

Shepperd, W.D., Battaglia, M.A. (2002). Ecology, silviculture, and management of Black Hills ponderosa pine. General Technical Report RMRS-GTR-97. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Snider, G., Daugherty, P.J., Wood, D. (2006). "The irrationality of continued fire suppression: an avoided cost analysis of fire hazard reduction treatments versus no treatment". Journal of Forestry 104, 431-437.

Song, B. (1998). Three-dimensional forest canopies and their spatial relationships to understory vegetation, Michigan Technological University.

Song, B., J. Chen, et al. (1997). "Modeling canopy structure and heterogeneity across scales: From crowns to canopy." Forest Ecology and Management 96(3): 217-229.

Spies, T. A. (1998). "Forest Structure: A Key to the Ecosystem." Northwest Science 72(special issue 2): 34-39.

Spies, T. A. and J. F. Franklin (1988). "Old growth and forest dynamics in the Douglas-fir region of western Oregon and Washington." Natural Areas Journal 8(3): 190-201.

Spies, T. A. and J. F. Franklin (1991). "The structure of natural young, mature, and old-growth Douglas-fir forests in Oregon and Washington." USDA Forest Service General Technical Report PNW-GTR. Portland (OR): Pacific Northwest Research Station: 91–109.

Spies, T. A. and J. F. Franklin (1996). "The diversity and maintenance of old-growth forests." Biodiversity in managed landscapes. Oxford University Press, New York, New York, USA: 296-314.

Spies, T. A., J. F. Franklin, et al. (1988). "Coarse Woody Debris in Douglas-Fir Forests of Western Oregon and Washington." Ecology 69(6): 1689-1702.

Spies, T. A., W. J. Ripple, et al. (1994). "Dynamics and Pattern of a Managed Coniferous Forest Landscape in Oregon." Ecological Applications 4(3): 555-568.

Spies, T. A. and M. G. Turner (1999). "Dynamic forest mosaics." Maintaining Biodiversity in Forest Ecosystems. Cambridge University Press. Cambridge, UK: 95-160.

Stuart-Smith, A. K., J. P. Hayes, et al. (2006). "The influence of wildfire, logging and residual tree density on bird communities in the northern Rocky Mountains." Forest Ecology and Management 231(1-3): 1-17.

Styskel, E. W. (1983). "Problems in snag management implementation—a case study." Davis, Jerry W.; Goodwin, Gregory A.; Ockenfels, Richard A., technical coordinators. Snag habitat management: proceedings of the symposium: 7-9.

Suzuki, N. and J. P. Hayes (2003). "Effects of Thinning on Small Mammals in Oregon Coastal Forests." The Journal of Wildlife Management 67(2): 352-371.

Szacki, J., J. Babinska-Werka, et al. (1993). "The influence of landscape spatial structure on small mammal movements." Acta Theriologica 38(2): 113-123.

Szaro, R. C. and C. E. Peterson (2004). "Evolving approaches toward science-based forest management." Forest Snow and Landscape Research 78(1/2): 9-20.

Szaro, R. C., C. E. Peterson, et al. (2004). "Creating a legacy for sustainable science-based forest management: lessons learned from field experiments." Papers from the IUFRO conference Applied forest ecological experiments, Davos, Switzerland, 5-7 August 2003. Forest Snow and Landscape Research 78(1/2): 208pp.

Szaro, R. C., C. E. Peterson, et al. (2006). "Operational experiments for sustainably managing forests (Grossflächige Feldversuche für die nachhaltige Waldnutzung)." Allgemeine Forst und Jagdzeitung 177 (6/7):98-104 Special Issue

Tabor, J., McElhinny, C., Hickey, J., Wood, J. (2007). "Colonisation of clearfelled coupes by rainforest tree species from mature mixed forest edges, Tasmania, Australia". Forest Ecology and Management 240, 13-23.

Talbert, C. and D. Marshall (2005). "Plantation productivity in the Douglas-fir region under intensive silvicultural practices: results from research and operations." Journal of Forestry 103(2): 65-70.

Tang, S. M., J. F. Franklin, et al. (1997). "Forest harvest patterns and landscape disturbance processes." Landscape Ecology 12(6): 349-363.

Tappeiner, J. C. (1989). "Early establishment and vegetative growth of understory species in the western hemlock- Sitka spruce forests of southeast Alaska." CanJ. Bot./J. Can. Boot. 67(1): 318-326.

Tappeiner, J. C., D. Huffman, et al. (1997). "Density, ages, and growth rates in old-growth and young-growth forests in coastal Oregon." Can. J. For. Res 27(5): 638-648.

Tappeiner, J. C., D. Lavender, et al. (1997). "Silvicultural systems and regeneration methods: current practices and new alternatives." Creating a forestry for the 21st century: the science of ecosystem management. Edited by Kathryn A. Kohm and Jerry F. Franklin. Island Press, Washington: 151–164.

Tappeiner, J. C. and J. C. Zasada (1993). "Establishment of salmonberry, salal, vine maple, and bigleaf maple seedlings in the coastal forests of Oregon." Can. J. For. Res./Rev. can. rech. for 23(9): 1775-1780.

Tarp, P., F. Helles, et al. (2000). "Modelling near-natural silvicultural regimes for beech: an economic sensitivity analysis." Forest ecology and management 130: 187-198.

Taulman, J. F., K. G. Smith, et al. (1998). "Demographic and Behavioral Responses of Southern Flying Squirrels to Experimental Logging in Arkansas." Ecological Applications 8(4): 1144-1155.

Taylor, P. D., L. Fahrig, et al. (1993). "Connectivity Is a Vital Element of Landscape Structure." Oikos 68(3): 571-573.

Thomas, J. W. (1979). Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington, Wildlife management institute, US Department of inetrior Bureau of Land Management.

Thomas, J. W., J. F. Franklin, et al. (2006). "The Northwest Forest Plan: Origins, Components, Implementation Experience, and Suggestions for Change." Conservation Biology 20(2): 277-287.

Thomas, S. C., C. B. Halpern, et al. (1999). "Plant Diversity in Managed Forests: Understory Responses to Thinning and Fertilization." Ecological Applications 9(3): 864-879.

Thompson, J. (2007). "Mountain meadows—here today, gone tomorrow? Meadow science and restoration." Science Findings (94) June 2007: 1-5

Thorpe, H.C., Thomas, S.C., Caspersen, J.P. (2008). "Tree mortality following partial harvests is determined by skidding proximity". Ecological Applications 18, 1652-1663.

Thorpe, H. C., and S. C. Thomas. (2007). "Partial harvesting in the Canadian boreal: success will depend on stand dynamic responses". Forestry Chronicle 83:319–325.

Thorpe, H. C., S. C. Thomas, and J. P. Caspersen. (2007). "Residual-tree growth responses to partial stand harvest in the black spruce (*Picea mariana*) boreal forest". Canadian Journal of Forest Research 37:1563–1571.

Thysell, D. R., A. B. Carey, et al. (2000). Effects of Forest Management on Understory and Overstory Vegetation a Retrospective Study, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Tóth, S. F. and M. E. McDill (2007). "Promoting Large, Compact Mature Forest Patches in Harvest Scheduling Models." Environmental Modeling and Assessment: 1-15.

Tóth, S. F., M. E. McDill, et al. (2006). "Finding the Efficient Frontier of a Bi-Criteria, Spatially Explicit, Harvest Scheduling Problem." Forest Science 52(1): 93.

Trzcinski, M. K., L. Fahrig, et al. (1999). "Independent Effects of Forest Cover and Fragmentation on the Distribution of Forest Breeding Birds." Ecological Applications 9(2): 586-593.

University of Washington College of Forest Resources (2007). "Timber Supply and Forest Structure" in The Future of Washington's Forests and Forestry Industries. University of Washington, Seattle, WA: 518.

USDI Fish and Wildlife Service (1980). "Habitat evaluation procedures (HEP)." USDI Fish and Wildlife Service 102.

USDA Forest Service. (2001). Sierra Nevada forest plan amendment. Final environmental impact statement. San Francisco, CA, UDSA Forest Service, Pacific Southwest Region.

Van Der Meer, P.J., Dignan, P., Savaneh, A., (1999). "Effect of gap size on seedling establishment, growth and survival at three years in mountain ash (Eucalyptus regnans F. Muell.) forest in Victoria, Australia". Forest Ecology and Management 117, 33-42.

Van Pelt, R. and J. F. Franklin (2000). "Influence of canopy structure on the understory environment in tall, old-growth, conifer forests." Can. J. For. Res 30: 1231-1245.

Van Pelt, R. and M. P. North (1996). "Analyzing canopy structure in Pacific Northwest old-growth forests with a stand-scale crown model." Northwest Science 70: 15-30.

Van Pelt, R. and M. P. North (1999). "Testing a ground-based canopy model using the Wind River Canopy Crane." Selbyana 20: 357-362.

Verboom, B. and H. Huitema (1997). "The importance of linear landscape elements for the pipistrelle Pipistrellus pipistrellus and the serotine bat Eptesicus serotinus." Landscape Ecology 12(2): 117-125.

Villard, M. A. and P. D. Taylor (1994). "Tolerance to habitat fragmentation influences the colonization of new habitat by forest birds." Oecologia 98(3): 393-401.

Villard, M. A., M. K. Trzcinski, et al. (1999). "Fragmentation Effects on Forest Birds: Relative Influence of Woodland Cover and Configuration on Landscape Occupancy." Conservation Biology 13(4): 774-783.

Wauters, L., P. Casale, et al. (1994). "Space Use and Dispersal of Red Squirrels in Fragmented Habitats." Oikos 69(1): 140-146.

Wegner, J. F. and G. Merriam (1979). "Movements by Birds and Small Mammals Between a Wood and Adjoining Farmland Habitats." The Journal of Applied Ecology 16(2): 349-357.

White, C.G., Schweitzer, S.H., Moore, C.T., Parnell, I.B., Lewis-Weis, L.A., (2005). "Evaluation of the landscape surrounding northern bobwhite nest sites: a multiscape analysis". Journal of Wildlife Management 69, 1528-1537.

Wiegand, J. F., R. W. Haynes, et al. (1994). High quality forestry workshop: The idea of long rotations. Special Paper 15. Seattle, WA, University of Washington College of Forest Resouces Center for International Trade in Forest Products.

Wielgus, R.B., Vernier, P.R., (2003). "Grizzly bear selection of managed and unmanaged forests in the Selkirk Mountains". Canadian Journal of Forest Research 33, 822-829.

Wilson, D.S., Puettmann, K.J., (2007). "Density management and biodiversity in young Douglas-fir forests: challenges of managing across scales". Forest Ecology and Management 246, 123-134.

Wilson, J. S. and C. D. Oliver (2000). "Stability and density management in Douglas-fir plantations." Can. J. For. Res 30(6): 910-920.

Wilson, S. M. and A. B. Carey (2000). "Legacy Retention Versus Thinning: Influences on Small Mammals." Northwest Science 74(2): 131-145.

Winter, L. E., L. B. Brubaker, et al. (2002). "Initiation of an old-growth Douglas-fir stand in the Pacific Northwest: a reconstruction from tree-ring records." Canadian Journal of Forest Research/Revue Canadienne de Recherche Forestiere 32(6): 1039-1056.

With, K. A. and T. O. Crist (1995). "Critical Thresholds in Species' Responses to Landscape Structure." Ecology 76(8): 2446-2459.

With, K. A. and A. W. King (1999). "Extinction Thresholds for Species in Fractal Landscapes." Conservation Biology 13(2): 314-326.

Witting, L. and V. Loeschcke (1995). "The optimization of biodiversity conservation." Biological Conservation 71(2): 205-207.

Woodruff, D. R., B. J. Bond, et al. (2002). "Effects of stand density on the growth of young Douglas-fir trees." Canadian Journal of Forest Research/Revue Canadienne de Recherche Forestiere 32(3): 420-427.

Zenner, E. K. (2000). "Do Residual Trees Increase Structural Complexity in Pacific Northwest Coniferous Forests?" Ecological Applications 10(3): 800-810.

Zenner, E. K. (2004). "Does old-growth condition imply high live-tree structural complexity?" Forest Ecology and Management 195(1/2): 243-258.

Zenner, E.K. (2005). "Development of tree size distributions in Douglas-fir forests under differing disturbance regimes". Ecological Applications 15, 701-714.

Zobrist, K. W., K. R. Gehringer, et al. (2004). "Templates for sustainable riparian management on family forest ownerships." Journal of Forestry 102(7): 19-25.

Zobrist, K. W. and T. M. Hinckley (2005). A literature review of management practices to support increased biodiversity in intensively managed Douglas-fir plantations. Seattle, WA, Rural Technology Initiative: 14.

2. Spatial forest management reviews & concepts -under multiple objectives

Baskent, E. Z. and G. A. Jordan (1995). "Characterizing spatial structure of forest landscapes." Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 25(11): 1830-1849.

Baskent, E. Z. (1997). "Assessment of structural dynamics in forest landscape management." Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 27(10): 1675-1684.

Baskent, E. Z. and S. Keles (2005). "Spatial forest planning: A review." Ecological Modelling 188(2-4): 145-173.

Bettinger, P. and J. Sessions (2003). "Spatial forest planning - To adopt, or not to adopt?" Journal of Forestry 101(2): 24-29.

Bettinger, P. and W. Chung (2004). "The key literature of, and trends in, forest-level management planning in North America, 1950-2001." International Forestry Review 6(1): 40-50.

Collinge, S. K. (1996). "Ecological consequences of habitat fragmentation: Implications for landscape architecture and planning." Landscape and Urban Planning 36(1): 59-77.

Kurttila, M. (2001). "The spatial structure of forests in the optimization calculations of forest planning - a landscape ecological perspective." Forest Ecology and Management 142(1-3): 129-142.

Seymour, R.S., White, A.S., deMaynadier, P.G. (2002). "Natural disturbance regimes in northeastern North America- evaluating silvicultural systems using natural scales and frequencies". Forest Ecology and Management 155, 357-367.

Weintraub, A. and A. T. Murray (2006). "Review of combinatorial problems induced by spatial forest harvesting planning." Discrete Applied Mathematics 154(5): 867-879

3. Spatial forest management, optimization methods, harvest scheduling with wildlife constraints and case studies

Arthaud, G. J. and D. W. Rose (1996). "A methodology for estimating production possibility frontiers for wildlife habitat and timber value at the landscape level." Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 26(12): 2191-2200.

Azevedo, J. C. M., S. B. Jack, et al. (2000). "Functional heterogeneity of forest landscapes and the distribution and abundance of the red-cockaded woodpecker." Forest Ecology and Management 127(1-3): 271-283.

Baskent, E. Z. (1997). "Assessment of structural dynamics in forest landscape management." Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 27(10): 1675-1684.

Baskent, E. Z. (1999). "Controlling spatial structure of forested landscapes: a case study towards landscape management." Landscape Ecology 14(1): 83-97.

Baskent, E. Z. and G. A. Jordan (1995). "Characterizing spatial structure of forest landscapes." Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 25(11): 1830-1849.

Baskent, E. Z. and G. A. Jordan (1996). "Designing forest management to control spatial structure of landscapes." Landscape and Urban Planning 34(1): 55-74.

Baskent, E. Z. and G. A. Jordan (2002). "Forest landscape management modeling using simulated annealing." Forest Ecology and Management 165: 29-45.

Baskent, E. Z., G. A. Jordan, et al. (2000). "Designing forest landscape management." Forestry Chronicle 76(5): 739-742.

Baskent, E. Z. and S. Keles (2005). "Spatial forest planning: A review." Ecological Modelling 188(2-4): 145-173.

Baskent, E. Z. and H. A. Yolasigmaz (1999). "Forest landscape management revisited." Environmental Management 24(4): 437-448.

Bettinger, P., K. Boston, et al. (2007). "Landscape-level optimization using tabu search and stand density-related forest management prescriptions." European Journal of Operational Research 176(2): 1265-1282.

Bettinger, P., K. Boston, et al. (1999). "Combinatorial optimization of elk habitat effectiveness and timber harvest volume." Environmental Modeling and assessment 4: 143-153.

Bettinger, P., K. Boston, et al. (1999). "Intensifying a heuristic forest harvest scheduling search procedure with 2-opt decision choices." Canadian Journal Of Forest Research-Revue Canadienne De Recherche Forestiere 29(11): 1784-1792.

Bettinger, P. and W. Chung (2004a). "The key literature of, and trends in, forest-level management planning in North America, 1950-2001." International Forestry Review 6(1): 40-50.

Bettinger, P., D. Graetz, et al. (2004b). "A density-dependent stand-level optimization approach for deriving management prescriptions for interior northwest (USA) landscapes." Forest Ecology and Management 217(2-3):171-186

Bettinger, P., D. Graetz, et al. (2002). "Eight heuristic planning techniques applied to three increasingly difficult wildlife planning problems." Silva Fennica 36(2): 561-584.

Bettinger, P., D. L. Johnson, et al. (2003). "Spatial forest plan development with ecological and economic goals." Ecological Modelling 169(2-3): 215-236.

Bettinger, P., K. N. Johnson, et al. (1996). "Forest planning in an Oregon case study: Defining the problem and attempting to meet goals with a spatial-analysis technique." Environmental Management 20(4): 565-577.

Bettinger, P. and J. Sessions (2003). "Spatial forest planning - To adopt, or not to adopt?" Journal of Forestry 101(2): 24-29.

Bettinger, P., J. Sessions, et al. (1997). "Using Tabu search to schedule timber harvests subject to spatial wildlife goals for big game." Ecological Modelling 94(2-3): 111-123.

Bevers, M. and J. Hof (1999). "Spatially optimizing wildlife habitat edge effects in forest management linear and mixed-integer programs." Forest Science 45(2): 249-258.

Bodin, Ö., Norberg, J., (2007). "A network approach for analyzing spatially structured populations in fragmented landscapes". Landscape Ecology 22, 31-44.

Boston, K. and P. Bettinger (1999). "An analysis of Monte Carlo integer programming, simulated annealing, and tabu search heuristics for solving spatial harvest scheduling problems." Forest Science 45(2): 292-301.

Boston, K. and P. Bettinger (2001). "Development of spatially feasible forest plans: a comparison of two modeling approaches." Silva Fennica 35(4): 425-435.

Boston, K. and P. Bettinger (2002). "Combining tabu search and genetic algorithm heuristic techniques to solve spatial harvest scheduling problems." Forest Science 48(1): 35-46.

Bowman, J. and J. F. Robitaille (2005). "An assessment of expert-based marten habitat models used for forest management in Ontario." Forestry Chronicle 81(6): 801-807.

Boyland, M., J. Nelson, et al. (2005). "A test for robustness in harvest scheduling models." Forest Ecology and Management 207(1-2): 121-132.

Calkin, D. E., C. A. Montgomery, et al. (2002). "Developing a production possibility set of wildlife species persistence and timber harvest value." Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 32(8): 1329-1342.

Caro, F., M. Constantino, et al. (2003). "A 2-Opt tabu search procedure for the multiperiod forest harvesting problem with adjacency, greenup, old growth and even flow constraints." Forest Science 49(5): 738-751.

Chappell, C. B., R. C. Crawford, et al. (2001). Wildlife habitats: Desriptions, status, trends, and system dyamics. WIldlife-Habitat Relationships in Oregon and Washington. D. H. Johnson and T. A. O'Neil. Corvallis, OR, Oregon State University Press: 22-114.

Chen, B. W. and K. Von Gadow (2002). "Timber harvest planning with spatial objectives, using the method of simulated annealing." Forstwissenschaftliches Centralblatt 121(1): 25-34.

Church, R. L., A.T. Murray, A. Weintraub(1998) "Locational issues in forest management" Location Science 6(1-4): 137-153.

Collinge, S. K. (1996). "Ecological consequences of habitat fragmentation: Implications for landscape architecture and planning." Landscape and Urban Planning 36(1): 59-77.

Cox, E. S. and J. Sullivan (1995). "Harvest scheduling with spatial wildlife constraints - an empirical-examination of tradeoffs." Journal of Environmental Management 43(4): 333-348.

Crookston, N. L. and G. E. Dixon (2005). "The forest vegetation simulator: A review of its structure, content, and applications." Computers and Electronics in Agriculture 49(1): 60-80.

Deng, W. H. and W. Gao (2005). "Edge effects on nesting success of cavity-nesting birds in fragmented forests." Biological Conservation 126(3): 367-370.

Dodd, N. L., R. E. Schweinsburg, et al. (2006). "Landscape-scale forest habitat relationships to tassel-eared squirrel populations: Implications for ponderosa pine forest restoration." Restoration Ecology 14(4): 537-547.

Ducheyne, E. I., R. R. De Wulf, et al. (2006). "A spatial approach to forest-management optimization: linking GIS and multiple objective genetic algorithms." International Journal of Geographical Information Science 20(8): 917-928.

Edenius, L. and G. Mikusinski (2006). "Utility of habitat suitability models as biodiversity assessment tools in forest management." Scandinavian Journal of Forest Research 21: 62-72.

Fahrig, L. (1999). Forest loss and fragmentation: Which has the greater effect on persistance of forest-dwelling animals? Forest Fragmentation: wildlife and management implications. J. A. Rochelle, L. A. Lehmann and J. Wisniewski. Leiden, The Netherlands, Brill: 61-86.

Fahrig, L. (2002). "Effect of habitat fragmentation on the extinction threshold: A synthesis." Ecological Applications 12(2): 346-353.

Felix, A. B., H. Campa, et al. (2004). "Development of landscape-scale habitat-potential models for forest wildlife planning and management." Wildlife Society Bulletin 32(3): 795-806.

Ferraz, G., J. D. Nichols, et al. (2007). "A large-scale deforstation experiment: Effects of patch area and isolation on Amazon birds." Science 315: 238-241.

Finn, S. P., J. M. Marzluff, et al. (2002). "Effects of landscape and local habitat attributes on northern goshawk site occupancy in western Washington." Forest Science 48(2): 427-436.

Gustafson, E. J. and T. R. Crow (1994). "Modeling the effects of forest harvesting on landscape structure and the spatial distribution of cowbird brood parasitism." Landscape Ecology 9(4): 237-248.

Gustafson, E. J., D. E. Lytle, et al. (2007). "Simulating the cumulative effects of multiple forest management strategies on landscape measures of forest sustainability." Landscape Ecology 22(1): 141-156.

Gustafson, E. J., L. J. Roberts, et al. (2006). "Linking linear programming and spatial simulation models to predict landscape effects of forest management alternatives." Journal of Environmental Management 81(4): 339-350.

Hagan, J. M. and A. L. Meehan (2002). "The effectiveness of stand-level and landscape-level variables for explaining bird occurrence in an industrial forest." Forest Science 48(2): 231-242.

Haight, R. G., R. A. Monserud, et al. (1992). "Optimal harvesting with stand density targets - managing rocky-mountain conifer stands for multiple forest outputs." Forest Science 38(3): 554-574.

Haimes, Y. Y., L. S. Lasdon, et al. (1971). "On a bicriterion forulation of the problems of integrated system identification and system optimization." IEEE Transactions on Systems, Man, and Cybernetics 1: 296-297.

Hanski, I. (1994). "Patch occupancy dynamics in fragmented landscapes." Trend in Ecology & Evolution 9: 131-135.

Hanski, I. (1994). "A practical model of metapopulation dynamics." Journal of Animal Ecology 63: 151-162.

Haveri, B. A. and A. B. Carey (2000). "Forest management strategy, spatial heterogeneity, and winter birds in Washington." Wildlife Society Bulletin 28(3): 643-652.

Higdon, J. W., D. A. MacLean, et al. (2005). "Evaluating vertebrate species risk on an industrial forest landscape." Forest Ecology and Management 204(2-3): 279-296.

Hochbaum, D. S. and A. Pathria (1997). "Forest harvesting and minimum cuts: A new approach to handling spatial constraints." Forest Science 43(4): 544-554.

Hof, J., M. Bevers, et al. (1994). "An Integer Programming Approach For Spatially And Temporally Optimizing Wildlife Populations." Forest Science 40(1): 177-191.

Hof, J. and M. G. Raphael (1997). "Optimization of habitat placement: A case study of the northern spotted owl in the Olympic Peninsula." Ecological Applications 7(4): 1160-1169.

Hof, J. G. and L. A. Joyce (1992). "Spatial optimization for wildlife and timber in managed forest ecosystems." Forest Science 38(3): 489-508.

Hof, J. G. and L. A. Joyce (1993). "A mixed-integer linear-programming approach for spatially optimizing wildlife and timber in managed forest ecosystems." Forest Science 39(4): 816-834.

Hoganson, M., G., Borges (2000) “Impacts of the time horizon for adjacency constraints in harvest scheduling” Forest Science 46(2): 176-187.

Holzkamper, A., A. Lausch, et al. (2006). "Optimizing landscape configuratlion to enhance habitat suitability for species with contrasting habitat requirements." Ecological Modelling 198(3-4): 277-292.

Hummel, S. and D. E. Calkin (2005). "Costs of landscape silviculture for fire and habitat management." Forest Ecology and Management 207(3): 385-404.

Hummel, S., Barbour, R.J. (2007). "Landscape silviculture for late-successional reserve management". In: Powers, R.F. (Ed.), Restoring fire-adapted ecosystems: proceedings of the 2005 national silviculture workshop. Pacific Southwest Research Station, USDA Forest Service. PSW-GTR-203, Albany, CA.

Hurme, E., M. Kurttila, et al. (2007). "Maintenance of flying squirrel habitat and timber harvest: a site-specific spatial model in forest planning calculations." Landscape Ecology 22(2): 243-256.

Hynynen, J., A. Ahtikoski, et al. (2005). "Applying the MOTTI simulator to analyse the effects of alternative management schedules on tiber and non-timber production." Forest Ecology and Management 207: 5-18.

Imaki, H. (2007) Optimizing timber harvest revenue with wildlife constraints for old-forest species using a spatially explicit habitat model and open source GIS. Master of Science thesis. University of Washington, Seattle. 119 pp.

Jaeger, J. and R. Holderegger (2005). "Thresholds of landscape fragmentation." GAIA-Ecological Perspectives for Science and Society 14(2): 113-118.

Jones J. G., Mneghin B. J., Kirby M. W. (1991) "Formulating adjacency constraints in linear optimization models for scheduling projects in tactical planning" Forest Science 37(5): 1283-1297

Juutinen, A., E. Mantymaa, et al. (2004). "A cost-effective approach to selecting forest stands for conserving species: A case study from northern Fennoscandia." Forest Science 50(4): 527-539.

Kremsater, L. L. and F. L. Bunnell (19991). Edges: Theory, evidence, and implications to management of western forsts. Forest Franmentation: Wildlife and Management Implications. J. A. Rochelle, L. A. Lehmann and J. Wisniewski. Leiden, Netherlands, Brill: 117-153.

Kroll, A. J. and J. B. Haufler (2006). "Development and evaluation of habitat models at multiple spatial scales: A case study with the dusky flycatcher." Forest Ecology and Management 229(1-3): 161-169.

Kurttila, M. (2001). "The spatial structure of forests in the optimization calculations of forest planning - a landscape ecological perspective." Forest Ecology and Management 142(1-3): 129-142.

Kurttila, M., T. Pukkala, et al. (2002). "The performance of alternative spatial objective types in forest planning calculations: a case for flying squirrel and moose." Forest Ecology and Management 166: 245-260.

Lande, R. (1993). "Risks of population extinction from demotraphic and environmental stochasticity and random catastrophes." American Naturalist 142: 911-927.

Larsen, E. W., E. H. Girvetz, et al. (2007). "Landscape level planning in alluvial riparian floodplain ecosystems: Using geomorphic modeling to avoid conflicts between human infrastructure and habitat conservation." Landscape and Urban Planning 79(3-4): 338-346.

Larson, M. A., F. R. Thompson, et al. (2004). "Linking population viability, habitat suitability, and landscape simulation models for conservation planning." Ecological Modelling 180(1): 103-118.

Li, H. B., J. F. Franklin, et al. (1993). "Developing alternative forest cutting patterns: A simulation approach." Landscape Ecology 8(1): 63-75.

Li, H. B., D. I. Gartner, et al. (2000). "A landscape model (LEEMATH) to evaluate effects of management impacts on timber and wildlife habitat." Computers and Electronics in Agriculture 27(1-3): 263-292.

Liu, J. G., F. W. Cubbage, et al. (1994). "Ecological and economic-effects of forest landscape structure and rotation length - simulation studies using ECOLECON." Ecological Economics 10(3): 249-263.

Lloyd, P., T. E. Martin, et al. (2005). "Linking demographic effects of habitat fragmentation across landscapes to continental source-sink dynamics." Ecological Applications 15(5): 1504-1514.

Loehle, C., P. Van Deusen, et al. (2006). "A method for landscape analysis of forestry guidelines using bird habitat models and the Habplan harvest scheduler." Forest Ecology and Management 232(1-3): 56-67.

Lu, F., L. O. Eriksson (2000) “Formation of harvest units with genetic algorithms.” Forest Ecology and Management 130 (1-3): 57-67.

Malcolm, J. R., B. D. Campbell, et al. (2004). "Potential indicators of the impacts of forest management on wildlife habitat in northeastern Ontario: A multivariate application of wildlife habitat suitability matrices." Forestry Chronicle 80(1): 91-106.

Marzluff, J. M., J. J. Millspaugh, et al. (2002). "Modeling changes in wildlife habitat and timber revenues in response to forest management." Forest Science 48(2): 191-202.

Marzluff, J. M., M. G. Raphael, et al. (2000). "Understanding the effects of forest management on avian species." Wildlife Society Bulletin 28(4): 1132-1143.

McCarter, J. B., J. S. Wilson, et al. (1988). "Landscape management through integration of existing tools and emerging technologies." Journal of Forestry 96: 17-23.

McDill M.E, J. Braze J. (2000). “Comparing Adjacency Constraint Formulations for Randomly Generated Forest Planning Problems with Four Age-Class Distributions ” Forest Science 46(3): 423-436.

McGrath, M. T., S. DeStefano, et al. (2003). "Spatially explicit influences on northern goshawk nesting habitat in the interior Pacific Northwest." Wildlife Monographs(154): 1-63.

McKenzie, D. and C. B. Halpern (1999). "Modeling the distributions of shrub species in Pacific northwest forests." Forest Ecology and Management 114(2-3): 293-307.

McLaren, B. E., S. P. Mahoney, et al. (2000). "Spatial and temporal patterns of use by moose of pre-commercially thinned, naturally-regenerating stands of balsam fir in central Newfoundland." Forest Ecology and Management 133(3): 179-196.

Miller, G. W. and J. Sullivan (1997). "Model for multi-stand management based on structural attributes of individual stands." Forest Ecology and Management 96(3): 261-271.

Moore, C. T. and M. J. Conroy (2006). "Optimal regeneration planning for old-growth forest: Addressing scientific uncertainty in endangered species recovery through adaptive management." Forest Science 52(2): 155-172.

Moore, C. T., M. J. Conroy, et al. (2000). "Forest management decisions for wildlife objectives: system resolution and optimality." Computers and Electronics in Agriculture 27(1-3): 25-39.

Moore, J. E. and R. K. Swihart (2005). "Modeling patch occupancy by forest rodents: Incorporating detectability and spatial autocorrelation with hierarchically structured data." Journal of Wildlife Management 69(3): 933-949.

Morris, D. W. (2003). "How can we apply theories of habitat selection to wildlife conservation and management?" Wildlife Research 30(4): 303-319.

Murphy, D. D. and B. R. Noon (1992). "Integrating scientific methods with habitat conservation planning - reserve design for northern spotted owls." Ecological Applications 2(1): 3-17.

Murray, A. T. (1998). "Ecosystem management or infeasible guidelines? Implications of adjacency restrictions for wildlife habitat and timber production." Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 28(7): 1093-1094.

Murray, A. T. and R. L. Church (1995). "Heuristic Solution Approaches To Operational Forest Planning Problems." Or Spektrum 17(2-3): 193-203.

Murray, A. T. and R. L. Church (1995). "Measuring The Efficacy Of Adjacency Constraint Structure In Forest Planning-Models." Canadian Journal Of Forest Research-Revue Canadienne De Recherche Forestiere 25(9): 1416-1424.

Nalle, D. J., J. L. Arthur, et al. (2005). "Economic impacts of adjacency and green-up constraints on timber production at a landscape scale." Journal of Forest Economics 10(4): 189-205.

Nalle, D. J., J. L. Arthur, et al. (2002). "Designing compact and contiguous reserve networks with a hybrid heuristic algorithm." Forest Science 48(1): 59-68.

Nalle, D. J., C. A. Montgomery, et al. (2004). "Modeling joint production of wildlife and timber." Journal of Environmental Economics and Management 48(3): 997-1017.

Nelson, J. D., S. T. Finn (1991) “The influence of cut-block size and adjacency rules on harvest levels and road networks.” Canadian Journal of Forest Research 21(5): 595-600.

Oregon Secretary of State (2002) Oregon Administrative Rules Department of Forestry, Division 665, Specified resource site protection rules, 629-665-0210(1)(a).

Polasky, S., E. Nelson, et al. (2005). "Conserving species in a working landscape: Land use with biological and economic objectives." Ecological Applications 15(4): 1387-1401.

Prather, J. W., N. L. Dodd, et al. (2006). "Landscape models to predict the influence of forest structure on tassel-eared squirrel populations." Journal of Wildlife Management 70(3): 723-731.

Radeloff, V. C., D. J. Mladenoff, et al. (2006). "Modeling forest harvesting effects on landscape pattern in the Northwest Wisconsin Pine Barrens." Forest Ecology and Management 236(1): 113-126.

Ransome, D. B. and T. P. Sullivan (2003). "Population dynamics of Glaucomys sabrinus and Tamiasciurus douglasii in old-growth and second-growth stands of coastal coniferous forest." Canadian Journal of Forest Research/Revue Canadienne de Recherche Forestiere 33(4): 587-596.

Rempel, R. S. and C. K. Kaufmann (2003). "Spatial modeling of harvest constraints on wood supply versus wildlife habitat objectives." Environmental Management 32(5): 646-659.

Ribe, R. G. (2006). "Perceptions of forestry alternatives in the US Pacific Northwest: Information effects and acceptability distribution analysis." Journal of Environmental Psychology 26(2): 100-115.

Richards, E. W., E. A. Gunn (2000) "A model and Tabu search method to optimize stand harvest and road construction schedules : Introduction to Spatial Modeling in Forest Management and Natural Resource Planning Reserve Site Selection" Forest Science 46(2): 188-203.

Richards, E. W., E. A. Gunn (2003) "Tabu search design for difficult forest management optimization problems." Can. J. For. Res. 33(6): 1126–1133.

Riitters, K. H., R. V. Oneill, et al. (1997). "Assessing habitat suitability at multiple scales: A landscape-level approach." Biological Conservation 81(1-2): 191-202.

Rohweder, M. R., C. W. McKetta, et al. (2000). "Economic and biological compatibility of timber and wildlife production: an illustrative use of production possibility frontier." Wildlife Society Bulletin 28(2): 435-447.

Russell, W. H. and C. Jones (2001). "The effects of timber harvesting on the structure and composition of adjacent old-growth coast redwood forest, California, USA." Landscape Ecology 16(8): 731-741.

Schumaker, N. H., T. Ernst, et al. (2004). "Projecting wildlife responses to alternative future landscapes in Oregon's Willamette Basin." Ecological Applications 14(2): 381-400.

Sessions, J. (1992). "Solving For Habitat Connections As A Steiner Network Problem." Forest Science 38(1): 203-207.

Seto, K. C., E. Fleishman, et al. (2004). "Linking spatial patterns of bird and butterfly species richness with Landsat TM derived NDVI." International Journal Of Remote Sensing 25(20): 4309-4324.

Shifley, S. R., F. R. Thompson, et al. (2006). "Simulated effects of forest management alternatives on landscape structure and habitat suitability in the Midwestern United States." Forest Ecology and Management 229(1-3): 361-377.

Smith, J. N. M. and J. J. Hellmann (2002). "Population persistence in fragmented landscapes." Trend in Ecology & Evolution 17(9): 397-399.

Snyder, S., C. ReVelle (1997) "Dynamic Selection of Harvests with Adjacency Restrictions: The SHARe Model." Forest Science **43**(2): 213-222.

Soule, M. E. (1991). "Land-Use Planning And Wildlife Maintenance - Guidelines For Conserving Wildlife In An Urban Landscape." Journal Of The American Planning Association 57(3): 313-323.

Spring, D. A., M. Bevers, et al. (2001). "Economics of a nest-box program for the conservation of an endangered species: a reappraisal." Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 31(11): 1992-2003.

Steventon, J. D., K. L. MacKenzie, et al. (1998). "Response of small mammals and birds to partial cutting and clearcutting in northwest British Columbia." Forestry Chronicle 74(5): 703-713.

Sturtevant, B. R., J. A. Bissonette, et al. (1996). "Temporal and spatial dynamics of boreal forest structure in western Newfoundland: Silvicultural implications for marten habitat management." Forest Ecology and Management 87(1-3): 13-25.

Thome, D. M., C. J. Zabel, et al. (1999). "Forest stand characteristics and reproduction of northern spotted owls in managed north-coastal California forests." Journal of Wildlife Management 63(1): 44-59.

Toth, S. F., M. E. McDill, et al. (2006). "Finding the efficient frontier of a bi-criteria, spatially explicit, harvest scheduling problem." Forest Science 52(1): 93-107.

Twedt, D. J., W. B. Uihlein, et al. (2006). "A spatially explicit decision support model for restoration of forest bird habitat." Conservation Biology 20(1): 100-110.

Van Deusen, P. C. (2001). "Scheduling spatial arrangement and harvest simultaneously." Silva Fennica 35(1): 85-92.

van Langevelde, F., A. Schotman, et al. (2000). "Competing land use in the reserve site selection problem." Landscape Ecology 15(3): 243-256.

Van Raffe, J. K. (2000). "Tactic: a decision support system for forest management planning." Computer and Electoronics in Agriculture.

Varghese, A. O. and Y. Murthy (2006). "Application of geoinformatics for conservation and management of rare and threatened plant species." Current Science 91(6): 762-769.

Venier, L. A., J. L. Pearce, et al. (2007). "Future forests and indicator-species population models." Forestry Chronicle 83(1): 36-40.

Verboom, J., R. Foppen, et al. (2001). "Introducing the key patch approach for habitat networks with persistent populations: an example for marshland bird populations." Biological Conservation 100: 89-101.

Verboom, J., A. Schotman, et al. (1991). "European nuthatch metapopulations in a fragmented agricultural landscape." Oikos 61: 149-156.

Villa, L. J., A. B. Carey, et al. (1999). Maturation and reproduction of northern flying squirrels in Pacific Northwest forests. USDA Forest Service Pacific Northwest Research Station. Gen. Tech. Rep. PNW-GTR-444. Portland, OR: 59.

Vos, C. C., J. Verboom, et al. (2001). "Toward ecologially scaled landscape indices." The American Naturalist 183(1): 24-41.

Wallinger, R.S. (2003). "SFI: Sustainable Forestry Initiative Program." Journal of Forestry 101(8): 9-19

Wei, Y. and H. M. Hoganson (2006). "Spatial information for scheduling core area production in forest planning." Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 36(1): 23-33.

Weintraub, A., F. Barahona, R. Epstein (1994) “A column generation algorithm for solving general forest planning problems with adjacency constraints.” Forest Science 40(1): 142-161

Weintraub, A., R. L. Church, A. T. Murray, M. Guignard. (2000) “Forest management models and combinatorial algorithms: analysis of state of the art.” Annals of Operations Research 96(1-4) 271-285.

Weintraub, A. and A. T. Murray (2006). "Review of combinatorial problems induced by spatial forest harvesting planning." Discrete Applied Mathematics 154(5): 867-879.

Welsh, H. H., J. R. Dunk, et al. (2006). "Developing and applying habitat models using forest inventory data: An example using a terrestrial salamander." Journal of Wildlife Management 70(3): 671-681.

Wigley, T. B. and T. H. Roberts (1997). "Landscape-level effects of forest management on faunal diversity in bottomland hardwoods." Forest Ecology and Management 90(2-3): 141-154.

Williams J.C. (1998). “Delineating protected wildlife corridors with multi-objective programming.” Environmental Modeling and Assessment 3(1-2): 77-86.

Wilson, D. E., F. R. Cole, et al., Eds. (1996). Measuring and monitoring biological diversity: standard methods for mammals. Biological diversity handbook series. Washington D.C., Smithonian Institute Press.

Winter, M., D. H. Johnson, et al. (2006). "Patch size and landscape effects on density and nesting success of grassland birds." Journal of Wildlife Management 70(1): 158-172.

With, K. A. and A. W. King (1999). "Extinction thresholds for species in fractal landscapes." Conservation Biology 13(2): 314-326.

Yoshimoto, A., J. D. Brodie, et al. (1994). "A New Heuristic To Solve Spatially Constrained Long-Term Harvest Scheduling Problems." Forest Science 40(3): 365-396.

Zheng, D. L. and J. Q. Chen (2000). "Edge effects in fragmented landscapes: a generic model for delineating area of edge influences (D-AEI)." Ecological Modelling 132(3): 175-190.

Zielinski, W. J., R. L. Truex, et al. (2006). "Using forest inventory data to assess fisher resting habitat suitability in California." Ecological Applications 16(3): 1010-1025.

4. Old-forest characteristics

Baker, P.J., and J.S. Wilson. (2000). "A quantitative technique for the identification of canopy stratification in tropical and temperate forests". Forest Ecology and Management 127:77-86.

Carey, A.B., B.R. Lippke, J. Sessions. (1999). "Intentional Systems Management: Managing Forests for Biodiversity". Journal of Sustainable Forestry 9(3/4):83-125.

Carey, A.B., C.E. Eliot, B.R. Lippke, J. Sessions, C.J. Chambers, C.D. Oliver, J.F. Franklin, and M.G. Raphael. (1996). Washington Forest Landscape Management Project – A Pragmatic, Ecological Approach to Small Landscape Management. Report No. 2 USDA Forest Service, Washington State Department of Fish and Wildlife and Washington State Department of Natural Resources, Olympia, Washington. 99pp.

Commission on Old Growth Alternatives for Washington’s Forest Trust Lands. (1989). Final Report submitted to the Commissioner of Public Lands. Olympia, Washington. 40pp. plus appendices.

Crookston, N.L., & Stage, A.R. (1999). Percent canopy cover and stand structure statistics from the forest vegetation simulator. General Technical Report 24. Ft. Collins, CO: USDA Forest Service Rocky Mountain Research Station. 11pp.

D'Amato, A.W., Orwig, D.A., Foster, D.R., (2008). "The influence of successional processes and disturbance on the structure of Tsuga canadensis forests". Ecological Applications 18, 1182-1199.

DNR. (2005). Definition and Inventory of Old Growth Forests on DNR-Managed State Lands. Olympia, Washington. 21pp. plus appendices.

DNR. (1997). Final Habitat Conservation Plan. Washington State Department of Natural Resources. Olympia, Washington. 223pp. plus appendices.

Esseen, P.A., Renhorn, K.E., Pettersson, R.B. (1996). "Epiphytic lichen biomass in managed and old-growth boreal forests: effect of branch quality". Ecological Applications 6, 228-238.

Everett, R., D. Baumgartner, P. Ohlson and R. Schellhaas. (2008). "Structural classes and age structure in 1860 and 1940 reconstructed fir-pine stands of eastern Washington". Western North American Naturalist. 68 (3): 278-290.

Everett, R., D. Baumgartner, P. Ohlson, R. Schellhaas and R. Harrod. (2007). "Development of current stand structure in dry fir-pine forests of eastern Washington". J. Torrey Botanical Society. 134 (2): 199-214.

Gehringer, K. R. (2006)." Structure-based nonparametric target definition and assessment procedures with an application in riparian forest management". Forest Ecology and Management 223(1-3):125-138

Franklin , J.F., T.A. Spies, R. Van Pelt. (2005). Definition and Inventory of Old Growth Forests on DNR-Managed State Lands (Section One). Report to the Washington Department of Natural Resources. Olympia, Washington. 22pp.

Franklin , J.F. and T.A. Spies. (1991). "Composition, Function, and Structure of Old-Growth Douglas-fir Forests" in General Technical Report: Wildlife and Vegetation of Unmanaged Douglas-fir Forests. PNW-GTR-285. Pacific Northwest Research Station, USDA Forest Service.

Forsman, E.D., A.R. Giese. (1997). "Nests of Northern Spotted Owls on the Olympic Peninsula, Washington". Wilson Bulletin. 109(1):28-41.

Hanson, E., D. Hays, L. Hicks, and L. Young. (1993). Spotted owl habitat in Washington, a report to the Washington Forest Practices Board, Washington Department of Natural Resources, Olympia. 116pp.

Larson, A.J., Lutz, J.A., Gersonde, R.F., Franklin, J.F., Hietpas, F.F., (2008). "Potential site productivity influences the rate of forest structural development". Ecological Applications 18, 899-910.

Lippke, B.R., J. Comnick, L. Johnson. (2004). "Environmental Performance Index for the Forest". CORRIM Phase I Final Report. Module O. 13pp. www.corrim.org

Lippke, B.R., J. Sessions, A.B. Carey. (1996). Economic Analysis of Forest Landscape Management Alternatives: Final report of the working group on the economic analysis of forest landscape management alternatives for the Washington Forest Landscape Management Project. Special Paper 21, CINTRAFOR, College of Forest Resources, Univ. of Washington, Seattle, WA. 157pp.

McCarter, J.B. (2001). Landscape management system (LMS): background, methods, and computer tools for integrating forest inventory, GIS, growth and yield, visualization and analysis for sustaining multiple forest objectives. Seattle, WA: University of Washington. 101pp. Ph.D. dissertation.

McCarter , J.B., J.S. Wilson, P.J. Baker, J.L Moffett, and C.D. Oliver. (1998). "Landscape management through integration of existing tools and emerging technologies". Journal of Forestry 96:17-23.

Nagel, T.A., Svoboda, M., (2008). "Gap disturbance regime in an old-growth *Fagus-Abies* forest in the Dinaric Mountains, Bosnia-Herzegovina". Canadian Journal of Forest Research 38, 2728-2737.

Nigh, G. (1995). "The geometric mean regression line: A method for developing site index conversion equations for species in mixed stands. " Forest Science 41(1):84-98.

Oliver, C., R. Greggs, L. Hicks, S. Boyd. (1995). Forest stand structural classification system developed for the Plum Creek Cascades Habitat Conservation Plan. Technical Report No. 10. Plum Creek Timber Company, LLP. Seattle, WA. 30pp.

Oliver, C.D. and B.C. Larson. (1990). Forest Stand Dynamics. McGraw Hill, New York. 419pp.

RTI (Rural Technology Initiative). (2001). Defining and Using Biologically Based Targets in Forest Management: Incorporating Forest Structure and Variability . RTI Fact Sheet #6. Rural Technology Initiative, College of Forest Resources, University of Washington. 4pp.

Zobrist, K.W., K.R. Gehringer, and B.R.Lippke. (2004). "Templates for Sustainable Riparian Management on Family Forest Ownerships", Journal of Forestry 102(7):19-25.

Zobrist, K.W., K.R. Gehringer, and B.R.Lippke (2005a). "A sustainable solution for riparian management". In Understanding Key Issues of Sustainable Wood Production in the Pacific

Northwest, Deal, R.L. and S.M. White eds. USDA Forest Service General Technical Report PNW-GTR-626:54-62.

Zobrist, K. W., T.M. Hinckley, M.G. Andreu, K.R. Gehringer, C.W. Hedman, and B.R. Lippke. (2005b). Templates for Forest Sustainability on Intensively Managed Private Forests. RTI Working Paper 5. Seattle WA: Rural Technology Initiative, College of Forest Resources, University of Washington. 106pp.

5. The 1996 landmark - Washington Forest Landscape Management Project

Amaranthus, M. P., D. S. Parrish, et al. (1989). "Decaying logs as moisture reservoirs after drought and wildfire." Proceedings of Watershed 89: 191-194.

Anthony, R. G., E. D. Forsman, et al. (1987). "Small Mammal Populations in Riparian Zones of Different-Aged Coniferous Forests." The Murrelet 68(3): 94-102.

Beechie, T. J., L. E. Benda, et al. (1992). "Fundamental Elements of Ecologically Healthy Watersheds in the Pacific Northwest Coastal Ecoregion." Watershed management: balancing sustainability and environmental change. Springer-Verlag, New York, New York: 127-188.

Bevers, M., J. Hof, et al. (1995). "Sustainable forest management for optimizing multispecies wildlife habitat: a coastal Douglas-fir example." Natural Resource Modeling 9: 1-23.

Bormann, F. H. and G. E. Likens (1994). Pattern and Process in a Forested Ecosystem: Disturbance, Development and the Steady State Based on the Hubbard Brook Ecosystem Study, Springer-Verlag.

Brown, E. R. (1985). "Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington."

Brown, G. and L. Steel (1994). "Impact of deer and elk sport hunting values on timber management regimes." Carey, AB; Elliott, C., comps. Olympia, WA: Washington Forest Landscape Management Project Report.

Brussard, P. F. (1991). "The Role of Ecology in Biological Conservation." Ecological Applications 1(1): 6-12.

Bull, E. L., A. D. Partridge, et al. (1981). "Creating snags with explosives." Pacific Northwest Forest and Range Experiment Station, US Forest Service. Research Note PNW-393.

Bury, R. B. (1991). Aquatic Amphibian Communities in Oregon and Washington, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Bury, R. B., P. S. Corn, et al. (1991). "Regional patterns of terrestrial amphibian communities in Oregon and Washington." Wildlife and vegetation of unmanaged Douglas-fir forests. Technical Report PNW-GTR-285. USDA Forest Service, Pacific Northwest Research Station, Portland OR.

Carey, A. B. (1981). "Multivariate analysis of niche, habitat, and ecotope". USDA Forest Service General Technical Report RM-87, Washington, DC, 104-113 p.

Carey, A. B. (1983). "Cavities in trees in hardwood forests." JW Davis, GA Goodwin, and RA Oekenfels (tech. coords.). Snag Habitat Management: Proceedings of a Symposium. General Technical Report RM-99, US Department of Agriculture, Forest Service, Fort Collins, CO: 167-184.

Carey, A. B. (1985). "A summary of the scientific basis for spotted owl management." GTR 185: 100-114 Pacific Northwest Forest and Range Experiment Station.

Carey, A. B. (1988). "The influence of small streams on the composition of upland bird communities." Streamside Management: Riparian Wildlife and Forestry Interactions. Institute for Forest Resources, Contribution: 153-159.

Carey, A. B. (1988). The influence of small streams on the composition of upland bird communities. Streamside management: riparian wildlife and foestry interactions. K. J. Raedeke. Seattle, WA, University of Washington: 153-162.

Carey, A. B. (1989). "Wildlife associated with old-growth forests in the Pacific Northwest." Natural Areas Journal 9(3): 151-162.

Carey, A. B. (1993). "Prey ecology and Northern Spotted Owl diet." Journal of Raptor Research 27: 53-54.

Carey, A. B. (1994). A critical look at the issue of species-habitat dependency. The Annual Convention of the Society of American Foresters.

Carey, A. B. (1995). "Interactions of Pacific Northwest canopies and arboreal mammals." Northwest Science.

Carey, A. B. (1995). "Sciurids in Pacific Northwest Managed and Old-Growth Forests." Ecological Applications 5(3): 648-661.

Carey, A. B. (1998). "Ecological Foundations of Biodiversity: Lessons from Natural and Managed Forests of the Pacific Northwest." Northwest Science 72(2): 127-133.

Carey, A. B., B. L. Biswell, et al. (1991). Methods for Measuring Populations of Arboreal Rodents, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Carey, A. B. and J. D. Gill (1983). "Direct habitat improvements—some recent advances." Snag Habitat Management: Proceedings of a Symposium. General Technical Report RM-99. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO: 80–87.

Carey, A. B., M. M. Hardt, et al. (1991). "Spring bird communities in the Oregon Coast Range." Wildlife and Vegetation of Unmanaged Douglas-Fir Forests. Portland (OR): USDA Forest Service, Pacific Northwest Research Station. General Technical Report PNW-GTR 285: 123–142.

Carey, A. B., S. P. Horton, et al. (1992). "Northern Spotted Owls: Influence of Prey Base and Landscape Character." Ecological Monographs 62(2): 223-250.

Carey, A. B., S. P. Horton, et al. (1989). Optimal Sampling for Radiotelemetry Studies of Spotted Owl Habitat and Home Range, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Carey, A. B. and M. L. Johnson (1995). "Small Mammals in Managed, Naturally Young, and Old-Growth Forests." Ecological Applications 5(2): 336-352.

Carey, A. B., R. G. McLean, et al. (1980). "The Structure of a Colorado Tick Fever Ecosystem." Ecological Monographs 50(2): 131-151.

Carey, A. B. and S. Or Pacific Northwest Research (1991). The Biology of Arboreal Rodents in Douglas-fir Forests, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Carey, A. B. and K. C. Peeler (1995). "Spotted owls: resource and space use in mosaic landscapes." Journal of Raptor Research 29(4): 223-239.

Carey, A. B., J. A. Reid, et al. (1990). "Spotted Owl Home Range and Habitat Use in Southern Oregon Coast Ranges." The Journal of Wildlife Management 54(1): 11-17.

Carey, A. B. and H. R. Sanderson (1981). "Routing to Accelerate Tree-Cavity Formation." Wildlife Society Bulletin 9(1): 14-21.

Carey, A. B., D. R. Thysell, et al. (1996). "Foundations of biodiversity in managed Douglas-fir forests." The Role of Restoration in Ecosystem Management: 68–82.

Carey, A. B., T. M. Wilson, et al. (1997). "Dens of Northern Flying Squirrels in the Pacific Northwest." The Journal of Wildlife Management 61(3): 684-699.

Cederholm, C. J. (1994). "A suggested landscape approach for salmon and wildlife habitat protection in western Washington riparian ecosystems." AB Carey and C. Elliott: 78-90.

Cederholm, C. J. and L. M. Reid (1987). "Impact of forest management on coho salmon (Oncorhynchus kisutch) populations of the Clearwater River, Washington: a project summary." Streamside Management: Forestry and Fishery Interactions: 373-398.

Chambers, C. J., Jr (1977). Chamber's principles of harvest regulation. DNR Note 19. Olympia, WA, Washington Department of Natural Resources: 9.

Chambers, C. J., Jr (1982). Biological implications of departure on Pacific Northwest forests sustained yield, Spokane, WA, Washington State University Cooperative Extension.

Chen, J., J. F. Franklin, et al. (1992). "Vegetation Responses to Edge Environments in Old-Growth Douglas-Fir Forests." Ecological Applications 2(4): 387-396.

Clark, D. L. and M. V. Wilson (1994). "Heat-treatment effects on seed bank species of an old-growth Douglas-fir forest." Northwest Science 68(1): 1-5.

Cole, E. C., W. C. McComb, et al. (1997). "Response of Amphibians to Clearcutting, Burning, and Glyphosate Application in the Oregon Coast Range." The Journal of Wildlife Management 61(3): 656-664.

Curtis, R. O. (1992). "A new look at an old question—Douglas-fir culmination age." Western Journal of Applied Forestry 7(4): 97-99.

Curtis, R. O. and D. D. Marshall (1993). "Douglas-fir rotations—time for reappraisal." Western Journal of Applied Forestry 8(3): 81-85.

Curtis, R. O. and S. Or Pacific Northwest Research (1995). Extended Rotations and Culmination Age of Coast Douglas-fir Old Studies Speak to Current Issues, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

DeBell, D. S. and R. O. Curtis (1993). "Silviculture and New Forestry in the Pacific Northwest." Journal of Forestry 91(12): 25-30.

Dickson, J. G. (1979). The Role of Insectivorous Birds in Forest Ecosystems, Academic Press.

Doyle, A. T. (1990). "Use of Riparian and Upland Habitats by Small Mammals." Journal of Mammalogy 71(1): 14-23.

Ehrlich, P. R. and G. C. Daily (1993). "Science and the management of natural resources." Ecological Applications 3(4): 558-560.

Ehrlich, P. R., D. S. Dobkin, et al. (1988). Birder's Handbook: A Field Guide to the Natural History of North American Birds, Simon and Schuster Inc.

Erman, D. C., J. D. Newbold, et al. (1977). "Evaluation of streamside buffer strips for protecting aquatic organisms". Technical completion report, contribution # 165, California Water Resources Center, University of California, Davis.

Fogel, R. (1975). Insect mycophagy: preliminary biblography. U.S. Forest Service General Technical Report PNW-36. F. E. M. A. T. (FEMAT), United States Department of Agriculture, Forest Service.

Forsman, E. D. and E. C. Meslow (1985). "Old-growth forest retention for spotted owls--how much do they need?" General Technical Report, Pacific Northwest Forest Range Experiment Station.: 58-59.

Forsman, E. D., E. C. Meslow, et al. (1984). Distribution and Biology of the Spotted Owl in Oregon, Wildlife Society.

Forsman, E. D., I. Otto, et al. (1991). "Diet of spotted owls on the Olympic Peninsula, Washington and the Roseburg District of the Bureau of Land Management." Ruggiero, Leonard, F.; Aubry, Keith, A.; Carey, Andrew, B.; Huff, Mark H., technichal coordinators. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: Pacific Northwest Research Station, USDA Forest Service 527.

Franklin, J. E., F. Hall, et al. (1986). "Old growth definition task group report: interim definitions for old-growth Douglas-Fir and Mixed-Conifer forests in the Pacific Northwest and California." USDA Forest Service, Pacific Northwest Research Station Research Note PNW 447.

Franklin, J. F. (1989). "Toward a new forestry." American Forests 95(11/12): 37-44.

Franklin, J. F. (1993). "Lessons from Old-Growth: Fueling Controversy and Providing Direction." Journal of Forestry 91(12): 10-13.

Franklin, J. F. (1993). "Preserving Biodiversity: Species, Ecosystems, or Landscapes?" Ecological Applications 3(2): 202-205.

Franklin, J. F. and C. T. Dyrness (1988). Natural Vegetation of Oregon and Washington, Oregon State University Press.

Franklin, J. F., O. P. N. Forest, et al. (1981). Ecological Characteristics of Old-growth Douglas-fir Forests, US Dept. of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

Franklin, J. F. and R. T. T. Forman (1987). "Creating landscape patterns by forest cutting: Ecological consequences and principles." Landscape Ecology 1(1): 5-18.

Gunther, P. M., B. S. Horn, et al. (1983). "Small mammal populations and food selection in relation to timber harvest practices in the western Cascade Mountains." Northwest Science 57(1): 32-44.

Gutierrez, R. J. and A. B. Carey (1985). "Ecology and Management of the Spotted Owl in the Pacific Northwest." US Department of Agriculture, Forest Service General Technical Report PNW-185.

Halpern, C. B. and T. A. Spies (1995). "Plant Species Diversity in Natural and Managed Forests of the Pacific Northwest." Ecological Applications 5(4): 913-934.

Hanley, T. A. and J. D. McKendrick (1985). "Potential Nutritional Limitations for Black-Tailed Deer in a Spruce-Hemlock Forest, Southeastern Alaska." The Journal of Wildlife Management 49(1): 103-114.

Hansen, A. J., S. L. Garman, et al. (1993). "An Approach for Managing Vertebrate Diversity Across Multiple-Use Landscapes." Ecological Applications 3(3): 481-496.

Hansen, A. J., T. A. Spies, et al. (1991). "Conserving Biodiversity in Managed Forests." BioScience 41(6): 382-392.

Happe, P. J., K. J. Jenkins, et al. (1990). "Nutritional Quality and Tannin Astringency of Browse in Clear-Cuts and Old-Growth Forests." The Journal of Wildlife Management 54(4): 557-566.

Harmon, M. E., J. F. Franklin, et al. (1986). "Ecology of coarse woody debris in temperate ecosystems." Advances in Ecological Research 15: 133-302.

Harris, L. D. (1984). The Fragmented Forest: Island Biogeography Theory and the Preservation of Biotic Diversity, University of Chicago Press.

Haskell, E. F. (1940). "Mathematical Systematization of" Environment,"" Organism" and" Habitat"." Ecology 21(1): 1-16.

Hawkins, C. P., M. L. Murphy, et al. (1983). "Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the northwestern United States." Canadian Journal of Fisheries and Aquatic Sciences 40(8): 1173-1185.

Hayward, G. D. and R. Rosentreter (1994). "Lichens as Nesting Material for Northern Flying Squirrels in the Northern Rocky Mountains." Journal of Mammalogy 75(3): 663-673.

Henderson, J. A. (1994). "The ecological consequences of long-rotation forestry." High quality forestry workshop: the idea of long rotations, JF Weigand, RW Haynes, and JL Mikowshi. University of Washington Center for International Trade in Forest Products, Seattle, WA: 4-26.

Henderson, J. A., P. N. Region, et al. (1989). Forested Plant Associations of the Olympic National Forest, USDA, Forest Service, Pacific Northwest Region.

Hof, J. G. and M. G. Raphael (1993). "Some mathematical programming approaches for optimizing timber age-class distributions to meet multispecies wildlife population objectives." Can. J. For. Res./Rev. can. rech. for 23(5): 828-834.

Holthausen, R. S. and S. Or Pacific Northwest Research (1995). The Contribution of Federal and Non-federal Habitat to Persistence of the Northern Spotted Owl on the Olympic Peninsula, Washington: Report of the Reanalysis Team, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Hopwood, D. (1991). "Principles and Practices of New Forestry." A guide for British Columbians. BC Min. of For. Land Management Report: 95.

Huff, M. H., J. K. Agee, et al. (1984). "Postfire succession of avifauna in the Olympic Mountains, Washington." Lotan, James E.; Brown, James K., comps. Fire's effects on wildlife habitat—symposium proceedings: 8-15.

Huff, M. H. and C. M. Raley (1991). "Regional patterns of diurnal breeding bird communities in Oregon and Washington." Wildlife and vegetation of unmanaged Douglas-fir forests. Edited by LF Ruggiero, KB Aubry, AB Carey, and MH Huff. USDA For. Serv. Gen. Tech. Rep. PNW-GTR-285: 177–205.

Hunter, M. L. (1990). Wildlife, forests, and forestry: principles of managing forests for biological diversity, Englewood Cliffs, NJ (EUA). Prentice Hall Career & Technology.

Hutchinson, G. E. (1978). An Introduction to Population Ecology, Yale University, New Haven. GB.

Jenkins, K. J. and E. E. Starkey (1984). "Habitat Use by Roosevelt Elk in Unmanaged Forests of the Hoh Valley, Washington." The Journal of Wildlife Management 48(2): 642-646.

Karr, J. R. (1991). "Biological Integrity: A Long-Neglected Aspect of Water Resource Management." Ecological Applications 1(1): 66-84.

Lee, K. N. (1993). "Compass and Gyroscope Integrating Science and Polities for the Environment." Washington DC.

Lee, K. N. (1993). "Greed, scale mismatch, and learning." Ecological Applications 3(4): 560-564.

Leonard, W. P. and S. Seattle Audubon (1993). Amphibians of Washington and Oregon, Seattle Audubon Society.

Leslie Jr, D. M., E. E. Starkey, et al. (1984). "Elk and Deer Diets in Old-Growth Forests in Western Washington." The Journal of Wildlife Management 48(3): 762-775.

Li, C. Y., C. Maser, et al. (1986). "Role of three rodents in forest nitrogen fixation in western Oregon: another aspect of mammal-mycorrhizal fungus-tree mutualism." Great Basin Naturalist 46(3): 411-414.

Lippke, B. and C. D. Oliver (1993). "Managing for Multiple Values: A Proposal for the Pacific Northwest." Journal of Forestry 91(12): 14-18.

Lippke, B. R., J. Sessions, et al. (1996). Economic Analysis of Forest Landscape Management Alternatives, College of Forest Resources, University of Washington; USDA Forest Service, Pacific Northwest Research Station: Washington State, Dept. of Natural Resources.

Ludwig, D. (1993). "Environmental sustainability: Magic, science, and religion in natural resource management." Ecological Applications 3(4): 555-558.

Ludwig, D., R. Hilborn, et al. (1993). "Uncertainty, resource exploitation, and conservation: lessons from history." Science 260(5104): 17-36.

Lundquist, R. W. and J. M. Mariani (1991). "Nesting habitat and abundance of snag-dependent birds in the southern Washington Cascade Range." Ruggerio, Leonard F.; Aubry, Keith B.; Carey, Andrew B.; Huff, Mark H., technical coordinators. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: Pacific Northwest Research Station, USDA Forest Service: 221-240.

Manuwal, D. A. (1991). "Spring bird communities in the southern Washington Cascade Range." LF Ruggiero, KB Aubry, AB Carey, and MH Huff, technical coordinators. Wildlife and Vegetation of unmanaged Douglas-fir Forests. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-285, Portland, Oregon: 161-174.

Manuwal, D. A. and M. H. Huff (1987). "Spring and Winter Bird Populations in a Douglas-Fir Forest Sere." The Journal of Wildlife Management 51(3): 586-595.

Maser, C., J. M. Trappe, et al. (1978). "Fungal-Small Mammal Interrelationships with Emphasis on Oregon Coniferous Forests." Ecology 59(4): 799-809.

McIntire, P. W. and A. B. Carey (1989). A Microhistological Technique for Analysis of Food Habits of Mycophagous Rodents, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Miller, R. E., D. Roger, et al. (1979). Fertilizing Douglas-fir Forests, Pacific Northwest Forest and Range Expriment Station, US Dept. of Agriculture, Forest Service.

Mills, L. S., R. J. Fredrickson, et al. (1993). "Characteristics of Old-Growth Forests Associated with Northern Spotted Owls in Olympic National Park." The Journal of Wildlife Management 57(2): 315-321.

Molina, R. and J. M. Trappe (1982). "Patterns of EcWmycorrhizal Host Specificity and Potential Among Pacific Northwest Conifers and Fungi." Forest Science 28(3): 423-458.

Naiman, R. J. (1992). Watershed management: balancing sustainability and environmental change: with 115 illustrations, Springer.

Neitro, W. A., V. W. Binkley, et al. (1985). "Snags (wildlife trees)." Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1: 192-1985.

North, M. (1993). Stand structure and truffle abundance associated with northern spotted owl habitat, University of Washington.

Noss, R. F. (1990). "Indicators for Monitoring Biodiversity: A Hierarchical Approach." Conservation Biology 4(4): 355-364.

Nussbaum, R. A., R. M. Storm, et al. (1983). Amphibians and Reptiles of the Pacific Northwest, University Press of Idaho.

Nyland, R.D., 2002. Silviculture: concepts and applications (2nd edition). Waveland Press, Inc. Long Grove, Illinois.

O'Neill, R. V. (1986). A Hierarchical Concept of Ecosystems.(MPB-23), Princeton University Press.

Oakley, A. L., J. A. Collins, et al. (1985). "Riparian zones and freshwater wetlands." Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington: 192-1985.

Odum, E. P. (1963). Ecology. New York, Holt, Rinehart and Winston Inc.

Odum, E. P. (1971). "Fundamentals of Ecology [M]." Philadelphia: Saunders.

Oliver, C. D. (1981). "Forest Development in North America Following Major Disturbances." Forest Ecology and Management 3(3): 153-168.

Oliver, C. D. and B. C. Larson (1996). "Forest Stand Dynamics." New York.

Overton, W. S. and L. M. Hunt (1974). "A view of current forest policy, with questions regarding the future state of forests and criteria of management." Transactions, 39th North American Wildlife and Natural Resources Conference. Washington, DC: Wildlife Management Institute: 334-353.

Perry, D. A., R. Molina, et al. (1987). "Mycorrhizae, mycorrhizospheres, and reforestation: current knowledge and research needs." Can. J. For. Res./Rev. can. rech. for 17(8): 929-940.

Peters, R. H. (1988). "Some General Problems for Ecology Illustrated by Food Web Theory." Ecology 69(6): 1673-1676.

Petranka, J. W. (1994). "Response to Impact of Timber Harvesting on Salamanders." Conservation Biology 8(1): 302-304.

Raedeke, K. J., R. College of Forest, et al. (1988). Streamside Management: Riparian Wildlife and Forestry Interactions, College of Forest Resources, University of Washington: University of Washington, Institute of Forest Resources.

Raedeke, K. J., R. D. Taber, et al. (1988). "Ecology of large mammals in riparian systems of Pacific Northwest forests." Streamside Management: Riparian Wildlife and Forestry Interactions. Institute of Forest Resources, Contribution: 113-132.

Ralph, C. J., G. L. Hunt Jr, et al. (1995). "Ecology and conservation of the Marbled Murrelet in North America: an overview." Ralph, CJ; Hunt, GL, Jr.; Raphael, MG; Piatt, JF, comps., eds. Ecology and Conservation of the Marbled Murrelet. Albany, CA: US Department of Agriculture, Forest Service, Pacific Southwest Research Station; Gen. Tech. Rep. PSW-GTR-152: 3-22.

Raphael, M. G., K. V. Rosenberg, et al. (1988). "Large-scale changes in bird populations of Douglas-fir forests, northwestern California." Bird Conservations ed. Jerome Jackson:63-71. International Council for Bird Preservation. University of Wisconsin Press.

Reeves, G. H. (1994). "Determining timber harvest impacts on fish." Washington forest landscape management project-progress report. Rep: 74-75.

Reeves, G. H., L. E. Benda, et al. (1995). "A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest." American Fisheries Society Symposium 17: 334-349.

Reid, W. V. and K. R. Miller (1989). "Keeping options alive: the scientific basis for conserving biodiversity." Washington DC.

Ruggiero, L. F., K. B. Aubry, et al. (1991). Wildlife and Vegetation of Unmanaged Douglas-fir Forests, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Ruth, R. H., R. A. Yoder, et al. (1953). Reducing Wind Damage in the Forests of the Oregon Coast Range, US Dept. of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

Schowalter, T. D., B. A. Caldwell, et al. (1992). "Decomposition of fallen trees: effects of initial conditions and heterotroph colonization rates." Tropical ecosystems: ecology and management. Edited by KP Singh and JS Singh. Wiley Eastern Ltd., New Delhi, India: 373–383.

Seagle, S. W., R. A. Lancia, et al. (1987). "Integrating timber and red-cockaded woodpecker habitat management." Transactions of the North American Wildlife Natural Resource Conference 52: 41-52.

Smith, C. C. (1970). "The Coevolution of Pine Squirrels (Tamiasciurus) and Conifers." Ecological Monographs 40(3): 349-371.

Smith, J. E., R. Molina, et al. (1995). "Occurrence of Ectomycorrhizas on Ericaceous and Coniferous Seedlings Grown in Soils from the Oregon Coast Range." New Phytologist 129(1): 73-81.

Smith, R. L. (1980). Ecology and field biology. Harper Collins 655 pages. New York.

Soukhanov, A. H. (1992). The American Heritage Dictionary of the English Language. Boston, Houghton Mifflin.

Squire, R. O. (1990). Report on the progress of the Silvicultural Systems Project–July 1986-June1989. Victoria, Department of Conservation and Environment: 85.

Swanson, F. J. and J. F. Franklin (1992). "New Forestry Principles from Ecosystem Analysis of Pacific Northwest Forests." Ecological Applications 2(3): 262-274.

Thomas, J. W. and I. S. Committee (1990). A Conservation Strategy for the Northern Spotted Owl. Washington D.C., U.S. Government Printing Office Publication.

Turner, M. G. (1989). "Landscape Ecology: The Effect of Pattern on Process." Annual Review of Ecology and Systematics 20(1): 171-197.

Wallin, D. O., F. J. Swanson, et al. (1994). "Landscape Pattern Response to Changes in Pattern Generation Rules: Land-Use Legacies in Forestry." Ecological Applications 4(3): 569-580.

Wells-Gosling, N. and L. R. Heaney (1984). "Glaucomys sabrinus." Mammalian Species(229): 1-8.

Whittaker, R. H. (1960). "Vegetation of the Siskiyou Mountains, Oregon and California." Ecological Monographs 30(3): 279-338.

Whittaker, R. H. (1969). "Evolution of diversity in plant communities." Brookhaven Symp Biol 22: 178-96.

Whittaker, R. H., S. A. Levin, et al. (1973). "Niche, Habitat, and Ecotope." The American Naturalist 107(955): 321-338.

Zarnowitz, J. E. and D. A. Manuwal (1985). "The Effects of Forest Management on Cavity-Nesting Birds in Northwestern Washington." The Journal of Wildlife Management 49(1): 255-263.