Birds	Oregon Coast Range			Oregon Cascade Range			Southern Washington Cascade Range			Regional Analyses for Oregon and Washington			Northern California and Southern Oregon			Endemic[a]	Broadly endemic[b]
Species	**Y**	**M**	**OG**	**Y**	**M**	**OG**	**Y**	**M**	**OG**	**Y**	**M**	**OG**	**Y**	**M**	**OG**		
Gray jay (spring)	P	P	P	P	P	P	P	P	+	P	P	P	?	?	?		
Gray jay (winter)	?	?	?	?	?	?	P	P	+	?	?	?	?	?	?		
Steller's jay	P	P	P	P	+	+	P	P	P	P	P	P	P	P	P		
Black-capped chickadee	P	P	P	?	?	?	?	?	?	?	?	?	/	/	/		
Chestnut-backed chickadee (spring)	P	P	+	P	P	+	P	P	+	P	P	+	P	+	+		×
Chestnut-backed chickadee (winter)	?	?	?	?	?	?	P	P	+	?	?	?	?	?	?		×
Red-breasted nuthatch (spring)	P	P	+	P	P	P	P	P	+	P	P	+	P	P	P		
Red-breasted nuthatch (winter)	?	?	?	?	?	?	P	P	+	?	?	?	?	?	?		
White-breasted nuthatch	P	P	P	?	?	?	?	?	?	?	?	?	?	?	?		
Brown creeper (spring)	P	P	+	P	+	+	P	+	+	P	+	+	P	+	*		
Brown creeper (winter)	?	?	?	?	?	?	P	P	P	?	?	?	?	?	?		
House wren	P	P	P	?	?	?	?	?	?	?	?	?	?	?	?		
Winter wren (spring)	P	P	P	P	+	+	P	P	+	P	P	P	+	P	+		
Winter wren (winter)	?	?	?	?	?	?	P	P	P	?	?	?	?	?	?		
Golden-crowned kinglet (spring)	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
Golden-crowned kinglet (winter)	?	?	?	?	?	?	P	P	P	?	?	?	?	?	?		
Ruby-crowned kinglet	P	P	P	?	?	?	?	?	?	?	?	?	?	?	?		
American robin	P	P	P	+	P	P	P	P	P	P	P	P	P	+	+		
Hermit thrush	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
Swainson's thrush	P	P	P	+	P	P	P	P	+	P	P	P	?	?	?		
Townsend's solitaire	P	P	P	P	P	P	P	P	P	P	P	P	+	P	P		
Varied thrush (spring)	P	+	+	P	+	+	P	P	+	P	P	P	P	P	P		×
Varied thrush (winter)	?	?	?	?	?	?	P	P	P	?	?	?	?	?	?		×

Birds	Oregon Coast Range			Oregon Cascade Range			Southern Washington Cascade Range			Regional Analyses for Oregon and Washington			Northern California and Southern Oregon			Endemic[a]	Broadly endemic[b]
Species	**Y**	**M**	**OG**	**Y**	**M**	**OG**	**Y**	**M**	**OG**	**Y**	**M**	**OG**	**Y**	**M**	**OG**		
Wrentit	P	P	P	/	/	/	/	/	/	P	P	P	P	P	+		
Black-throated gray warbler	P	P	P	+	P	P	+	P	P	+	P	P	+	+	P		
Hermit warbler	+	P	P	P	P	P	?	?	?	?	?	?	P	+	+		
Hermit/Townsend's warbler	/	/	/	/	/	/	+	P	P	+	P	P	/	/	/		
MacGillivray's warbler	P	P	P	P	P	P	P	P	P	P	P	P	?	?	?		
Nashville warbler	+	P	P	P	P	P	?	?	?	P	P	P	P	P	P		
Orange-crowned warbler	+	P	P	?	?	?	?	?	?	P	P	P	P	P	P		
Townsend's warbler	?	?	?	+	P	P	?	?	?	?	?	?	?	?	?		
Wilson's warbler	P	P	P	+	P	P	P	P	+	P	P	P	P	P	P		
Yellow-rumped warbler	P	P	P	+	+	P	P	P	P	P	P	P	P	P	P		
Hutton's vireo	+	P	P	P	P	P	+	P	P	P	P	P	P	P	P		
Solitary vireo	?	?	?	+	+	P	P	P	P	?	?	?	P	+	+		
Warbling vireo	+	P	P	?	?	?	P	P	P	?	?	?	P	P	P		
Western tanager	+	P	P	+	+	P	+	+	P	P	P	P	P	+	+		
Chipping sparrow	P	P	P	?	?	?	?	?	?	?	?	?	?	?	?		
Dark-eyed junco	+	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
Rufous-sided towhee	P	P	P	?	?	?	?	?	?	?	?	?	P	P	P		
Song sparrow	P	P	P	?	?	?	P	P	P	?	?	?	?	?	?		
Black-headed grosbeak	+	P	P	+	P	P	P	P	P	P	P	P	P	+	+		
Evening grosbeak	P	+	P	+	+	P	+	+	P	P	P	P	P	P	P		
Pine siskin (spring)	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
Pine siskin (winter)	?	?	?	?	?	?	P	P	+	?	?	?	?	?	?		
Purple finch	+	P	P	?	?	?	P	P	P	P	P	P	P	P	P		
Red crossbill (spring)	P	P	P	P	P	+	P	P	+	P	P	P	P	P	P		

Birds	Oregon Coast Range			Oregon Cascade Range			Southern Washington Cascade Range			Regional Analyses for Oregon and Washington			Northern California and Southern Oregon			Endemic[a]	Broadly endemic[b]
Species	**Y**	**M**	**OG**	**Y**	**M**	**OG**	**Y**	**M**	**OG**	**Y**	**M**	**OG**	**Y**	**M**	**OG**		
Red crossbill (winter)	?	?	?	?	?	?	P	P	+	?	?	?	?	?	?		
Guilds																	
Aerial foragers	?	?	?	?	?	?	?	?	?	+	P	+	?	?	?		
Bark foragers (spring)	P	P	+	P	P	+	P	P	+	P	P	*	?	?	?		
Bark foragers (winter)	?	?	?	?	?	?	P	P	+	?	?	?	?	?	?		
Canopy seedeaters (winter)	?	?	?	?	?	?	P	P	+	?	?	?	?	?	?		
Totals																	
All resident species	?	?	?	?	?	?	?	?	?	P	P	+	?	?	?		
Total abundance (spring)	?	?	?	?	?	?	P	P	+	P	P	+	?	?	?		
Total abundance (winter)	?	?	?	?	?	?	P	P	*	?	?	?	?	?	?		

Mammals

Species	Oregon Coast Range			Oregon Cascade Range			Southern Washington Cascade Range			Regional Analyses for Oregon and Washington			Northern California and Southern Oregon			Endemic[a]	Broadly endemic[b]
	Y	M	OG	Y	M	OG	Y	M	OG	Y	M	OG	Y	M	OG		
Marsh shrew	P	+	+	P	P	P	P	P	P	P	P	P	?	?	?	×	
Montane shrew	/	/	/	+	+	P	P	P	P	P	P	P	/	/	/		
Pacific shrew	P	+	P	P	+	+	/	/	/	P	P	P	P	P	P	×	
Trowbridge's shrew	P	+	P	P	P	P	P	P	P	P	P	P	P	P	P		×
Vagrant shrew	P	P	P	+	P	P	P	P	P	P	P	P	?	?	?		
Coast mole	P	P	P	P	+	P	P	P	P	P	P	P	?	?	?		
Shrew-mole	P	+	+	P	+	+	P	P	P	P	P	*	?	?	?	×	
Big brown bat and/or Fringed myotis	P	P	*	?	?	?	?	?	?	?	?	?	?	?	?		
Long-legged myotis	P	P	*	?	?	?	P	P	*	?	?	?	?	?	?		
Myotis A bats[d]	P	P	*	?	?	?	P	P	*	?	?	?	?	?	?		
Myotis B bats[e]	P	P	*	?	?	?	P	P	*	?	?	?	?	?	?		
Silver-haired bat	P	P	*	?	?	?	P	P	+	?	?	?	?	?	?		
Douglas' squirrel (spring)	?	?	?	?	?	?	?	?	?	?	?	?	P	+	+		×
Douglas' squirrel (winter)	?	?	?	?	?	?	P	P	+	?	?	?	?	?	?		×
Northern flying squirrel	P	P	+	+	P	P	?	?	?	P	P	P	?	?	?		
Townsend's chipmunk	?	?	?	P	P	P	P	P	P	?	?	?	/	/	/	×	
Creeping vole	?	?	?	P	P	P	P	P	P	P	P	P	?	?	?	×	
Red tree vole	P	P	*	P	*	*	/	/	/	P	P	*	P	P	+	×	
Southern red-backed vole	/	/	/	/	/	/	P	P	P	?	?	?	/	/	/		
Western red-backed vole	P	+	P	P	+	P	/	/	/	P	P	P	P	+	+	×	
Deer mouse	P	P	P	P	+	+	P	P	+	P	P	+	P	P	P		
Forest deer mouse	/	/	/	/	/	/	P	+	+	?	?	?	/	/	/	×	
Piñon mouse	/	/	/	/	/	/	/	/	/	/	/	/	P	P	P		
Pacific jumping mouse	?	?	?	P	P	P	P	P	P	?	?	?	?	?	?	×	

Mammals	Oregon Coast Range			Oregon Cascade Range			Southern Washington Cascade Range			Regional Analyses for Oregon and Washington			Northern California and Southern Oregon			Endemic[a]	Broadly endemic[b]
Species	Y	M	OG	Y	M	OG	Y	M	OG	Y	M	OG	Y	M	OG		
Ermine	?	?	?	P	P	P	?	?	?	P	P	P	?	?	?		
Fisher[c]	P	P	+	P	P	+	P	P	+	P	P	+	P	P	+		

Amphibians and Reptiles	Oregon Coast Range			Oregon Cascade Range			Southern Washington Cascade Range			Regional Analyses for Oregon and Washington			Northern California and Southern Oregon			Endemic[a]	Broadly endemic[b]
Species	Y	M	OG	Y	M	OG	Y	M	OG	Y	M	OG	Y	M	OG		
Amphibians																	
Northwestern salamander	P	P	P	P	P	+	P	P	*	P	P	*	?	?	?	×	
Cope's giant salamander	/	/	/	?	?	?	P	P	+	/	/	/	/	/	/	×	
Olympic salamander	P	P	*	P	P	+	P	P	+	P	P	+	P	P	*		×
Pacific giant salamander	P	P	+	P	P	+	P	P	+	P	P	+	P	P	P		×
Black salamander	/	/	/	/	/	/	/	/	/	/	/	/	P	P	P		×
California slender salamander	/	/	/	/	/	/	/	/	/	/	/	/	P	+	+		×
Clouded salamander	P	P	+	P	P	+	/	/	/	/	/	/	P	P	+	×	
Del Norte salamander	/	/	/	/	/	/	/	/	/	/	/	/	P	P	*	×	
Dunn's salamander	P	P	+	P	P	P	/	/	/	/	/	/	?	?	?	×	
Ensatina	P	P	P	P	P	P	P	P	P	P	P	P	P	P	+		
Oregon slender salamander	/	/	/	P	P	+	/	/	/	/	/	/	/	/	/	×	
Western redback salamander	+	P	P	P	P	P	+	P	P	*	P	P	/	/	/	×	
Roughskin newt	P	P	+	+	P	P	P	P	*	P	P	P	P	P	P		×
Pacific treefrog	?	?	?	?	?	?	?	?	?	?	?	?	P	P	P		
Tailed frog	P	P	+	+	P	+	P	+	+	P	P	+	P	*	*		×
Foothill yellow-legged frog	?	?	?	/	/	/	/	/	/	/	/	/	P	P	P		
Red-legged frog	+	P	P	P	P	P	P	P	P	P	P	P	?	?	?		
Reptiles																	
Northern alligator lizard	?	?	?	?	?	?	?	?	?	?	?	?	P	P	P		×

[a] Geographic distribution is located primarily within the Douglas-fir/western hemlock zone of western Oregon and Washington and northwestern California.
[b] Geographic distribution is located primarily within the humid coastal zone north of San Francisco and the northern Sierra Nevada and west of the Cascade Crest in Oregon, Washington, and British Columbia.
[c] Degree of association with old-growth forests based on data from other studies.
[d] Includes the little brown and/or Yuma myotis.
[e] Includes the California, Keen's, long-eared, and/or western small-footed myotis.

Applying Results of Old-Growth Research to Management: Information Needs, Development of Technical Tools, and Future Research

Richard S. Holthausen and Bruce G. Marcot

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Introduction

The objectives of this paper are to describe the application of results from the Old-Growth Forest Wildlife Habitat Program to forest management in the Pacific Northwest Region of the Forest Service, and to identify needed research on old-growth Douglas-fir forests.

The analysis of vertebrate community data presented in this book was designed primarily to identify vertebrate species associated with old growth and to describe habitat features that may account for observed patterns of association. While it does not lend itself to precise predictions about the effects of management on those species, it could and should play an important and immediate role in implementing Forest Plans. Information presented here allows, for the first time, the development of a reliable and scientifically defensible list of vertebrate species associated with old-growth Douglas-fir forests. All of these species should be carefully considered when allocations for late-seral habitat on the National Forests are actually implemented. Information on the habitat associations of these species will help managers make better decisions about the types of forests to include in old-growth management areas, and how best to provide critical habitat features, such as large snags and down wood, in managed stands. Information on the effects of forest fragmentation on wildlife will enable managers to make better decisions about the sequence and spatial arrangement of management activities scheduled in Forest Plans.

During the time this information is being used to help guide the implementation of Forest Plans, it should also be evaluated to see if amendments to Plans are appropriate. Amendments will be appropriate if these results, and other new research and monitoring information, indicate that the Plans will not meet objectives for wildlife habitat, including maintaining viable populations within diverse communities. Recognizing that absolute knowledge is not attainable, managers must make reasonable judgments about the viability of species based on existing information. Amendments may also be made for other reasons, such as the identification of new issues or unexpected effects from implementing Forest Plans. Experience from other Regions of the Forest Service suggests that such amendments may be fairly common and serve to keep the Plans up to date between major revisions. Finally, this information (along with other new findings from monitoring and continued research) will be used to revise Forest Plans either after 10 years or sooner.

Goals, Objectives, and Legal Requirements for Old Growth

For old-growth research information to be applied to management, the goals, objectives, and legal requirements for old growth must be understood. Goals for old-growth management on National Forests include providing recreation, esthetic experiences, and opportunities for scientific study; maintaining water quality; producing high-quality wood products; maintaining biological diversity and long-term productivity; and providing wildlife habitat. The specific goals for wildlife habitat management are established in the National Forest Management Act of 1976 and pursuant regulations (36 CFR 219.19 and 219.27). They are:

- Manage "to maintain viable populations of existing native and desired non-native vertebrate species in the planning area;"

- "...establish objectives for the maintenance and improvement of habitat for management indicator species" selected during the planning process; and

- "...provide for diversity of plant and animal communities...in order to meet overall multiple-use objectives."

Information presented here can eventually help managers address all three of these mandates. Results of the community studies provide the initial scientific basis for determining whether viability is a concern for any of the species demonstrated to be closely associated with old growth. The results will also allow managers to do a better job of selecting management indicator species for future amendments and revisions of Forest Plans. Although using indicator species in forest planning has been controversial, we believe that all species found to be closely associated with old growth should be considered in the management process. Results from these studies will provide information on how to establish and meet objectives for such species. Finally, these results will help to answer questions about biological diversity. A fundamental aspect of managing for diversity of plant and animal communities is to provide for persistence of the full array of seral stages in all forest types. To ensure that we have identified all significant types and stages, forest (and especially, old-growth) classifications should be based on both plant and wildlife communities. Information presented here will be fundamental to developing these classifications.

Information Needed From Old-Growth Research

To develop very specific objectives for management, devise alternative actions that could meet those objectives, and evaluate the effectiveness of such alternatives, very specific information about old-growth habitats and associated species is required. Some specific questions that must be addressed include:

- What species occur in old-growth forests, and how consistent and close is their association with old growth?

- What stand attributes are associated with each species? Can species be classified according to sets of stand attributes? What is the effect on species of different amounts and patterns of these attributes in unmanaged and managed stands?

- What amounts and patterns of old-growth forests should be provided across the landscape to maintain viable and well-distributed populations of old-growth-associated species? What sizes and shapes of old-growth stands are best for providing for old-growth species? What kinds and patterns of edges adversely affect old-growth forest habitat conditions, and how can such effects be mitigated? How is dispersal affected by different forest conditions and the juxtaposition of those conditions?

- What forest management activities (for example, roads, recreation, hunting, timber production) can take place in or near old-growth stands and still be compatible with maintaining adequate habitat for old-growth-associated species? What is the effect of various rotation lengths on old-growth attributes in managed stands? How suitable are stands where elements of old growth (for example, large snags and logs) are maintained, but the surrounding stand is modified by timber harvest? Can old-growth conditions be created in areas currently lacking old-growth forest habitats?

Research information available in this book goes a long way toward answering the first set of questions and provides some information on the second. Ongoing research, especially at the landscape (multi-stand) scale, will provide additional insights into the second and third set of questions. Autecological studies will provide better information on the relationship of old-growth species to their environment, and proposed manipulative experiments will directly test the effects of habitat type, edge, size, and configuration on population and community response.

Answers to the fourth set of questions may be inferred from correlations between habitat attributes and abundances of old-growth species. We believe, however, that providing old-growth conditions or attributes in managed stands and landscapes as a means of increasing the viability of old-growth wildlife populations should be treated as a working hypothesis that needs to be tested empirically. Experimental forests may be ideal settings for testing how well we can create old-growth systems through management, and whether or not old-growth species will persist if provided with old-growth components in habitats modified by timber harvesting.

Developing Information From Research Into Needed Tools and Evaluation Procedures

Once basic information on the ecology and biology of old-growth forests is available from research, it must be assimilated by managers to guide specific management prescriptions. Ultimately, the information must be incorporated into existing administrative procedures and policies for assessing and planning old-growth forest management. This process entails developing the research information into classification and inventory systems, particularly on the abundance and distribution of old-growth forest types and associated wildlife species; summaries of habitat conditions or attributes associated with old-growth wildlife species; summaries of demographics of old growth-associated species; and models depicting the response of wildlife populations to habitat conditions at both stand and landscape scales.

Forest Service wildlife biologists at both Forests and Districts will use the information and assessment procedures in daily operational tasks. These tasks include assessing the effects of proposed forest management activities, and identifying activities consistent with conserving old-growth resources. In addition, specialists in related disciplines-specifically, fisheries biologists, silviculturists, botanists, ecologists, and landscape architects-must also play central roles. They would help bring old-growth evaluation tools and information to the forefront of multiple-resource planning. Educating specialists and managers alike should be part of the development and application of old-growth research information.

Classification Systems

Applying old-growth information to habitat management requires a system of classifying habitats and wildlife communities. Five major objectives and uses define the need for habitat and community classification systems: to reliably predict the successional development of habitats and related changes in wildlife communities; to identify forest conditions with which specific sets of old-growth-dependent wildlife species may be associated; to predict responses of habitat conditions and wildlife populations to management activities; to serve as precursors to inventories and monitoring; and to provide a basis for planning and implementing both research and management activities. In particular, predicting successional development is important for projecting future habitat conditions and response by vegetation and wildlife communities to proposed management activities.

Plant community classifications-Classifications of old-growth forest types should be based on the ecological characteristics of climax or subclimax forest stands and their successional states. The objective is to array ecological forest types along a successional gradient. Successional stages can be inferred from studies on vegetation structure across an age gradient (chronosequence) of young, mature, and old-growth forests. A classification of old-growth habitats may build on the Franklin and Spies (this volume) approach of an index of "old-growthness," much as Raphael and Barrett (1984) developed multivariate correlations of vegetation conditions with stand age in old-growth forests in northwestern California. An old-growth index would describe the degree to which a forest stand, given its dominant plant species and its age, provides various attributes associated with increasing stand age and successional development. These attributes in turn can be related to use by wildlife species. An old-growth index of this type encourages the view of late-successional forests as developmental gradients rather than as discrete types.

Forest habitat conditions associated with each wildlife species and community can be further analyzed to produce a classification of old-growth forest habitats. Several analytical techniques may prove useful. For example, a hierarchical clustering algorithm (see Gauch and Whittaker 1981, Hill and others 1975) applied to the vegetation data from each stand may help identify sets of stands with unique conditions. This approach, however, may merely serve to mirror the criteria that were used originally to select the study stands. Other techniques with which a vegetation classification could be developed include discriminant function analysis and various ordination techniques, such as principal component analysis (see Hill and Gauch 1980, Kantrud and Kologiski 1982, Whittaker 1987).

These classification techniques rely on analysis of vegetation data alone. An old-growth habitat classification could also be developed by correlating the abundance of wildlife species with various old-growth forest attributes. One useful approach is canonical correlation analysis (Gauch 1973, Goldstein and Grigal 1972, Smith 1981), in which variation in the vegetation data is explained through correlations with variation in wildlife abundance data. Conversely, canonical correlation could be used to explain variation in wildlife data, given the vegetation data (see McIntire 1978). Results of canonical correlation analysis are sometimes difficult to interpret, however, and the procedure requires many samples (study stands) relative to the number of variables (vegetation and wildlife attributes of each stand) (Pimentel 1979, Smith 1981). Also, like other ordination techniques, canonical correlation analysis does not produce a classification per se, although component scores can be ordinated along the canonical vectors and a classification of sites (or species) can be derived (see Noy-Meir 1973).

Care must be taken to avoid errors when interpreting results of multivariate analyses (Garsd 1984, Rexstad and others 1988, Wilson 1981). Errors may result from spurious correlations, inadequate sample sizes, and violations of assumptions of normality, linearity, and independence of the data.

Ideally, old-growth habitat classifications would be based on variables found in forest inventory information used by Ranger Districts and National Forests. Forest inventories currently available include Total Resource Inventory (TRI) data bases and ongoing updates to Vegetative Resource Surveys (VRS). Results of Mature and Overmature (MOM) inventories are reported elsewhere in this volume by Marcot and others. A first step will be to determine if TRI, VRS, and MOM data bases contain the necessary habitat variables for use in an old-growth habitat classification system, and if the data have acceptable precision and resolution (scale). At present, the kinds, accuracy, and precision of data bases on old-growth forest habitats vary among National Forests and Districts. Old-growth classification strategies should be flexible enough to be useful in the short term with data bases of varying resolution and accuracy. They should also help identify additional inventory needs in the longer term-that is, define new variables or refine existing variables to greater precision or resolution.

Wildlife community classifications-The objective in developing wildlife community classifications is to identify wildlife guilds and species assemblages that are associated with various forest types and successional stages. A wildlife community classification would identify sets of species associated with specific old-growth conditions and stages, which could be done by producing classifications of species occurring in various successional stages or along gradients of various habitat attributes. Analysis techniques include clustering algorithms, as discussed above. One approach might be to apply gradient analyses on the abundance of each wildlife species, guild, or assemblage for various habitat attributes. Analytical techniques may include ordinations and various multivariate methods that produce mathematical models of species distribution or abundance as functions of habitat conditions.

We anticipate that both classification and gradient approaches will prove useful. Classifications would reveal which groups of wildlife species are likely to be associated with specific sets of habitat conditions. Various species groups may overlap. Gradient analyses may provide information on how the relative abundances of species or species groups change along various environmental gradients, such as stand development, elevation, latitude, or moisture regime in old-growth forests (see Smith and MacMahon 1981).

Specifically, what is needed is a test of how well wildlife species can be classified based on various gradients associated with old-growth forests. Clustering or ordination techniques may be used to test further associations of wildlife species, guilds, or assemblages with unmanaged forest age-classes, moisture-classes, and especially old-growthness gradients and indices. For the latter, a much better understanding of the contribution to wildlife species presence and abundance from old-growth attributes in younger stands is needed, particularly in intensively managed, even-aged stands. One approach might be to use scatter diagrams, simple correlations, stepwise multiple linear regression, logistic regression, and discriminant function analysis to predict the presence or abundance of wildlife species as a function of old-growth stand attributes in young unmanaged forests. Prediction variables may include density of large snags, large logs, large-diameter live trees, and high foliage volumes. Then, the models would be applied to young managed forests, to help identify the kinds and amounts of late-successional forest conditions that might provide for old-growth wildlife species.

Inventories

Inventories are required to apply predictive models of old-growth habitats and species. Although uses of inventory data will vary, basic guidelines for inventories should be rigorously standardized among National Forests.

Habitat-The main objective of producing inventories of old-growth forest habitats is to provide reliable information on location, distribution, and amount of old-growth and younger forests that contain old-growth attributes, such as large live trees, large snags, and large logs. Appropriate sampling and inventory techniques should be applied to various forest types at stand, landscape, and National Forest scales, and under several standards of reliability.

Habitat inventories should ultimately provide vegetation class-specific and stand-specific data on vegetation structures and flora. Inventories on all National Forests must be conducted by supplementing remotely sensed data with field surveys. Identifying which old-growth habitat attributes to sample will come from analysis of both community and species-specific old-growth research data.

Ongoing VRS and MOM inventories on National Forests in Washington and Oregon (Marcot and others, this volume) are currently scheduled for completion by 1994. The MOM inventory will include data on structures of late-successional forest stands for each plant association. Once entered into a geographic information system, these data can provide information on the distribution and extent of stand conditions specified by the user. Such specifications could include, for example, the quantitative "ecological" definitions of old growth advanced by the Old-Growth Definition Task Group (1986). They may also include definitions of stands corresponding to quantitative descriptions of habitat for wildlife species or species groups associated with various forest conditions. Forest inventory data must be accessible to Ranger Districts to help in planning and executing projects in an integrated approach to resource management (Chalk and others 1984).

Wildlife species-Inventories of selected wildlife species associated with late-successional forests are also needed. Such species include those identified in this volume as "closely associated" with old-growth conditions (table 1; see also Ruggiero and others, this volume).

Other species classified as "associated" with old growth, which are expected to decline in a managed forest landscape, may also need to be inventoried. These include cavity-nesting birds (Lundquist and Mariani, this volume; Manuwal, this volume), birds associated with old-growth forests during winter (Huff and others, this volume), some amphibians (Aubry and Hall, this volume; Bury and others, this volume), and vertebrate species sensitive to edges and other landscape patterns created by forest management activities. Also of interest are species recognized by administrative or legal directives, and keystone species whose functions in late-successional forest ecosystems affect the presence and abundance of other plant and animal species (table l), such as mycophagous small mammals and prey species for spotted owls.

Developing inventories of the distribution, abundance, and trends of populations for each of these species--especially those that are wide-ranging, rare, or secretive-is a formidable and expensive task (see Franzreb 1977, Raphael and Rosenberg 1983, Ratermann and Brode 1983). Complete censuses of all of these species (table 1) will never be possible because of the huge investments of time and money required for even one species in a small area. Sample surveys, however, can determine distributions, relative abundances, and population trends. Sampling could be undertaken among physiographic provinces, National Forests, or any given land allocation. Validated models of habitat relationships could be used to identify appropriate habitats to inventory within such strata.

Table I-Categories of species that may require extensive inventories or additional study

- Species closely associated with old-growth conditions in one or more physiographic provinces
  - Northern spotted owl
  - Vaux's swift
  - Marbled murrelet
  - Hairy woodpecker
  - Red-breasted sapsucker
  - Brown creeper
  - Western flycatcher
  - Big brown bat
  - Fringed myotis
  - Long-legged myotis
  - Silver-haired bat
  - Shrew-mole
  - Red tree vole
  - Olympic salamander
  - Northwestern salamander
  - Del Norte salamander
  - Roughskin newt
  - Tailed frog
- Species associated with old-growth forests that may suffer declines in managed forest landscapes
  - Cavity-nesting birds
  - Birds and mammals closely associated with late-successional forests during winter
    - Chestnut-backed chickadee
    - Red-breasted nuthatch
    - Red crossbill
    - Gray jay
    - Douglas' squirrel
  - Species associated with interior late-successional forest conditions
- Keystone species
  - Selected prey species of the spotted owl
    - Northern flying squirrel
  - Mycophagous mammals
  - Insectivorous birds, especially those preying on forest insect pests
- Species with special administrative or legal status
  - Old-growth indicator species
    - Northern spotted owl
    - Pileated woodpecker
    - Marten
  - Rare, threatened, endangered, or sensitive species
    - Northern spotted owl
    - Northern goshawk
    - Great gray owl

In addition to sampling habitats for the presence and distribution of late-successional forest wildlife species, appropriate techniques may need to be developed for estimating the absolute abundance and reproductive attainment of certain species. Substantial progress has been made on region-wide inventories of northern spotted owls, although at high cost (O'Halloran and others, this volume). Similarly, survey protocols are being developed for determining the distribution and relative abundance of marbled murrelets at inland sites (Nelson, this volume; Paton and Ralph, this volume). No reliable methods for assessing the reproductive success or absolute abundance of marbled murrelets are currently available, however. Such intensive efforts to gather data on the absolute abundance and reproductive success of other wildlife species associated with late-successional forests may be initiated only for those species that are listed (or proposed to be listed) by the U.S. Fish and Wildlife Service as threatened or endangered.

Information on Wildlife Habitat Relationships

Understanding habitat relationships of old-growth wildlife species is crucial to predicting their responses to present and future habitat conditions in managed landscapes. Habitat relationships should be evaluated throughout the geographic range in which each species occurs, and for each habitat that may be used for various life-history functions, such as feeding, resting, reproduction, migration, or dispersal.

Habitat relationships information can be used to predict the abundance of wildlife species in various structural or successional stages of late-successional or other forest types. Information on the habitat relationships of old-growth-associated species should include specific habitat elements associated with the species' presence, variation in abundance and reproductive success, and other life-history traits. Applying such information for each species would help identify the range of occurrence of various habitat elements in the landscape-density, size, and quality of habitats-and effects on species' presence and abundance. Of particular concern are the effects on wildlife population sizes and trends of fragmenting old-growth forests. Fragmentation greatly changes spacing, size, shape, context, and amount of edge of old growth in the landscape.

Managers need to understand to what degree different vegetation structures and species assemblages (at both stand and landscape scales) provide for viability of each old-growth wildlife species. Integral to this understanding is predicting stand and landscape conditions that result from management activities by all land owners throughout each species' range. To help develop such predictions, researchers and managers need to know what stand and landscape attributes to track. The old-growth research results presented in this volume represent the first step toward developing information for such uses. To use such information, we also need to test how well variation in species presence, abundance, survival, reproductive success, and long-term population viability can be predicted by using existing habitat data or that which can be collected through typical forest inventory procedures.

One main objective is to produce area-analysis models for assessing cumulative effects on late-successional forest wildlife species from management activities at both the stand and landscape scale. Such analyses may initially be useful only for predicting the presence of various species. Ongoing studies of landscape-scale patterns (Lehmkuhl and others, this volume) will provide essential information for this purpose.

In such models, attributes would be defined along gradients rather than by discrete stand age-classes. An example would be a discriminant function equation that estimates the probability that a species is present based on habitat conditions. The equation would discriminate between stand conditions with which the species' presence is highly likely and those with which it is highly unlikely. Of course, species' presence is not simply a function of habitat: historical factors, random catastrophic events, and barriers to colonization are also important determinants.

Predictive species models developed from the old-growth research data should be validated, especially against an independent data set. Where additional data sets are lacking, predictive models can be developed with cross-validation techniques, such as bootstrap or jackknife analyses (Meyer and others 1986, Solow 1989). In such tests, the robustness of the models are assessed by developing prediction equations or correlations from multiple, randomly chosen subsets of the data base and testing how values of the model parameters vary. Cross-validation also entails testing the predictions of a model derived from a portion of a data base against a complementary portion not used to develop the model.

Demography Information

Finding through field inventories that a wildlife species is present in a particular area, or predicting its presence by a habitat capability model, does not ensure that existing habitat conditions or landscape patterns will provide for either reproductive success or long-term population viability (Van Home 1983). Empirical information on demographic parameters is critical for making such determinations. Such expensive and time-consuming studies, however, will likely be conducted on only a few species of key scientific, administrative, or social concern, such as spotted owls and their prey.

Priorities among species may need to be set for these studies. Forest species with a high priority for demographic studies may include those that are associated with late-successional forests; have restricted or disjunct ranges and small population sizes; or that are known or suspected to have suffered recent population declines, especially those resulting from management activities. Forest-scale inventories may need to be conducted to determine which species associated with late-successional forests would fall into these priority categories.

Advisor or Prescription Models

To aid resource managers, advisor or prescription models can be built to help evaluate old-growth habitat conditions at stand and landscape scales and to recommend appropriate courses of action to meet specified management objectives (Marcot and others 1988). Such models may include expert systems, in which knowledge bases of if-then rules represent expert assessments of habitat conditions (Marcot 1986). An example is the expert system developed for guiding habitat management for black-tailed deer in coastal British Columbia (McNay and others 1987).

Advisory models are used to assess habitat conditions for various species and to set priorities and guide management prescriptions. At a landscape scale, they can also be used to guide cumulative effects analysis. That such models be evaluated through peer review and validated with independent empirical data is critical, however (Marcot 1987). Also, such models should not be used to make decisions, but merely to provide information. For example, an expert systems model could be designed to advise on priorities for retention or silvicultural treatment of late-successional forest stands in a given landscape. Especially if tied to a geographic information system to visualize stand conditions and habitat patch patterns, such a decision-aiding tool would provide a consistent and reliable means of interpreting old-growth forest conditions for wildlife.

Development of these models is several years away. Key information still needs to be gathered or developed to produce prediction equations at stand and landscape scales and expert advice on habitat and species' responses to various management presciptions. Inventories of vegetative conditions at the stand scale need to be conducted or refined. Regardless of whether such an advisory system is produced in the form of a model per se, or as an evaluation process for resource managers to follow, a thorough understanding of species-habitat relationships is needed to guide such prescriptions.

Further Research Needs

We consider further research needs to fall into five basic categories: autecological studies, studies on developmental patterns in old-growth forests, landscape studies, research on inventory and monitoring techniques, and studies on the effects of management activities and natural disturbances such as fire.

The team that planned the research reported in this book has identified autecological studies as the next phase of research after the community studies (Research Work Unit Description on file at the Forestry Sciences Laboratory in Olympia, Washington). The results presented in this volume will go a long way towards identifying species for which autecological study is needed. In addition, researchers and managers can work together to identify priorities for other species that were not included in the sampling design for the community studies reported here. The species presented in table 1 should all be considered candidates for more detailed study. Autecological studies must be conducted over a wide range of stand conditions so that the effects of various stand conditions can be adequately evaluated. Such studies may sometimes require manipulation of existing stands to simulate conditions likely to exist in the managed stands of the future.

Further information on developmental patterns in old-growth forests is essential to providing full understanding of options for managing old growth. Many areas currently contain forests that have some of the characteristics of old growth but fail to meet all criteria for ecological old growth (see Franklin and Spies, this volume; Morrison 1988; Old-Growth Definition Task Group 1986). We need to fully understand developmental patterns in older forests so that we better predict their future characteristics.

Landscape ecology studies must focus on two essential questions. The first is how fragmentation affects old-growth forest conditions. How the integrity of old-growth habitats can be maintained at the landscape scale must be understood. Research is needed to determine how well adjacent stands of different ages and structures act to buffer the effects of fragmentation on old-growth stands. Some of this research is already being conducted by Forest Service scientists in the Pacific Northwest. The second essential question at the landscape scale concerns the effects of various amounts and patterns of old growth and other forest types on populations of wildlife species that are associated with old growth. Such studies must focus (to the extent possible) on long-term rather than short-term effects on species. Although these studies are likely to prove very difficult and expensive, they offer the only real means of evaluating management hypotheses about landscape conditions that will sustain species' viability over time. These studies must include demographic measures of the species being investigated. They must also be designed to look at a broad array of landscape conditions. The careful setting of priorities of species to be studied at the landscape scale, and of needed standards of reliability, will be critical because of the expense and time required for such studies.

The third category of studies needed are those directed at developing more effective inventory and monitoring techniques for both old-growth habitats and wildlife species associated with those habitats. Such inventories are time consuming and expensive, but management plans cannot be properly implemented without site-specific knowledge of habitats and species. In addition to more efficient techniques, evaluation systems that would set priorities among stands for species-specific inventories would be useful. Inventories could then be conducted in those habitats that are most likely to support species of interest.

Finally, studies are needed on the effects of management and of natural disturbance on old-growth conditions. Studies of management techniques should ask what techniques are useful to retain elements of old-growth forests in newly regenerated stands; accelerate the development of these characteristics in young, unmanaged stands; and accelerate the development of these characteristics in stands that have already come under management. Studies of natural disturbances should address questions about the frequency, size, and intensity of natural disturbances and the ways in which they may be influenced by various stand and landscape characteristics.

Conclusions

The information presented in this volume provides clear evidence about species' associations with old-growth forests. That information should be further analyzed to provide a better understanding of the stand characteristics associated with each of these species. Community-scale analyses of this data set has provided information on the diversity of old-growth forest communities and associated wildlife communities. This information will allow managers to make more-informed decisions about which stands to include in old-growth management areas. Such information can be applied directly in implementing Forest Plans. A combination of further analysis of this information and collection of additional data will elucidate how different amounts and patterns of old-growth stands will affect the species that are most closely associated with them. Such analyses will also play a role in determining if amendments to Forest Plans are needed.

It is vitally important that the research and management branches of the Forest Service work closely together to further develop this information and identify priorities for needed information. Although we acknowledge that additional information is always desirable, we urge resource managers to make the best possible use of the results presented here. A cooperative effort between researchers and managers is currently underway to make this information more readily accessible to potential users. The products of this effort should provide essential tools to managers faced with tough decisions about maintaining old-growth forest conditions in a multiple-use context. ❑

Research on Wildlife in Old-Growth Forests: An Attempt at Perspective

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This volume presents the results of research conducted under the auspices of the Forest Service's Old-Growth Forest Wildlife Habitat Program. At least another 100 papers have been prepared from research conducted by or funded by the Program; more are to come. Some of these papers are published, some in press, and some undergoing review. A vast amount of data was gathered by the Old-Growth Program. Such a comprehensive, detailed data set on animal communities related to the successional or structural stages in Douglas-fir forests of western Oregon and Washington is unlikely ever to be collected again.

New evidence and insights about the relationships (or lack thereof) of a myriad of wildlife species to Douglas-fir forests in western Oregon and Washington has been presented in this volume. And, more specifically, the degree of association between many wildlife species and old-growth forests, as compared to earlier stages of forest development, has been extensively examined.

In my introductory paper (Thomas, this volume), I suggested that the research reported here would be used to formulate an answer to an overriding question-do old-growth Douglas-fir forests represent unique wildlife habitat compared to other forested environments? In my opinion, the answer to this question is yes. The papers included here have shown that many wildlife species in Douglas-fir forests occur in greater abundances in old-growth than in young or mature forest stages, and that several wildlife species are closely associated with old growth.

The studies reported here, however, dealt with a comparison of wildlife and habitat relationships across a spectrum of unmanaged forest conditions in young, mature, and old-growth stands (and sometimes, in clearcuts). The stands examined in these studies were naturally regenerated, usually after fire, and had not been silviculturally treated during their development. Such stands are not likely to contain communities representative of those in managed stands that have been subject to site preparation, planting with spacing to selected stock of selected species, thinning to predetermined spacing, control of competing vegetation, and so on.

Intuition tells me (and I submit that for scientists to offer intuition and opinion is acceptable, provided they are identified as such) that fully managed stands are apt to be more simplified in structure than unmanaged stands. And, in turn, managed stands would be expected to support simplified plant and animal communities compared to unmanaged stands of similar age. The comparisons of animal communities across the spectrum of unmanaged successional stages reported here must not be uncritically assumed to apply to managed stands or forested landscapes of the future.

Information presented on habitat features in these successional stages typically showed a carryover of some of the ecological attributes of the preceding old-growth stand in younger stands. Such attributes include large, down woody material, large snags, and some large living trees, all of which provide important habitat for wildlife (Thomas 1979). Do these carryover attributes influence the habitat quality of the young and mature stands studied? That seems likely.

Initiating wildlife studies in intensively managed stands will be critical, regardless of the limitations on available study sites. Obviously, locating fully managed stands much older than 60 to 80 years will be impossible. In most areas, only fully managed stands of 50 years of age or less will be available for study. Stands that are studied should be as large as possible, however, to accommodate the broadest array of wildlife species that might occur there. Comparisons of wildlife densities in younger managed stands with those in unmanaged stands of the same age will be required to adequately evaluate the quality of wildlife habitat provided in managed forests. Such studies are necessary to determine if, as several authors have suggested, simplication of forest structure and tree species composition in managed stands is indeed reflected in simplication of the attendant animal community.

Any research effort usually ends with the researchers' cautioning against inappropriate use of the data presented or the conclusions drawn, and identifying additional needed research. There is no final truth in ecological research--only better and better approximations of what passes as truth; and there are no final questions-only better and more specific questions whose answers put us closer to truth. Managers will, of course, ***use*** the research to guide management in spite of the researchers' cautions; they have no other choice.

Today's forest planning procedures rely heavily on the use of linear mathematical models that consider the effect of several variables and their interactions to predict outcomes of various biological processes-say timber production or population sizes of a wildlife species. The data that goes into these models are seldom precise, and the interactions between the variables considered are even less perfectly understood. Such models were not intended by their developers to provide precise information. Rather, they ***were*** intended to provide indications of the direction of change, rough estimates of the magnitude of expected change, and the time frames surrounding such change.

Unfortunately, because the predictions of these models are numbers that have been used to guide management allocations, some have taken the results to be more precise than is justified. Political conflict over the allocation of resources results in political demands for more and more precision, whether or not more precision is possible. The models are then, sometimes, "tweaked" over and over to satisfy demands for greater accuracy and "politically correct" decisions. Such continued tweaking often only provides an illusion of precision that produces increasingly unwarranted faith in what finally appears on the computer printouts. Such events make monitoring the results of management applications (as required by law and regulations, and promised in the Forest Plans) so very critical. Only adequate monitoring can enable the necessary mid-course corrections in management activities to be made if the models have produced projections that are out of line with reality-whether too high or too low. All concerned have a vested interest in ensuring that adequate monitoring is carried out. And that means adequate design and resources to get the job done.

The biology of certain wildlife populations and wildlife habitat relationships are not conducive to precise estimates, no matter how much they are studied. The precision of such estimates can only become marginally better regardless of how politically desirable that may be. The answer will always involve a mean and be qualified with confidence intervals. Year-to-year perturbations in number will occur that are unrelated to habitat. Extremes or exceptions will always tempt those who long for a different answer than that indicated by the mean. Collecting enough data to determine long-term trends associated with habitat quality and quantity will be difficult and expensive. But good monitoring will require that.

The political process is not yet attuned to dealing with science as part of that process. When land-use decisions are to be made that have large-scale economic, social, and political impacts, individuals who stand to lose from those decisions typically demand unreasonable degrees of certainty in the information on which those decisions are based. All concerned need to recognize that the provision of a degree of certainty adequate to satisfy those whose welfare is threatened by the result is not likely to be attained. This problem is exacerbated when the decision criteria involve biological systems that are dynamic and highly variable. When is the information base adequate to support emotionally laden, economically explosive decisions so that all parties will be satisfied? The answer, likely, is never, In addition, scientists do not seem well suited by training or inclination to deal with the political process. Some biologists dwell on qualification of extant data and lean toward emphasizing uncertainty and the need for more information. Although they are quite correct, scientists also need to be cognizant that the world marches on, regardless of the state of knowledge. So the scientific community, while imparting the caution that science demands, needs to emphasize the considerable knowledge that is available, rely on extant theory, and contribute in whatever way they can to forest planning and management.

Decision-makers in land management agencies are usually not biological scientists. That may be fortunate. Some say that scientists think too much, feel too little, and have inadequate appreciation for economics and politics. Biologists should recognize that biological considerations are only part of any political land-use decision-making process-including any resulting legal proceedings. Such recognition implies some degree of sympathy, if not empathy, for those who must ultimately make land-use decisions. Those decision-makers must consider the law, policy, public desire, political pressures, economics, politics, and budgetary direction from Congress, as well as any biological considerations. To pretend otherwise is both naive and foolish.

In the United States, the management of old-growth forests in the Pacific Northwest, and the political events that surround this issue, could emerge as the most significant natural resource issue of this century. The ultimate resolution of this controversy will set the tone for natural resource management in the first half of the 21st century. What lies ahead? Intensified conflict? Total preservation? Management for old-growth habitat features? Emergence of a "new" forestry? Compromise? Changes in law? Abandonment of multiple-use concepts in favor of dedication of land to various uses? Other actions? Who knows?

Certainly there is much more to understand about the ecological aspects of this issue. Given the huge potential economic and social impacts of land-use decisions on managing old growth, support seems likely to be available for additional ecological studies. But it is critical, now, for the scientific community to step back and carefully examine our ecological knowledge of old-growth forests. At what questions should new research on old growth be directed? How much more of the limited funds available for wildlife and forest ecology research should be shifted to the old-growth arena? Perhaps the questions and approaches that would emerge from debate within the scientific community would differ markedly from the "hot issues" that may be targeted by the political and congressional appropriations processes. These issues may well be settled, one way or the other, before adequate research can be conducted and brought to bear on them. The scientific community and those in the research arena must be careful not to be used inappropriately in the fight over old-growth management. The scientific community should not take part in premature actions predicated on inadequate understanding, nor in the use of research as a means of delaying management decisions where adequate information exists to justify action.

Undoubtedly, hot-issue research on potentially threatened and endangered species will be given increased funding. But, at the same time, scientists and managers should strive to ensure that additional research on the community ecology of managed and unmanaged forests goes on simultaneously-perhaps as part of the hot-issue research. For therein lies the information of more lasting scientific and political value as the old-growth issue evolves to encompass the broader issues to be faced by forest managers over the next decades. Foremost among these will be the need to determine the size and spacing of old-growth stands within managed forest landscapes that will provide for the "maintenance of viable populations of native species...well-distributed" throughout public lands.

The results presented in this volume have moved us a bit closer to truth. The challenge, now, is to synthesize this information so that it may be incorporated into decision-making processes, political debates, and legal proceedings on the management of old-growth forests.

As a last word, I am reminded of the admonitions of several who philosophize about ecology, mixed together here in paraphrase. There is no final ecological truth. All knowledge is a current approximation, and each addition to that knowledge is but a small, incremental step toward understanding. For not only are ecosystems more complex than we think-they are more complex than we **can** think. □

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