A Bibliography on Old-Growth Forests in British Columbia

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With Annotations and Abstracts

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Introduction

British Columbia's old-growth forests are valued for many ecological, economic, social, and cultural reasons. Concerns have arisen, however, that these values cannot be sustained given our current land-use practices and our limited knowledge of old-growth temperate ecosystems. As a result, in November 1989, a working group was formed to develop a strategy for handling old-growth issues. Participants in the "Old Growth Strategy Working Group" were drawn from government, industry, universities, and public interest groups. This group has provided the incentive for a number of projects to compile and synthesize information about old growth.

One such project is this bibliography. It is intended to provide resource managers, researchers, and the Working Group with background information on the biological characteristics, ecological relationships, and management implications for British Columbia's old growth.

Our first step was to conduct an extensive review of the literature on old-growth forests of western North America and a cursory review of literature from eastern North America and other countries facing similar forestry-related issues. From this broad range of material, we selected references that we considered most relevant to British Columbia in eight general topic areas:

1. Forest types
2. Stand structure
3. Harvesting and silviculture systems
4. Biological diversity
5. Wildlife and wildlife habitat
6. Landscape ecology
7. Values and conservation strategies
8. Ecosystem function (nutrient cycling, water cycle, etc.)

Because of the breadth of the subject, it was not a simple task to limit entries or ensure that the criteria for selection were followed without exception. The material cited either describes some aspect of the natural forest types in British Columbia (similar types in adjacent geographic areas are also included here), or discusses principles and theories applicable to old growth in general. No doubt we excluded some useful references, particularly ones dealing with research methods, modeling, and ecosystem processes not specific to old growth.

What we have included are classic works, review articles, bibliographies, and research papers current up to the winter of 1990. Proceedings papers or chapters within books are cited individually; the source book or proceedings is also cited if two or more of the papers or chapters met the selection criteria.

We decided to exclude the numerous government reports and field guides that describe the biogeoclimatic subzones of British Columbia. Lists of these references are readily available from the B.C. Ministry of Forests, Victoria, BC.

The bibliography has three parts: 1) an alphabetical listing of references; 2) a listing of dissertations; and 3) a listing of unpublished works. All references have been indexed by subject, geographical location (if applicable), and author. Organization of the subject index emphasizes the main topic areas listed previously. These areas are then subdivided into more specific subjects.

Whenever available, the paper's original abstract is provided. Papers without an original abstract were annotated. These are noted with a double asterisk following the annotation. Abstracts are not included for unpublished works or dissertations.

Bibliography

1. **Abee, A.** and **D. Lavender**. 1972. Nutrient cycling in throughfall and litterfall in 450-year-old Douglas-fir stands. *In* Research on coniferous forest ecosystems: first year progress in the Coniferous Forest Biome, US/IBP. J.F. Franklin, L.J. Dempster, and R.H. Waring (editors). U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR, pp. 133-143.

Comparisons of nutrient concentrations (N, P, K^+, Ca^{++}, Mg^{++}) found in canopy throughfall and litterfall were made on the H.J. Andrews Experimental Forest. Six old-growth Douglas-fir (*Pseudotsuga menziesii*) stands were studied which represented six forest communities common to the western Cascades of Oregon. These community types span a large portion of the temperature and moisture gradients present in the area. The preliminary data indicate that nutrient concentration in throughfall was highest during the summer and fall, and lowest during the winter. Nutrient input through throughfall generally followed the same trends. Nutrient return through litterfall was greatest in the needles. More amounts of N, P, and Ca^{++} were transferred to the soil through litterfall than through throughfall, while more K^+ and Mg^{++} were added to the soil through throughfall. Litterfall was maximum during the winter. Future studies will correlate the results from the nutrient analysis to the moisture and temperature gradients.

2. **Achuff, P.L.** 1989. Old-growth forests of the Canadian Rocky Mountain National Parks. Nat. Areas J. 9(1):12-26.

The Canadian Rocky Mountain national parks comprise Waterton Lakes, Banff, and Jasper national parks in Alberta, and Kootenay and Yoho national parks in British Columbia. The forested landscape is divided into montane and subalpine ecoregions (zones) based primarily on forest community physiognomy and composition. Both north-south and east-west climatic and floristic gradients affect the forests. Environmental, community, and geographical attributes of major forest categories are described for montane (Douglas-fir, limber pine, white spruce, western redcedar), lower subalpine (Engelmann spruce-subalpine fir), and upper subalpine (Engelmann spruce-subalpine fir, whitebark pine, subalpine larch) old-growth forests.

3. **Achuff, P.L.** and **G.H. La Roi**. 1977. *Picea-Abies* forests in the highlands of northern Alberta. Vegetatio 33(2/3):127-146.

This paper provides classification and description of 30 mature *Picea glauca - Abies balsamea* stands. Important physical site properties for each stand as well as the taxonomic status of *Picea, Abies,* and *Pinus* populations are reported. The relationship of physical site properties to the floristic and physiognomic attributes of the stands, the classification, and apparent introgressive hybridization of *P. glauca* and *P. engelmannii* and *A. balsamea* and *A. lasiocarpa* are further discussed. **

4. **Adams, D.L.** and **G.W. Barrett.** 1976. Stress effects on bird-species diversity within mature forest ecosystems. Am. Midl. Nat. 96(1):179-194.

Two beech-maple forests, one virgin (control) and one selectively cut (experimental), were analyzed in detail for man-made stress effects upon tree-avian community structural relationships. Vegetation analyses revealed that Hueston Woods, a virgin beech-maple forest in southwestern Ohio, was stratified into two distinct canopy layers, whereas Lewis Woods, a previously thinned beech-maple forest in E-central Indiana, contained four distinct canopy strata. Although sugar maple (*Acer saccharum*) and American beech (*Fagus grandifolia*) were most abundant in both community types, they were truly dominant in terms of importance values in Hueston Woods. Lewis Woods had a more heterogeneous vegetational structure and greater absolute density, species diversity (H'), species richness (D) and

species evenness (e) values than Hueston Woods. Lewis Woods resembled an earlier seral stage of ecological succession. This supports the hypothesis that species diversity is less in a climax community than in preclimax conditions.

Avian analyses revealed significant differences ($P \leq .05$) for the resident evenness (apportionment) values between the two study areas. This difference was consistent through the 10-week (25 April-3 July 1973) observation period. Although Hueston Woods contained 38 resident species within a 15-acre (6.1 ha) study plot as compared to 32 species for Lewis Woods, evenness values were slightly greater for Lewis Woods. These findings support the concept of birds representing an "equilibrium" taxon in terms of the evenness component of species diversity.

This study presents strong evidence that birds do tend to depict and to respond to the overall structure of a major plant community. It is suggested that resident bird populations be considered as "indicator taxa" when attempting to measure and evaluate the impact of man-made stress on total ecosystems.

5. **Aho, P.E.** 1974. Decay. *In* Environmental effects of forest residues management in the Pacific Northwest. O.P. Cramer (technical editor). U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-224, pp. Q-1 - Q-17.

Forest residues from logging and catastrophes are deteriorated by associations of insects and micro-organisms. Insects are vectors, create infection courts, and provide for rapid spread of micro-organisms within residues. Many kinds of micro-organisms attack dead wood; however, Basidiomycete fungi—particularly *Polyporus abietinus, P. volvatus, Ganoderma applanatum, Lenzites saepiaria,* and *Fomes pinicola*—cause the greatest amount of decay.

The primary factors affecting deterioration of residues are moisture, temperature, and decay resistance of the wood. Soil type, slope aspect and percent, elevation, and degree of shading strongly influence temperature and moisture of residues. Tree species, age, and growth rate affect degree of resistance to decay. Management decisions, such as type of cutting operation and time of year that it is made, also influence decay rate of residues.

Alternative residue treatments are needed in excessively wet or dry sites, in recreation areas, or where fire hazard is high.

6. **Alaback, P.B.** 1982. Dynamics of understory biomass in Sitka spruce - western hemlock forests of southeast Alaska. Ecology 63(6):1932-1948.

Understory vegetation undergoes successional stages during the 1st 300 yr after logging or fire disturbance in the coastal *Picea-Tsuga* forests of southeast Alaska. Residual shrubs and tree seedlings increase their growth within 5 yr after overstory removal. Understory biomass peaks at 5 Mg/ha/yr about 15-25 yr after logging. Shrubs and herbs are virtually eliminated (<0.1 Mg/ha) from the understory after forest canopies close at stand ages of 25-35 yr. Bryophytes and ferns dominate understory biomass during the following century. An understory of deciduous shrubs and herbs is reestablished after 140-160 yr. Thereafter, biomass of the shrubs, herbs, and ferns continues to increase, while bryophyte biomass and tree productivity decline. Departures from this developmental sequence are related to unusual types of stand establishment, soil, microclimate, or disturbance.

The development and duration of the depauperate understory that succeeds canopy closure in southeast Alaska is closely related to the canopy structure of shade-tolerant *Tsuga* forests with their high foliar biomass. In young-growth forests (<100 yr), the decline in understory development immediately after canopy closure is significantly associated with tree basal area and percentage of tree diameter, age, and volume. It is hypothesized that understory development over the chronosequence responds primarily to changes induced in the light environment by developments in the forest canopy.

Maintenance of the most productive forests in the aggradation stages of development (0-100 yr) through forest management will minimize the development of a productive vascular understory and thus deprive herbivores of forage during 70-80% of the forest rotation.

7. ——————. 1984a. A comparison of old-growth forest structure in the western hemlock-sitka spruce forests of southeast Alaska. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1982, Juneau, AK. Amer. Inst. Fish. Res. Biol., Morehead City, NC, pp. 219-226.

Forty-six stands ranging in age from 40 to 600 years were examined on gently sloping, low-elevation sites in southeast Alaska from the Ketchikan area north to Haines. The greatest variation in stand structure occurred in stands greater than 200 years of age. A discriminant analysis of old-growth and second-growth stands showed variance in mean stand diameter, wider average tree spacing, increased dominance of western hemlock, and increased understory productivity to be key structural characteristics that distinguish the two forest age-classes. Old-growth stands have wider tree diameter distributions than second-growth, reflecting their uneven-aged structure.

Forest and wildlife managers should be cautious in applying single, generalized, forest structural statistics to the classification of old-growth forests. A multiple-factor characterization is more appropriate for evaluating the relative value of old-growth as wildlife habitat. Until more research is conducted on the causes of observed variation in old-growth forest structure and the significance of these structural features to wildlife, it will be difficult to assess the long-term impacts of the conversion of low-elevation, old-growth forests to second-growth in the region.

8. ——————. 1984b. Plant succession following logging in the Sitka spruce - western hemlock forests of southeast Alaska: implications for management. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-173. 26 p.

Preliminary information on general landscape patterns in southeast Alaska suggests that two major, compositionally distinct vegetation zones can be defined for the closed-forest type: western hemlock-Sitka spruce/Alaska huckleberry/bunchberry on the uplands, and Sitka spruce/devil's club-salmonberry on alluvial flats and terraces.

Recent clearcuts (0-30 years old) produce the most shrubby vegetation of any age class in the forest succession. Even-aged forests (30 to 150 years old) produce the least understory vegetation. Forests with open, patchy canopies tend to produce the most understory vegetation. More data is needed before forest management techniques can be used to improve the quality of habitat for wildlife over that presently found in unmanaged old-growth forests.

9. ——————. 1989. Logging of temperate rainforests and the greenhouse effect: ecological factors to consider. *In* Proc. of Watershed '89, Conf. on the Stewardship of Soil, Air and Water Resources. E.B. Alexander (editor). March 21-23, Juneau, AK. U.S. Dep. Agric. For. Serv., Alaska Reg., Juneau, AK. R10-MB-77, pp. 195-202.

This is a review of the carbon budget and the principal ecological processes regulating carbon flow in forest ecosystems and includes preliminary data on carbon cycling in temperate rainforest regions. Old-growth forests in southeast Alaska were estimated to accumulate 150-300 t C/ha on average to productive sites. Second growth sites were estimated to accumulate 131-227 t C/ha at 110 years of age on average sites. The highest biomass accumulations generally occur at 200-300 years of age. Logs were estimated to contain 20-40 t C/ha in old-growth sites. Southern hemisphere sites had similar carbon storage in second growth hardwood sites, but had as much as 3 times greater storage in old-growth conifer types. Little information is available on how much soil and forest floor carbon is lost following logging in the temperate rainforest zone.

In temperate forests studied to date, deforestation and subsequent management has resulted in a net emission of carbon to the atmosphere due to lower equilibrium carbon pools (in trees and soil) and a more rapid turnover of carbon. Disposition of forest products is a key variable in determining the net effect of forest management activities on atmospheric carbon. Because of the small land area involved and the high degree of reforestation following logging, effects of land use practices in the temperate rainforest zone are expected to have little effect on global atmospheric carbon. Basic research on decomposition, microclimate and soils changes with logging are needed to better understand the productivity potential of the full range of temperate rainforest sites and to more precisely predict what impact land-use practices may have on atmospheric carbon.

10. **Alaback, P.B.** and **F.R. Herman**. 1988. Long-term response of understory vegetation to stand density in *Picea-Tsuga* forests. Can. J. For. Res. 18:1522-1530.

The 17-year response of understory vegetation to forest thinning experiments was examined in two study sites on the central Oregon coast to determine the role of overstory species composition and stand density on forest succession. At 6 months, no significant difference in shrub, herb, and moss species composition or abundance was detected between the two study sites. Seventeen years after treatment, however, the *Picea sitchensis* (Bong.) Carr. site had much less vegetation cover and diversity than the *Tsuga heterophylla* (Raf.) Sarg. site. Overall response of most vascular species to thinning was insignificant because of their high variability in the medium and heavy treatments. Carpet-forming mosses were consistent in increasing their percent ground cover following thinning in the *Picea* site, and were the only species group to increase cover relative to initial conditions. *Tsuga* saplings were significantly more abundant under *Picea* canopies than under *Tsuga* canopies, probably because of the increased openness of *Picea* canopies. The increased abundance of saplings at both sites, particularly following heavy thinning, led to a two-layered overstory canopy and relatively less shrub and herb cover and diversity. Except for ferns, most plants that persisted had animal-dispersed seed. Thinning had little effect on the loss of understory species relative to the controls. Increases in diversity with thinning occurred primarily as the result of increased invasion by shade-tolerant species. Regardless of thinning treatment, only one-third or less of the original plant cover was maintained on study plots at stand age 30 years. Early thinnings without subsequent treatments are unlikely to maintain stable herb and shrub populations in forest types where the understory would otherwise be eliminated during the intermediate stages of stand development.

11. **Alaback, P.B.** and **G.P. Juday**. 1989. Structure and composition of low elevation old-growth forests in research natural areas of southeast Alaska. Nat. Areas J. 9(1):27-39.

Pristine examples of low elevation productive old-growth forest were studied in three existing and four proposed research natural areas in coastal Alaska. The study was designed to document changes in structure and composition of these forests to provide a base for future study. The tallest and most productive forests were on protected islands in southeast Alaska, the shortest and least productive toward the northern and western range limit of the Sitka spruce-western hemlock area in southcentral Alaska. Old-growth forests in coastal Alaska supported less basal area, were lower in stature, occur in smaller patches and are more increasingly fragmented than coastal forests in the Pacific Northwest. But old-growth is abundant due to relatively low frequency of catastrophic disturbance. Additional RNA's are needed to represent the range of ecosystem and climatic diversity of this region and to provide a comprehensive baseline to compare against management activities in coastal Alaska.

12. **Alexander, E.B.** (editor). 1989. Proc. of Watershed '89, Conf. on the Stewardship of Soil, Air, and Water Resources, March 21-23, 1989, Juneau, AK. U.S. Dep. Agric. For. Serv., Alaska Reg., Juneau, AK. R10-MB-77. 215 p.

This proceedings focuses on air, soil, and water management of watersheds in the Pacific Northwest. Papers on the following topics are presented: 1) ecology, soils, wetlands, and riparian issues; 2) streams and fisheries in watersheds; 3) erosion and cumulative watershed effects; 4) seedling response to watershed conditions; and 5) ecosystem carbon and global implications of logging in watersheds. Mass wasting, streams, and fisheries received the greatest coverage. Less emphasis was placed on soils and wildlife habitat in watersheds. **

13. **Alexander, R.R.** 1975. Partial cutting in old-growth lodgepole pine. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Res. Pap. RM-136. 17 p.

Guidelines are provided to aid the forest manager in developing partial cutting practices to maintain continuous forest cover in travel influence zones, and in areas of high recreational value or outstanding scenic beauty. These guidelines consider stand conditions, windfall risk situations, and insect and disease problems. These cutting practices may also be used in combination with small cleared openings to create the kinds of stands desirable for increased water yields, improvement of wildlife habitat, and to integrate timber production with other uses. On areas where timber production is the primary objective, clearcutting in small, dispersed units is the recommended method of harvesting trees.

14. ———————. 1986a. Silvicultural systems and cutting methods for old-growth lodgepole pine forests in the central Rocky Mountains. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-127. 31 p.

Guidelines are provided to help forest managers and silviculturists develop even- and uneven-aged cutting practices needed to convert pure and mixed old-growth lodgepole pine forests into managed stands. Guidelines consider stand conditions, succession, windfall risk, and insect and disease susceptibility. Cutting practices—clearcutting, shelterwood, and selection—are designed to integrate timber production with increased water yield, maintained water quality, improved wildlife habitat, and enhanced opportunities for recreation and scenic beauty.

15. ———————. 1986b. Silvicultural systems and cutting methods for old-growth Spruce-Fir forests in the Central and Southern Rocky Mountains. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-126. 33 p.

Guidelines are provided to help the forest manager and silviculturist develop even- and/or uneven-aged cutting practices needed to convert old-growth spruce-fir forests into managed stands for a variety of resource needs. Guidelines consider stand conditions, succession, windfall risk, and insect and disease susceptibility. Cutting practices are designed to integrate timber production with increased water yield, maintain water quality, improve wildlife habitat, and enhance opportunities for recreation and scenic viewing.

16. ———————. 1987a. Ecology, silviculture, and management of the Engelmann spruce-subalpine fir type in the central and southern Rocky Mountains. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Agric. Handb. No. 659. 144 p.

This publication presents a detailed summary of the ecology, resource and silvics, silviculture and management of spruce-fir forests. Major emphasis is placed on silviculture and management of old-growth and the establishment of new stands. While not all questions can be answered, this publication provides the comprehensive body of knowledge available for managing spruce-fir forests. It is intended to guide land managers and land use planners who are responsible for prescribing and supervising the application of cultural treatments in the woods. (From the author's preface)

17. ———————. 1987b. Silvicultural systems, cutting methods, and cultural practices for Black Hills Ponderosa pine. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-139. 32 p.

Guidelines are provided to help forest managers and silviculturists develop even- and/or uneven-aged cutting methods and associated silvicultural practices needed to convert ponderosa pine forests in the Black Hills into managed stands, and maintain them, for a variety of resource needs. Guidelines consider stand conditions and insect susceptibility. Cutting practices are designed to maintain water quality, improve wildlife habitat, and enhance opportunities for recreation and scenic viewing, and provide wood products.

18. ———————. 1988. Forest vegetation on national forests in the Rocky Mountain and Intermountain Regions: habitat types and community types. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-162. 47 p.

Habitat types and community types and their phases for the major forest tree species in the Rocky Mountain and Intermountain regions are tabulated. Included are the name(s), general location, elevation, relative site, successional status, principal tree and undergrowth associates, and the authority.

19. **Amaranthus, M.P., D.S. Parrish,** and **D.A. Perry.** 1989. Decaying logs as moisture reservoirs after drought and wildfire. *In* Proc. of Watershed '89: Conf. on the Stewardship of Soil, Air and Water Resources. E.B. Alexander (editor). March 21-23, 1989, Juneau, AK. U.S. Dep. Agric. For. Serv., Alaska Reg., Juneau, AK. R10-MB-77, pp. 191-194.

Decaying wood on the forest floor retains large reservoirs of moisture and thus provides long-lasting, high-moisture microsites that aid in forest recovery after prolonged drought or fire. Examination of logs after the Galice Complex fires in southwest Oregon revealed considerable root and mycorrhizal activity. Mean log moisture (157%) was 25 times greater than mean soil moisture (6%). After extended drought and wildfire, the moisture stored in logs may expedite forest recovery by providing important refuges for roots and associated mycorrhizal fungi of pioneering vegetation.

20. **Ambrose, J.D.** and **R.S. Mitchell.** 1990. Conservation strategies: a focus on cooperative action. *In* Ecosystem management: rare species and significant habitats. R.S. Mitchell, C.J. Sheviak, and D.J. Leopold (editors). N. Y. State Museum, Albany, NY. Bull. o. 471, pp. 11-13.

Public awareness of the rapidly degrading state of our biosphere is becoming widespread, in terms of the physical environment as well as biological systems and diversity. In that context, it seems timely to consider the activities of agencies, plant and animal repositories, and individual projects involved in diverse aspects of conservation, preservation, habitat reconstruction and land management, then to consider how they might function to complement one another more effectively in a coordinated program of interagency cooperation and action. It is also appropriate to question the harboring of endangered species in artificial environments like zoos and botanic gardens at the risk of reducing interest in conservation efforts aimed at wild populations. With current global concern for improving environmental quality and retaining diversity within viable, functioning biological systems, both natural and reconstructed, we also need to re-assess ongoing projects in terms of their effectiveness in further raising the awareness of the public and establishing a support-base for wiser and more integrated conservation objectives.

21. **Anderson, H.M.** 1988. Old-growth forests: a conservationist's perspective. Nat. Areas J. 8(1):13-16.

In the Pacific Northwest (defined here as Washington, Oregon, northern California, and southwest Alaska), only a small fraction of original old-growth forest remains. In Washington and Oregon, it is estimated that over 80% of the old growth has already been cut. In addition, it has been the policy of federal land managers to liquidate old-growth forests as rapidly as possible, with timber cutting currently at record levels. Conservationists find this to be an unacceptable loss of the biological, cultural, and spiritual values of old-growth forest.

The author provides a conservationist's perspective of three of the most contentious forestry issues in the Pacific Northwest: 1) old growth and the spotted owl (conservationists try to save the owl by obtaining threatened or endangered status for the owl and suing the Bureau of Land Management to stop logging the owl's old-growth habitat); 2) National Forest Plans (in which policy continues to be liquidation of old growth); and 3) congressional funding (congressional timber appropriations from the Pacific Northwest which increase original Forest Service budget requests but result in increased harvests and below cost sales). **

22. **Anderson, H.W. 1956.** Forest-cover effects on snow pack accumulation and melt, Central Sierra Snow Laboratory. Trans. Am. Geophys. Union 37(3):307-312.

Snowpack accumulation and melt at measurement points within snow courses were related to two forest cover variables. Water equivalent of the snowpack on April 1 of each year and melt rate after April 1 per unit of degree-days above 35° F were studied. Cover variables were the amount of shade from trees to the south of a snow measurement point and the amount of shielding from trees to the north of the point. The amount of shade was expressed as the duration of shading between April 1 and June 15, multiplied by the amount of direct solar energy which would have struck the snow surface in the absence of shading. Shielding was expressed by the ratio of average tree height to distance of the trees from the measurement point. Data from five points in each of five snow courses for three years of record were analyzed by the method of covariance. The analyses showed a high degree of association between the snowpack and forest-cover variables. The results are interpreted in terms of the timber-cutting pattern that would result in maximum accumulation of snow, minimum melt rate, and maximum prolonged release of snow water in the spring.

23. ————————. 1967. Snow accumulation as related to meteorological, topographic, and forest variables in Central Sierra Nevada, California. International Assoc. Sci. Hydrol. 76:215-224.

Snow accumulation at individual points in coniferous forest and openings in forests was studied by selecting 16 periods in the winter of 1957-58 under different meteorological conditions. Wide differences in topography and forest conditions were obtained by selection of 250 points from 1,300 available. Snow accumulation was the difference in water equivalent of the snowpack between measurements. Meteorological variables included functions of clouds, wind, humidity, temperature, and precipitation. Forest variables included indexes of shade, back radiation, interception, cold air drainage, and shelter from the wind. Topography was expressed in terms of solar energy received and exposure to prevailing winds. The factors related to snow accumulation were studied by reduced rank procedure of principal components, principal axis, canonical, and alpha factoring with varimax rotation of the factors. The best regressions relating the variables to snow accumulations arose from principal components analysis when highly correlated variables were included. Snow accumulation depended strongly on combinations of meteorological and forest variables, and on forest-meteorological interactions. Interception of snow, as indexed by the canopy over the point, averaged 10 per cent of the precipitation. Snow accumulation in forest openings, forest margins, and in large areas of uniform forest had different relations to meteorological and topographic variables. Forest shade and back radiation from trees were most important on high energy south slopes.

24. **Anderson, H.W., M.D. Hoover,** and **K.G. Reinhart.** 1976. Forests and water: effects of forest management on floods, sedimentation and water supply. U.S. Dep. Agric. For. Serv., Pac. SW For. Range Exp. Stn., Arcata, CA. Gen. Tech. Rep. PSW-18. 115 p.

From the background of more than 100 years' collective experience in watershed research and from comprehensive review of the literature of forest hydrology, the authors summarize what is known about the forest's influence on the water resource, particularly the effects of current forestry practices. They first examine the fundamental hydrologic processes in the forest. They then discuss how water supply, floods, erosion, and water quality are affected by timber harvesting, regeneration, tree planting, type conversion, fire, grazing, and the application of fertilizers and pesticides. They consider and present the special problems of fire-prone chaparral, phreatophytes, wetland forests, and surface-mined sites. Finally, they assess potential increases in water yield that might be achieved by forest management in each of six major forest regions in the United States and venture some predictions about future management of watersheds. Nearly 600 references provide a fairly comprehensive overview of the literature.

25. **Anderson, H.W., R.M. Rice,** and **A.J. West.** 1958. Snow in forest openings and forest stands. *In* Proc. Soc. Am. For. on Multiple-use Forestry in the Changing West. Sept. 28 - Oct. 2, 1958, Salt Lake City, UT. Arthur B. Myer and F.H. Eyre (editors). Soc. Am. For., Bethesda, MD, pp. 46-50.

Analysis of 57 snow courses incorporating 28 openings, forests of varying density and all aspects and slopes. In openings, greatest SWE's were found on downslope sides subject to cold air drainage. Within forest stands adjacent to openings, maximal accumulations were found to the southwest. Snow appears to have been "stolen" from the northeast side. Forest margins had 5-8 inches less SWE than the openings. Minimum melt was found on the south side of the openings. Except for east slopes, snowmelt was faster in the openings than in the adjacent forest. Openings 1-2 TH (tree heights) in width held snow the longest. Tables 2 and 3 present SWE's on April 22 and June 1 in 3 densities of forest on all aspects and various slopes. Maximal snow accumulations were in the least dense forests but melt was faster. Quamanigs were measured and found to be deepest on the north and east sides of trees.

26. **Anderson, J.A., D.H. Peter, R.D. Lesher,** and **D.C. Shaw.** 1989. Forest plant associations of the Olympic National Forest. U.S. Dep. Agric. For. Serv., Pac. NW Reg., Portland, OR. R6-ECOL-TP 001-88. 502 p.

A potential vegetation classification system is presented for the Olympic National Forest. It is based on a sample of 1046 reconnaissance and 408 intensive plots. The hierarchical classification includes six vegetation series and 64 plant associations. Diagnostic keys are presented to aid in the identification of series and associations. Descriptions are presented for each series and association which are oriented toward the application of this classification for land management objectives. Association descriptions include information about plant species occurrences, including mosses and lichens, mammals, birds, insect pests, and diseases. Most descriptions include information on timber productivity and soils. Background information is also presented on the ecology, geology, soils, and history of the Olympic Mountains.

27. **Anderson, N.H., G.M. Cooper,** and **D.G. Denning.** 1982. Invertebrates of the H.J. Andrews Experimental Forest, western Cascades, Oregon II. An annotated checklist of caddisflies (*Trichoptera*). U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Res. Note. PNW-402. 16 p.

At least 99 species, representing 14 families of *Trichoptera*, are recorded from the H.J. Andrews Experimental Forest, near Blue River, Oregon. The collecting sites include a wide diversity of environmental conditions in a 6000-hectare watershed of the western Cascade Range (from 400 to 1630 meters in altitude and from 1st- to 7th-order streams).

28. **Anderson, N.H.** and **J.R. Sedell.** 1979. Detritus processing by macroinvertebrates in stream ecosystems. Ann. Rev. Entomol. 24:351-377.

The effects of addition, or removal, of detritus from stream ecosystems are largely speculative. However, it is apparent that logging and stream cleanup both influence channel morphology and the stream biota. Debris removal may reduce the diversity of available habitats and may also lead to channelization. Channelization, coupled with shorter forest rotation, may keep the stream perpetually cleaned and unstable, both physically and biologically. Under these conditions the role of the stream biota in utilizing and recycling nutrients within the watershed would seem to be minimized. (From author's conclusion)

29. **Anderson, N.H., J.R. Sedell, L.M. Roberts,** and **F.J. Triska.** 1978. The role of aquatic invertebrates in processing of wood debris in coniferous forest streams. Am. Midl. Nat. 100:64-82.

A study of the wood-associated invertebrates was undertaken in seven streams of the Coast and Cascade Mountains of Oregon. The amount of wood debris was determined in terms of both weight and surface area. Standing crop of wood per unit area decreases with increasing stream order.

Invertebrates associated with wood were functionally categorized and their biomass on wood determined. Major xylophagous species were the caddisfly (*Heteroplectron californicum*), the elmid beetle (*Lara avara*), and the snail (*Oxytrema silicula*). Standing crop of these species is greater on wood in the Coast Range than in the Cascades, which is attributed to species composition of available wood debris. The density of *L. avara* was strongly correlated with the amount of wood available irrespective of stream size within a drainage. The standing crop of invertebrates was about two orders of magnitude greater on leaf debris than on wood.

A potential strategy for wood consumption, based on microbial conditioning, is presented. The data are used to develop a general scheme of wood processing by invertebrates in small stream ecosystems. Their impact is similar to that of invertebrates which process leaf litter in terrestrial and aquatic environments when the full decomposition cycle of wood debris is considered.

30. **Andrus, C.W., B.A. Long,** and **H.A. Froehlich.** 1988. Woody debris and its contribution to pool formation in a coastal stream 50 years after logging. Can. J. Fish. Aquat. Sci. 45(12):2080-2086.

Large quantities of woody debris persisted 50 yr after logging and fire in stream channels of a small coastal Oregon watershed. Debris from the current stand represented only 14% of total debris volume and 8% of debris volume responsible for creating pools. The greatest number of pools were located in downstream sections of the watershed where gradient was reduced, discharge was increased, and streambed material was finer. Seventy percent of pools with a volume greater than 1.0 m^3 were associated with woody debris in the channel. Composition of the current riparian forest varied with topography. Alder stands dominated moist terrace sites adjacent to channels, whereas slopes contained a mixture of alder and conifer. Study results indicate that riparian trees must be left to grow longer than 50 yr to ensure that an adequate, long-term supply of woody debris is available to stream channels. Debris from previous stands plays a crucial role in the interim and should not be removed from stream channels.

31. **Anthony, R.G., E.D. Forsman, G.A. Green, G. Witmer,** and **S.K. Nelson.** 1988. Small-mammal populations in riparian zones of coniferous forests in Western Oregon. *In* Streamside management: riparian wildlife and forestry interactions. K.J. Raedeke (editor). University Wash., Seattle, WA. Contrib. No. 59, pp. 163-181.

The purpose of the study was to compare small-mammal populations inhabiting low-order riparian zones in three age classes of forests and to contrast species composition and capture rates for streamside versus riparian fringe transects. Small mammals were snap-trapped in young, mature, and old-growth forests during the spring and summer of 1983. Traps were set in paired lines, with one line placed within 1 m of the stream (streamside) and the other placed along the riparian fringe (15-25 m from the stream). Each line consisted of 25 stations spaced at 15 m intervals, with three rat traps at each station.

Deer mice (*Peromyscus maniculatus*) were the most abundant species and made up 76 and 83 percent of the total captures during spring and summer, respectively. Total small-mammal abundance was greater in old-growth forests than in young and mature forests. *Microtus oregoni, Phenacomys albipes, Neotoma cinerea, Sorex palustris, S. monticolus*, and *Neurotrichus gibbsii* were captured only in old-growth or mature forests. Six species of insectivorous mammals, including five species of shrews (*Sorex* spp.), were captured, which exemplifies the importance of riparian zones for this group.

More species but fewer individuals were captured on the streamside transects in comparison to the riparian fringe transects. *Sorex palustris, S. bendirii, Phenacomys albipes, Neurotrichus gibbsii,* and *Microtus richardsoni* were captured only along streamside transects, but numbers of each species captured were small. Additional studies with more intensive trapping designs are needed to define the specific habitat relationships of these five species.

32. **Aplet, G.H., F.W. Smith,** and **R.D. Laven.** 1989. Stemwood biomass and production during spruce-fir stand development. J. Ecol. 77:70-77.

    (1) A 600-year chronosequence of Engelmann spruce - subalpine fir forest was used to examine the effects of changes in forest structure on stemwood biomass and production in a mixed-species community.

    (2) Fir size-class and age-class structure stabilized early in stand development, but spruce size and age structure changed throughout stand development.

    (3) Community stemwood biomass remained nearly constant through time as an increase in spruce biomass compensated for mortality in the fir component.

    (4) Fir production decreased from initially high levels with change in size-class structure, but spruce production remained nearly constant.

    (5) Stemwood production was related to leaf area in both species, but patterns of leaf area allocation differed between species.

    (6) Constant fir leaf area and production are achieved after stand structure stabilizes, but constant spruce leaf area and production occurred despite changes in stand structure.

33. **Armentano, T.V.** and **C.W. Ralston.** 1980. The role of temperate zone forests in the global carbon cycle. Can. J. For. Res. 10:53-60.

    Recent growth and harvest trends in commercial timberlands of the temperate zone suggest that these forests have been serving as a net sink for about 1.0×10^9 to 1.2×10^9 t of carbon annually over the past 3 decades. This is 20 to 60% of the annual carbon release from combustion of fossil fuels over the period, indicating that recovery transients in temperate zone forests apparently have been partially dampening the increase in atmospheric CO_2 caused by fossil fuel combustion and tropical forest reduction. Net forest growth is occurring throughout the temperate zone with principal carbon sinks found in North America and Siberia. Timber inventories for North America show an excess of growth over harvest equivalent to over 5×10^{15} g of C since the 1950s. Limited data suggest that in Siberia there is a large stock of slowly growing conifers that are underexploited, forming a sink equivalent to that of North America. Reafforestation in western Europe has expanded forest area by 5% since World War II. Similar recovery may now be occurring in temperate Asia. Problems of data reliability, particularly for the U.S.S.R., and the limited basis for estimating carbon balance in entire forests, suggest a severalfold uncertainty in the carbon sink estimates.

34. **Armleder, H.M., R.J. Dawson,** and **R.N. Thomson.** 1986. Handbook for timber and mule deer management co-ordination on winter ranges in the Cariboo Forest Region. B.C. Min. For., Victoria, BC. Land Manage. Handb. No. 13. 98 p.

Directed at forest managers, field technicians, and contractors, Part I of this handbook provides biological and ecological principles of mule deer winter range management. Part II is a step-by-step outline of the decision-making process: 1) determination of winter range area using principles outlined in the handbook; 2) evaluation of the winter range, considering treatment options described in the handbook; 3) formulation of site-specific management prescriptions through the application of principles described in Part I to operational planning; and 4) carrying out harvesting and spacing operations which follow specific principles described here. Although the step-by-step process initially appears rigid, the authors clearly state that the handbook should be used within the broad context of interdisciplinary resource management and should include consultation with Ministry of Environment personnel. **

35. **Arno, S.F.** 1980. Forest fire history in the Northern Rockies. J. For. 78:460-465.

Recent fire-scar studies in the northern Rocky Mountains have documented forest fire history over the past few centuries. They reveal that in some forest types fire maintained many-aged open stands of seral trees. In other types, major fires caused replacement of the stands. Often, however, fires burned at variable intensities, creating a mosaic of stands differing in composition and structure.

36. **Arno, S.F., G.E. Gruell, J.G. Mundinger,** and **W.C. Schmidt.** 1987. Developing silvicultural prescriptions to provide both deer winter habitat and timber. West. Wildl. 12(4):19-24.

The authors discuss results of research conducted by the U.S. Forest Service and the University of Montana examining the effects of particular silvicultural treatments on deer winter habitat. The objective is to manage timber to maintain overstory and enhance browse production, an alternative to setting aside old-growth forest for habitat. Five silvicultural options being tested are described in the paper. **

37. **Arno, S.F.** and **J.R. Habeck.** 1972. Ecology of alpine larch (*Larix lyallii* Parl.) in the Pacific Northwest. Ecol. Monogr. 42(4):417-450.

Alpine larch (*Larix lyallii*) grows in or near the timberline zone on high mountains of the inland northern portion of the Pacific Northwest. Unlike other subalpine conifers, which are evergreens, this deciduous larch displays an affinity for cold rocky sites and often grows in tree form higher up on north slopes than even krummholz (shrubby) forms of its associates. Overstory and understory vegetations in alpine larch communities were only indirectly correlated. *Vaccinium scoparium, Luzula glabrata,* and *Phyllodoce empetriformis* were the most common understory dominants. The distinctly snowy-cold-timberline nature of alpine larch habitats is emphasized by the presence of *Cassiope mertensiana, Phyllodoce glanduliflora,* and *Abies lasiocarpa* krummholz among the 11 most common understory species. Unlike the larch, which is generally restricted to the timberline zone, nearly all associated plants have broader distributions in the subalpine forest proper or above tree limit.

Alpine larch is a climax species on a wide variety of sites too severe for the more shade-tolerant evergreens to form unbroken stands because of shortness of growing season, rocky terrain, avalanches, blizzards, or extreme dryness or bogginess. When alpine larch ascends into what would otherwise be a strictly alpine habitat (above the limits of other conifers), its stands apparently modify the surface environment since subalpine understory species are generally able to ascend with it. Rarely the undergrowth is dominated by tundra species. Alpine larch is superior in invading freshly glaciated sites. The positive correlation of alpine larch to acidic substrates poor in mineral ions is in contrast to the substrate relationship of many other timberline conifers, which are calciphiles.

38. **Arno, S.F., D.G. Simmerman,** and **R.E. Keane.** 1985. Forest succession on four habitat types in Western Montana. U.S. Dep. Agric. For. Serv., Intermtn. For. Range Exp. Stn., Missoula, MT. Gen. Tech. Rep. INT-177.

Presents classifications of successional community types on four major forest habitat types in western Montana. Classifications show the sequences of seral community types developing after stand-replacing wildfire and clearcutting with broadcast burning, mechanical scarification, or no followup treatment. Information is provided for associating vegetational response to treatment.

39. **Arthur, M.A.** and **T. Fahey.** 1990. Mass and nutrient content of decaying boles in an Engelmann spruce - subalpine fir forest, Rocky Mountain National Park, Colorado. Can. J. For. Res. 20:730-737.

We classified dead bole wood in an old-growth Engelmann spruce - subalpine fir (*Picea engelmannii* Parry - *Abies lasiocarpa* (Hook.) Nutt.) forest in Rocky Mountain National Park, Colorado, into decay classes and measured dead bole surface area, volume, biomass, and nutrient content. Biomass of dead boles was 70 Mg/ha, about half as large as aboveground live biomass in these forests. Net accumulation of N, P, Ca, and Na occurred with increasing decay. The N:P ratio varied little with decay, approaching a value of 20 in the most decayed wood, typical of that found in other studies of dead boles. Loss of K during bole decay exceeded the rate of weight loss, whereas Mg loss followed weight loss. The total pools of nutrients in dead boles and in the amount of nutrients stored in dead boles as a percentage of total above- and below-ground living, forest floor, and dead wood nutrients were 92.2 kg N/ha (7%), 4.89 kg P/ha (5%), 67.9 kg K/ha (16%), 156.6 kg Ca/ha (12%), 28.9 kg Mg/ha (17%), and 0.74 kg Na/ha (9%). Storage of relatively high amounts of Ca in dead wood of most natural forests indicates that management could have a significant effect on its availability in the long term.

40. **Asher, S.C.** and **V.G. Thomas.** 1985. Analysis of temporal variation in the diversity of a small mammal community. Can. J. Zool. 63:1106-1109.

The validity of using single-sample surveys to measure small mammal diversity was assessed by measuring the effect of short-term, temporal variation in species diversity on the spatial diversity of small mammals occupying fencerow habitats. The diversity of small mammals varied seasonally. Interaction between changes in richness and evenness accounted for the temporal variation in diversity. Temporal variation was attributed to the response of the small mammals to seasonal changes in the vegetation, to the fluctuation in meadow vole (*Microtus pennsylvanicus*) captures among seasons, and the appearance of small numbers of several mammal species during the summer. Significant spatial variation in species diversity existed, but was masked by the effect of seasonal changes in habitat on the small mammals. Erroneous conclusions could therefore be drawn from the pooling of many single-sample surveys of small mammal diversity.

41. **Attiwill, P.M.** 1986. Interactions between carbon and nutrients in the forest ecosystem. Tree Physiol. 2:389-399.

"There is little understanding of how improved plant nutrition increases the production of dry matter" (Linder and Rook 1984). Much of the work with forest trees has been at the broad level of concentration of nutrients, rather than with detailed physiological studies of nutrient response functions, of factors controlling "efficiency" of nutrient utilization, and of the redistribution of nutrients from aging to developing tissues.

The sustained supply of nurients in forest ecosystems depends on processes by which nutrients are cycled from plant (in organic combinations) to soil and back to plant (in simple inorganic form). Studies of the key processes of decomposition and mineralization, and of equilibria determining nutrient availability have been hampered by lack of both appropriate chemical methods and of methods that distinguish among fractions of organic matter of varying nutritional quality.

The root systems of forests must also be studied more intensively. In particular, mechanisms by which nutrients in short supply are taken up (for example, the role of mycorrhizae and of specialized systems such as proteoid roots) and the redistribution of nutrients associated with turnover of the fine root system are fields for future research.

42. **Aubry, K.B., L.L.C. Jones,** and **P.A. Hall.** 1988. Use of woody debris by Plethodontid salamanders in Douglas-fir forests in Washington. *In* Proc. Symp. on Management of Amphibians, Reptiles, and Small Mammals in North America. R.C. Szaro, K.E. Severson, and D.R. Patton (technical coordinators). July 19-21, 1988, Flagstaff, AZ. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-166, pp. 32-44.

Ensatina eschscholtzii was found most often under pieces of bark, whereas *Plethodon vehiculum* occurred primarily under logs. Captures of both species were highest in young stands, but occurred in all age classes. Our results suggest that the retention of coarse woody debris in managed forests would provide for the habitat needs of these species.

43. **Auclair, A.N.D.** and **A.N. Rencz.** 1982. Concentration, mass, and distribution of nutrients in a subarctic *Picea mariana - Cladonia alpestris* ecosystem. Can. J. For. Res. 12:947-968.

The concentration and mass of nutrient elements (N, P, K, Ca, Mg, Cu, Fe, Mn, Na, Zn) were examined in 110-year-old lichen woodland in the subarctic of eastern Canada. Biomass plus soil organic matter contained two-fifths (41%) of the total nutrient mass in the system. Calcium (85%), P (76%), Mg (67%), and K (64%) were largely in live biomass. Nitrogen was equally in biomass plus organic soil (45%) and mineral soil (55%). Micronutrients were mainly in the soil inorganic fraction. Nitrogen was acutely deficient for rapid growth. Potential loss of Ca under logging and burning regimes consistently exceeded exchangeable soil reserves. A realistic evaluation of these impacts was dependent on more complete knowledge of net atmospheric and soil inputs and vegetation requirements. Dominant tree, shrub, and lichen genera all differed strongly in the concentration of tissue elements. Among vascular species, total element concentration related inversely to species abundance. Since evergreen perennial plants of low nutrient concentration prevailed at maturity, we postulated that nutrients increasingly limited the abundance of deciduous shrubs.

44. **Aumen, N.G., P.J. Bottomley, G.M. Ward,** and **S.V. Gregory.** 1983. Microbial decomposition of wood in streams: distribution of microflora and factors affecting [^{14}C] lignocellulose mineralization. Appl. Environ. Microbiol. 46(6):1409-1416.

The distribution and lignocellulolytic activity of the microbial community was determined on a large log of Douglas-fir (*Pseudotsuga menziesii*) in a Pacific Northwest stream. Scanning electron microscopy, plate counts, and degradation of [^{14}C]lignocelluloses prepared from Douglas fir and incubated with samples of wood taken from the surface and within the log revealed that most of the microbial colonization and lignocellulose-degrading activity occurred on the surface. Labeled lignocellulose and surface wood samples were incubated in vitro with nutrient supplements to determine potential limiting factors of [^{14}C] lignocellulose degradation. Incubations carried out in a nitrogenless mineral salts and trace elements solution were no more favorable to degradation than those carried out in distilled water alone. Incubations supplemented with either $(NH_4)_2SO_4$ or organic nitrogen sources showed large increases in the rates of mineralization over incubations with mineral salts and trace elements alone, with the greatest effect being observed from an addition of $(NH_4)_2SO_4$. Subsequent incubations with $(HN_4)_2SO_4$, KNO_3, and NH_4NO_3 revealed that KNO_3 was the most favorable for lignin degradation, whereas all three supplements were equally favorable for cellulose degradation. Supplementation with glucose repressed both lignin and cellulose mineralization. The results reported in this study indicate that nitrogen limitation of wood decomposition may exist in streams of the Pacific Northwest. The radiotracer technique was shown to be a sensitive and useful tool for assessing relative patterns of lignocellulose decay and microbial activity in wood, along with the importance of thoroughly characterizing the experimental system before its general acceptance.

45. **Azevedo, J.** and **D.L. Morgan.** 1974. Fog precipitation in coastal California forests. Ecology 55(5):1135-1141.

Summer fog precipitation beneath coastal forests was examined at two forested sites on ridges bordering the Eel River Valley in northern California. Each site was outfitted with bottle-funnel gauges and standard mechanical gauges placed on the forest floor and screened bottle-funnel gauges to trap fog in open areas.

As much as 42.5 cm of fog water were collected beneath the forest crown during the summer fog season although differences in crown exposure and dimension caused high variability in seasonal totals caught beneath individual trees. A typical fog precipitation event begins during late evening and ends just after sunrise. It sometimes continues for several days and produces fog drip amounts of up to 8 cm.

The nutrients and water captured from drifting fog by intercepting trees, shrubs, and grasses affect water balances and nutrient cycling within such coastal ecosystems. Fog may influence species composition, and the character of the soils and vegetation of such coastal forests must certainly reflect to some degree the prevalence of summer fog.

46. **Baker, J.H., R.Y. Morita,** and **N.H. Anderson.** 1983. Bacterial activity associated with the decomposition of woody substrates in a stream sediment. Appl. Environ. Microbiol. 45(2):516-521.

Ground bark and heartwood from *Alnus rubra* and *Pseudotsuga menziesii* were added to a muddy sediment from a small Oregon stream and incubated in situ. Carbon dioxide and methane production rates were increased by all amendments, the biggest increase being shown with *A. rubra* wood. Nitrogen fixation rates from all treatments (including the control) were approximately 0.1 nmol/g per h throughout the 6-month study period. Contrary to expectations, neither bark had a noticeable adverse effect on microbial activity, but the *A. rubra* wood promoted nitrogen fixation. These results help to explain the faster rate of decomposition of *A. rubra* wood in water compared with that of *P. menziesii* described in the literature. The uptake kinetics of glucose (V_{max}) did not follow the same pattern as gas evolution.

47. **Baker, W.L.** 1989. A review of models of landscape change. Landscape Ecol. 2(2):111-133.

Models of landscape change may serve a variety of purposes, from exploring the interaction of natural processes to evaluating proposed management treatments. These models can be categorized as either whole landscape models, distributional landscape models, or spatial landscape models, depending on the amount of detail included in the models. Distributional models exclude spatial detail important for most landscape ecological research. Spatial models require substantial data, in geographical information systems. Spatial modelling is poorly developed largely because landscape change itself is poorly understood.

To facilitate further development of landscape models I suggest: 1) empirical multivariate studies of landscape change; 2) modelling of individual landscape processes; 3) explicit study of the effect of model scale on model behavior; and 4) "scaling-up" results of studies, on smaller land areas, that have landscape relevance.

48. **Barnes, B.V.** 1989. Old-growth forests of the Northern Lake States: a landscape ecosystem perspective. Nat. Areas J. 9(1):45-57.

Old-growth forest ecosystems of the northern lake states provide the opportunity to study the composition and structure of vegetation, the occurrence and behavior of animals, and the interaction of plants and animals in relation to physiography, microclimate, and soil. From a general nonrestrictive viewpoint, old-growth forest is defined as forest ecosystems dominated by old trees. The definition may be amplified, as appropriate, for different landscape ecosystem types using attributes of tree age, disturbance history, forest structure and species composition, and other characteristics relating to ecosystem processes. Understanding old growth from a landscape ecosystem perspective means that the

ecosystem itself, stressing interactions of climate, physiography, soil, and vegetation, is the object-of-interest rather than just the old-growth trees (or vegetation). Emphasis on plant community types and the use of generalized type names has obscured understanding of the great regional and local diversity of old-growth ecosystems. Processes occurring in old-growth ecosystems are key features in the definition of old growth, and their understanding is critical to old-growth management. Abiotic factors, such as climate, landform, soil, and water movement, should be emphasized in identifying and conserving new and nontraditional old-growth ecosystems. Landscape ecosystems of different scales provide a basis for understanding the nature of plant and animal diversity and its change during succession and along abiotic gradients. Most, if not all, of the existing old-growth forests require management as well as protection and preservation.

49. **Barrett, S.C.H.** and **B.C. Husband.** 1990. The genetics of plant migration and colonization. *In* Plant population genetics, breeding, and genetic resources. A.H.D. Brown, M.T. Clegg, A.L. Kahler, and B.S. Weir (editors). Sinauer Assoc. Inc., Sunderland, MA, pp. 254-277.

Migration and colonization are processes shared by all organisms, yet it is unlikely that the genetic consequences are the same for all. Colonizing episodes will be important in determining population genetic structure when they occur frequently, as in species of ephemeral environments, or when as a result of long-distance dispersal, genetically isolated populations occur. The effects of small populations through founder events or bottlenecks, inbreeding, and strong directional selection in novel environments can all influence population genetic structure depending on the ecology of the species and the scale of colonization. While a theoretical framework for understanding the genetics of migration and colonization is well developed, few studies of plant populations exist that test the predictions of the models. Two particular deficiencies are evident. First, quantitative data on the significant parameters of colonization models, e.g., effective population size and migration rates, are lacking. Second, information on the effects of stochastic processes on quantitative traits is not available for plant populations, yet such traits are likely to be of major importance to survival and reproductive success. Satisfactory explanations for the success or failure of colonizing episodes will most likely come from demographic genetic studies of natural colonization events or from experimental work on artificially established colonies.

50. **Barrett, S.W.** and **S.F. Arno.** 1982. Indian fires as an ecological influence in the northern Rockies. J. For. 80:647-651.

The importance of fire as an ecological disturbance in the Northern Rockies is well accepted. Lightning is generally thought to have been the main source of ignition prior to settlement by Europeans. But writings of explorers and pioneers mention deliberate burning by Indians frequently enough to warrant an investigation of its importance. Interviews with descendants of Native Americans and of pioneer settlers in western Montana suggest that Indian burning was widespread, had many purposes, but was generally unsystematic. Fire chronologies based upon scars on old-growth trees indicate that fire intervals within similar forest types were shortest near Indian-use zones. Comparisons of presettlement fire intervals with those calculated from modern lightning-fire records suggest that Indian-caused fires substantially augmented lightning fires over large areas. As dependence on lightning alone may not create or perpetuate certain desirable plant communities or stand conditions, prescribed burning may be needed.

51. **Bartos, L.** 1989. A new look at low flows after logging. *In* Proc. of Watershed '89, Conf. on the Stewardship of Soil, Air, and Water Resources. E.B. Alexander (editor). March 21-23, 1989, Juneau, AK. U.S. Dep. Agric. For. Serv., Alaska Reg., Juneau, AK. R10-MB-77, pp. 95-98.

On the west side of Prince of Wales Island, a 51.6 square mile drainage basin was used to systematically evaluate low flow trends, before and after timber harvest. Both yearly flow duration curves and the 2 and 20 year recurrence low flow derived by Log Pearson Type III analysis, showed significantly greater low flows after timber harvesting 35 percent of the drainage areas.

52. **Bean, M.J.** 1987. International wildlife conservation. *In* Audubon wildlife report. R.L. Di Silvestro (editor). San Diego, CA, pp. 307-319.

Recent developments in traditional international conservation programs of the U.S. Department of the Interior and other agencies, particularly the regulation of international trade in endangered plants and animals, are discussed in this chapter. The role of multilateral development agencies in the destruction of the world's richest remaining wildlife habitats is also examined. Some important recent legislative developments for international wildlife conservation are noted. **

53. **Beaton, J.D., A. Moss, I. MacRae, J.W. Konkin, W.P.T. McGhee,** and **R. Kosick.** 1965. Observations on foliage nutrient content of several coniferous tree species in British Columbia. For. Chron. 41:222-236.

Concentration of nitrogen, phosphorus, potassium, calcium, magnesium and sulphur in needles of alpine fir, amabilis fir, western red cedar, Douglas fir, western hemlock, lodgepole pine, Engelmann spruce and Sitka spruce trees growing in a number of areas of British Columbia was determined.

Concentration of N, P, K, Ca, Mg and S in current needles of three groups of alpine fir seedlings was 1.05-1.85, 0.18-0.26, 0.70-1.08, 0.29-.044, 0.07-0.11, and 0.12-0.16 per cent, respectively. The nutrient content in the same order was 0.99, 0.16, 1.20, 0.30, 0.08, and 0.12 per cent in a single group of amabilis fir samples.

In the lone set of western red cedar samples the concentration of N, P, K, Ca, Mg and S was in the order of 0.73, 0.13, 0.52, 1.16, 0.10, and 0.07 per cent.

The percentage of the six nutrients in current Douglas fir needles from seven locations was 0.88-1.37, 0.12-0.22, 0.38-0.70, 0.16-0.44, 0.07-0.18, and 0.14-0.25 for N, P, K, Ca, Mg and S, respectively.

The nutrient content of current needles of western hemlock from three sites was NN=0.86-1.17, P=0.11-0.19, K=0.28-0.57, Ca=0.18-0.27, Mg=0.08-0.12, and S=0.10-0.15 per cent.

Nitrogen, P, K, Ca, Mg and S concentration in current needles from three lots of lodgepole pine seedlings was 1.18-1.77, 0.15-0.18, 0.45-0.62, 0.16-0.26, 0.11-0.14, and 0.12-0.21 per cent, respectively. The corresponding values in needles from older trees were in the order 0.97-1.12, 0.09-0.12, 0.35-0.39, 0.15-0.16, 0.08-0.12, and 0.09-0.11.

Per cent N, P, K, Ca, Mg and S in current needles of three groups of Engelmann spruce seedlings was in the order 1.26-1.72, 0.21-0.29, 0.71-0.80, 0.44-0.58, 0.13-0.15, and 0.13-0.19. Concentration of these nutrients in older trees was 0.92-1.08, 0.20, 0.70-0.88, 0.28-0.33, 0.11-0.12 and 0.12-0.14 per cent, respectively.

In the one set of Sitka spruce samples concentration of N, P, K, Ca, Mg and S in current needles was 1.15, 0.18, 0.82, 0.42, 0.09, and 0.14 per cent, respectively.

Phosphorus concentration appeared to increase with age of needles in the Douglas fir and hemlock samples. However, with alpine and amabilis fir, lodgepole pine and spruce, the current needles usually contained more P than the older needles.

Current needles of all species frequently contained a higher concentration of K than the older needles.

Calcium tended to accumulate in older needles.

Although age of needles had little or no influence on Mg content of most needles, there was some indication that older needles of lodgepole pine and Engelmann and Sitka spruce contained more Mg than current needles.

Sulphur accumulated in older needles of Douglas fir and hemlock while it tended to decrease with age in lodgepole pine and spruce.

54. **Beatty, S.W.** and **E.L. Stone.** 1985. The variety of soil microsites created by tree falls. Can. J. For. Res. 16:539-548.

The uprooting of forest trees leads to the formation of microsites on the forest floor, contributing to fine-scale heterogeneity in soil properties. We found the types of microsites formed depended on the way the tree fall occurred. Tree falls were classified as either hinge or rotational types. Hinge tree falls formed when the root mat of a tree and the surrounding soil were uplifted vertically, leaving an adjacent pit in the soil. Hinge tree falls varied as to thickness of the root mat and angle of uplift. Rotational tree falls were usually a result of a ball and socket motion of the root mat and soil, which positioned the tree bole over the newly created pit. The tree falls disrupted and redistributed surface soil organic matter and subsoil. In rotational tree falls, the surface material remained intact, covering some of the pit and the adjacent side of the mound. In hinge tree falls, the surface organic matter was deposited on the throw side of the mound, leaving subsoil on the other side and in the pit. With time, however, hinge-type pits accumulated litter and eventually had more organic matter than mounds. Old mounds from both hinge and rotational tree falls had lower concentrations of calcium and magnesium, lower pH, and less moisture than pits. The tree fall process creates long-term soil patterns and maintains microsite heterogeneity in forest communities.

55. **Beaudry, P.G.** and **D.L. Golding.** 1983. Snowmelt during rain on snow in coastal British Columbia. *In* Proc. Western Snow Conf. 51st Ann. Meet. B.A. Shafer (editor). April 19-21, 1983, Vancouver, WA. Col. State Univ., Fort Collins, CO, pp. 55-66.

A study was conducted in Jamieson Creek experimental watershed near Vancouver, BC, to determine differences in melt rates during rain-on-snow events between a cutover and a Coastal Western Hemlock old-growth forest. An energy balance approach was used to quantify the energy fluxes involved in the snow-melting process. Each site was equipped with two independent lysimeters: a pair of small (0.3 m^2) barrel lysimeters and a large (28m^2) plastic sheet lysimeter for preliminary snow melt measurements, with outflow being measured in a tipping-bucket arrangement. Wind speed, relative humidity and air temperatures were measured at 0.6 meters and 1.5 meters above the snow pack to evaluate turbulent fluxes. Snowpack and ground heat exchange was measured with a profile of 6 thermocouples at 0, 0.30, 0.60, and 1.0 meter above ground surface and 0.05 and 0.1 meter below the ground surface. Radiation was monitored with net all-wave radiometers (1 in cutover, 3 in forest). Lysimeter results are compared to U.S. Corps of Engineers equations and theoretical calculations. **

56. **Bega, R.V.** (technical coordinator). 1979. Diseases of Pacific Coast conifers. U.S. Dep. Agric. For. Serv., Pac. SW For. Range Exp. Stn., Arcata, CA. Agric. Handb. No. 521. 206 p.

This handbook provides basic information needed to identify the common diseases of Pacific Coast conifers. Hosts, distribution, damage, disease cycle, and identifying characteristics are described for 31 needle diseases; 17 canker, dieback, and gall diseases; 23 rusts; 8 root diseases; 15 forms of mistletoe; and 18 forms of rot. Diseases in which abiotic agents are contributory factors are also described. Also included are: color and black-and-white illustrations; a descriptive key to field identification for each major group of diseases; a glossary; and host plant and disease causal agent indexes.

57. **Benner, P.A.** and **J.R. Sedell.** 1987. Chronic reduction of large woody debris on beaches at Oregon river mouths. *In* 8th Ann. Meet. Soc. Wetland Scientists. May 26-29, 1987, Seattle, WA.

This article discusses the findings of a study conducted to document the amount of large woody debris found on beaches from the mid-1800's to about 1985. Historical records showed a significant amount of large woody debris in coastal rivers. Recently, size and volume of debris has decreased. A 15-year chrono-sequence of photographs indicated a 70% reduction in volume of wood of four Oregon river mouth beaches since 1970. The natural sources of wood on beaches included creek to estuary inputs, but deforestation of riparian corridors resulted in a significant decrease in the contribution of large woody debris from these sources. Changes in forestry practices and firewood use are recent factors responsible for reducing the amounts of wood reaching river mouths. Such losses of large woody debris have many ecological impacts on community structure in coastal areas. **

58. **Benson, R.E.** and **M.J. Niccolucci.** 1985. Costs of managing nontimber resources when harvesting timber in the northern Rockies. U.S. Dep. Agric. For. Serv., Intermtn. Res. Stn., Ogden, UT. Res. Pap. INT-351. 22 p.

Some 187 Forest Service timber sales in western Montana and northern Idaho were analyzed to determine the costs of protecting or enhancing nontimber resources during timber harvesting. Linear regression models were used to estimate how various activities undertaken to meet nontimber concerns affected costs for various phases of logging, and also the bids for stumpage. Costs of managing nontimber resources averaged $26 per thousand board feet of stumpage sold.

59. **Berndt, H.W.** 1961. Some influences of timber cutting on snow accumulation in the Colorado Front Range. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Res. Note No. 58.

To learn how canopy reduction by logging might influence snow accumulation in ponderosa pine - Douglas-fir stands, an exploratory study was made. The study was conducted on the Pike National Forest at 8,500 feet elevation within the Long Hollow drainage 35 miles northwest of Colorado Springs, Colorado. In the fall of 1957 six rectangular plots, 1 acre in size, were established on north-facing slopes of 10 to 30 percent. Twenty-five snow sampling points were permanently marked on each plot. At all points snow depth and moisture content were measured with a Mount Rose snow sampler after each major storm and periodically during snowmelt.

60. **Berntsen, C.M.** 1960. Productivity of a mature Douglas-fir stand. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Res. Note No. 188. 4 p.

The occurrence of large amounts of mortality and small but measurable periodic annual increases in wood volume indicates this 250-year-old Douglas-fir stand is still highly productive. Barring catastrophic losses, a final harvest could reasonably be deferred many years without loss of net volume. On the other hand, salvage of mortality during the "holding" period could provide earlier income without reduction of growing stock. Periodic salvage could also be expected to increase total yields through the recovery of wood material that would otherwise deteriorate if left until the tract is clear cut in a final harvest.

61. **Berris, S.N.** and **R.D. Harr.** 1987. Comparative snow accumulation and melt during rainfall in forested and clear-cut plots in the western Cascades of Oregon. Water Resour. Res. 23(1):135-142.

Snow accumulation was compared between forested and clear-cut plots in the transient snow zone of the western Cascade Range of Oregon, and measured snowmelt in both plots was compared to melt predicted by energy balance analyses. The absence of forest vegetation affected both snow accumulation and amount of energy available for melt during rainfall. Because intercepted snow melted in the forest canopy and reached the ground as

meltwater, water equivalents in the clear-cut plot were commonly 2-3 times greater than those in the forested plot. During the largest rain-on-snow event of the study, measured water outflow (rain plus snowmelt) in the clear-cut plot was 21% greater than in the forested plot. Estimates made from microclimatological data show that during the common period of melt, total energy available in the clear-cut plot was 40% greater than that in the forested plot. Because of greater wind speed in the clear-cut plot, combined sensible and latent heat transfers in the clear-cut plot were nearly triple those of the forested plot.

62. **Berry, J.F.** 1989. Reflections on conflicts over forests: work, jobs, income and a new approach to economics. Trumpeter 6(2):54-56.

Taking a philosophical approach, the author examines our current definition of "work" and questions its value relative to the value of the natural resource which is the support system of this "work." Does a shipload of Kleenex have the same value as a standing forest? The process of converting trees into Kleenex adds to our Gross National Product. The Exxon oil spill increased local GNP. Is this what we really want?

The first law of economics is to "preserve the source". To accomplish this we need to redefine "work." Human work should be aimed at human well-being, which translates into taking care of the earth. The author believes that "public works" jobs preserving and maintaining our support system could replace logging industry jobs which currently destroy this system. **

63. **Beschta, R.L.** 1979. Debris removal and its effects on sedimentation in an Oregon Coast Range stream. N.W. Sci. 53(1):71-77.

The removal of large organic debris obstructing anadromous fish passage in a Coast Range stream in Oregon accelerated downcutting of previously stored sediments. As a result, turbidity and suspended sediment levels increased during several storms after debris removal. Streamflow eroded more than 5,000 m^3 of sediment along a 250 m reach the first winter after debris removal. Therefore, fisheries managers who want to remove debris jams from streams must consider the stored sediments that will be scoured from the stream beds and deposited downstream.

64. **Beschta, R.L.** and **W.S. Platts.** 1986. Morphological features of small streams: significance and function. Water Resour. Bull. 22(3):369-379.

Throughout the United States, land managers are becoming increasingly aware of the importance of small streams for a wide range of resource benefits. Where channel morphology is modified or structural features are added, stream dynamics and energy dissipation need to be considered. Unit stream power, defined here as the time-rate loss of potential energy per unit mass of water, can be reduced by adding stream obstructions, increasing channel sinuosity, or increasing flow resistance with large roughness elements such as woody root systems, logs, boulders, or bedrock. Notable morphological features of small streams are pools, riffles, bed materials, and channel banks. Pools, which vary in size, shape, and causative factors, are important rearing habitat for fish. Riffles represent storage locations for bed material and are generally utilized for spawning. The particle size and distributions of bed material influence channel characteristics, bedload transport, food supplies for fish, spawning conditions, cover and rearing habitat. Riparian vegetation helps stabilize channel banks and contributes in various ways to fish productivity. Understanding each stream feature individually and in relation to all others is essential for proper stream management. Although engineered structures for modifying habitat may alter stream characteristics, channel morphology must ultimately be matched to the hydraulic, geologic, and (especially) vegetative constraints of a particular location.

65. **Bilby, R.E.** 1981. Role of organic debris dams in regulating the export of dissolved and particulate matter from a forested watershed. Ecology 62:1234-1243.

An organic debris dam is an accumulation of organic matter in a stream which obstructs water flow. Debris dams trap sediments in the pool formed upstream from them and the dam structure itself collects particulate matter.

This study was done at Hubbard Brook Experimental Forest, in New Hampshire, to examine the relative importance of these structures in retention of sediment and organic matter in a small stream ecosystem. An experimental approach was used in which all organic debris dams were removed from a 175-m section of second-order stream, just above a gauging weir. The material being exported from the watershed was separated into three site categories: dissolved matter (<0.5µm), fine particulate matter (0.5µm to 1 mm), and coarse particulate matter (>1 mm). Export of each size fraction was monitored for at least 1 yr prior to dam removal, and for 1 yr following removal.

Following dam removal, export of dissolved matter increased slightly due to an increase in the concentration of dissolved organic carbon in the stream water during periods of high discharge. Fine particulate matter export increased dramatically at high discharges following dam removal; concentrations in some instances achieved values five times higher than any observed before dam removal. Coarse particulate matter was also greatly increased.

Calculating dissolved matter and particulate matter export from the watershed, with and without organic debris dams, showed that dam removal brought about a 6% increase in the export of dissolved matter and a 500% increase in the export of both fine particulate and coarse particulate matter.

66. ————————. 1984. Removal of woody debris may affect stream channel stability. J. For. 82:609-613.

Several western states mandate the removal of logging debris from streams in order to prevent accumulations impassable to anadromous fish. Monitoring a small western Washington stream revealed large changes in channel structure during the first high flow after cleaning. Nearly 60 percent of the monitored pieces of debris moved during this storm, channel cross sections were substantially altered by movement of stored sediment, and the number, area, and volume of pools decreased. The degree of channel rearrangement was greater than in a comparable undisturbed stream. Subsequent storms caused much less debris movement and channel change than the first high flow, even though some of the later flows were of greater magnitude. An interim guide to stream cleaning is prescribed.

67. ————————. 1985. Influence of stream size on the function and characteristics of large organic debris. *In* Proc. West Coast Meet. of the National Counc. of the Paper Industry for Air and Stream Improvement, Portland, OR. Tech. Bull. 446, pp. 1-14.

This article presents some preliminary data on the influence of stream size on debris size, frequency, and function. Generally, debris which is able to sustain its position in the channel is beneficial to the stream system. A study during the winter of 1980 and 1981 indicated that two factors that seem to contribute to debris stability were size and features of the channel which anchored the debris in place. Length of debris related closely to its stability.

A study examining the relationship between stream size and characteristics of woody debris was undertaken. The first phase of the study focused on streams flowing through old-growth timber. Information collected was used to determine how the size of a stream influences the size of debris found in that stream and how debris size relates to the size of channel features influenced by it.

The author concludes that with this information it will be possible to determine the kinds of streams in which debris input requirements can be met with present forest management practices, and those which will require some alternative scheme to ensure a continued supply of appropriately sized woody debris. **

68. ——————. 1988. Interactions between aquatic and terrestrial systems. *In* Streamside management: riparian wildlife and forestry interactions. K.J. Raedeke (editor). Univ. Wash., Seattle, WA. Contrib. No. 59, pp. 13-29.

This paper will briefly outline the major interactions between aquatic and terrestrial ecosystems and delineate some of the factors responsible for dictating the relative magnitude of these processes. Streams and rivers will be the aquatic systems considered, since they represent the majority of the land/water interfaces found on forested lands in the Pacific Northwest (Oakley, *et al.* 1985). Interactions have been separated into two broad categories, those dictating structural attributes of the systems (such as soil characteristics, composition of vegetation, and channel morphology) and those primarily influencing functional characteristics (such as energy flow and nutrient cycling). Special emphasis will be placed on examining the changes in the relative importance of the interactions between the aquatic and terrestrial systems as a result of changes in stream size. (From author's introduction)

69. **Bilby, R.E.** and **G.E. Likens.** 1980. Importance of debris dams in the structure and function of stream ecosystems. Ecology 61:1107-1113.

Removal of all organic debris dams from a 175-m stretch of second-order stream at the Hubbard Brook Experimental Forest in New Hampshire led to a dramatic increase in the export of organic carbon from this ecosystem. Output of dissolved organic carbon (<0.50µm) export increased 18%. Fine particulate organic carbon (0.50 µm - 1mm) export increased 623% and coarse particulate organic matter (>1 mm) export increased 138%.

Measurement of the standing stock of coarse particulate organic matter on streambeds of the Hubbard Brook Valley revealed that organic debris dams were very important in accumulating this material. The proportion of organic matter held by dams drops to 58% in second-order streams and to 20% in third-order streams.

Organic debris dams, therefore, are extremely important components of the small stream ecosystem. They retain organic matter within the system, thereby allowing it to be processed into finer size fractions in headwater tributaries rather than transported downstream in a coarse particulate form.

70. **Bilby, R.E.** and **J.W. Ward.** 1989. Changes in characteristics and function of woody debris with increasing size of streams in Western Washington. Trans. Am. Fish. Soc. 118:386-387.

In second- to fifth-order streams that drain old-growth timber in western Washington, characteristics and function of woody debris changed in relation to stream size. Average diameter, length, and volume of pieces of wood increased as stream size increased, whereas the frequency of occurrence of woody debris decreased. In streams with channel widths less than 7 m, 40% of the pieces of debris were oriented perpendicularly to the axis of flow; in streams with channel widths over 7 m, more than 40% of the pieces were oriented downstream. The types of pools most commonly associated with pieces of wood changed from plunge pools in small streams (42%) to debris scour pools in larger systems (62%). Pool area was correlated with the volume of the piece of wood forming the pool in streams of all sizes. However, this relationship was most evident in larger channels. Nearly 40% of the pieces of wood in channels less than 7 m wide were associated with sediment accumulations. Less than 30% of the pieces retained sediment in channels from 7 to 10 m wide, and less than 20% retained sediment in channels greater than 10 m wide. Surface area and sediment accumulations and the volume of the pieces of wood forming the accumulations were related in all streams, but the relationship was clearest in the larger channels. Accumulations of particulate organic matter associated with woody debris were more frequent in small streams but were larger in large streams. No relationship was observed between the volume of fine particulate organic matter accumulated by a piece of wood and the piece of wood's volume.

71. **Binkley, D.** 1984. Does forest removal increase rates of decomposition and nitrogen release? For. Ecol. Manage. 8:229-233.

Little information is yet available concerning the effects of forest harvest on rates of decomposition and nutrient release. This study examines decomposition and nitrogen availability in adjacent cut and uncut sites by means of cellulose-filled litterbags and ion exchange resin bags located at three elevations on Vancouver Island, BC, Canada. Cellulose weight loss was no greater in clear-cut than in uncut sites at the forest floor interface of litter and fragmented layers, but was 3 to 5 times greater at the interface of fragmented and humified layers and the interface of the humified layer and mineral soil. Resin-based estimates of nitrogen availability were 7 to 20 times greater in clear-cut sites.

72. **Binkley, D., K. Cromack, Jr.** and **R.L. Fredriksen.** 1982. Nitrogen accretion and availability in some snowbrush ecosystems. For. Sci. 28(4):720-724.

We examined two chronosequences in the Oregon Cascade Mountains to assess nitrogen accretion and availability in relation to snowbrush (*Ceanothus velutinus* Dougl.). In two 12-year-old snowbrush ecosystems, total soil nitrogen to 30-cm depth exceeded levels in adjacent old-growth stands by 500 and 570 kg/ha. Inclusion of the approximate nitrogen content of aboveground snowbrush and forest floor biomass raised the estimate of nitrogen fixation to 94 to 100 kg/ha/hr over 12 years. Snowbrush also increased the availability index of soil nitrogen, but nitrogen availability appeared high in all ecosystems. We speculate that nitrogen fixation by snowbrush during early succession in these ecosystems has been sufficient to prevent nitrogen limitation throughout the entire successional sequence. The presence of snowbrush for 12 years also increased soil carbon 40 and 60 percent in the two chronosequences.

73. **Binkley, D.** and **R.L. Graham.** 1981. Biomass, production, and nutrient cycling of mosses in an old-growth Douglas-fir forest. Ecology 62(5):1387-1389.

This study was initiated at the H.J. Andrews Experimental Forest to assess the contribution of ground layer mosses to biomass and nutrient cycling in old-growth Douglas-fir - western hemlock forests. Biomass per hectare was assessed by collection of moss samples at random intervals along four 50-m transects. Moss age, structure, productivity, and nutrient content were determined from the collection of one random 25- x 25-cm sample along each transect. *Stokesiella oregana* (Sull.) Robins. accounted for 92% and *Hylocomium splendens* (Hedw.) B.S.G. accounted for 7% of the total biomass. Based on age/biomass distributions, it was estimated that 39% of the standing crop of *Stokesiella* and 18% of *Hylocomium* represented net annual production. Data from this experiment were compared to ecosystem budgets of other studies to examine the role of mosses in the total ecosystem for this habitat. In the understory, mosses added 20% to total biomass and 95% to photosynthetic tissue. In the ecosystem, moss production added 5% to aboveground estimates of primary production and uptake of Ca and K; and 10% to estimates of N and P uptake. The authors conclude that despite the fact that ground layer mosses accounted for only 0.13% of the aboveground biomass, they contributed substantially to the system dynamics. **

74. **Binkley, D.** and **D. Richter.** 1987. Nutrient cycles and H^+ budgets of forest ecosystems. Adv. Ecol. Res. 16:1-51.

Atmospheric deposition and natural nutrient cycling contribute to the production and consumption of H^+ in forest ecosystems. The effects of these fluxes on soil pH depends on net changes in large, long-term pools of H^+. Studies of changes in soil acidity from pollution or various forest management methods require the use of H^+ budgets with appropriate spatial and temporal scales. Despite the fact that internal ecosystem cycling of nutrients generates and consumes large quantities of H^+, these cycles generally balance themselves and have no long term effect on forest soil acidity. Soil acidification over long periods of time are the result of non-cyclic H^+ transfers and other elements across ecosystem boundaries. Limitations and benefits of the creation of H^+ budgets are discussed. **

75. **Bisson, P.A., R.E. Bilby, M.D. Bryant, C.A. Dolloff, G.B. Grette, R.A. House, M.L. Murphy, K.V. Koski, and J.R. Sedell.** 1987. Large woody debris in forested streams in the Pacific Northwest: past, present, and future. *In* Streamside management: forestry and fishery interactions. E.O. Salo and T.W. Cundy (editors). Univ. Wash., Seattle, WA. Contrib. No. 57, pp. 143-190.

This paper reviews the form, function, and management of woody debris in streams, and reaches three major conclusions: (1) Large woody debris enhances the quality of fish habitat in all sizes of stream. (2) Removal of most trees in the riparian zone during logging, combined with thorough stream cleaning and short-rotation timber harvest, has altered the sources, delivery mechanisms, and redistribution of debris in drainage systems, leading to changes in fish population abundance and species composition. (3) There is an urgent need for controlled field experiments and long-term studies that focus on the protection of existing large woody debris in stream channels and the recruitment of new debris from the surrounding forest. (From authors' abstract)

76. **Bisson, P.A. and J.R. Sedell.** 1984. Salmonid populations in streams in clearcut vs. old-growth forests of western Washington. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 121-129.

Cutthroat trout (*Salmo clarki*), juvenile steelhead trout (*S. gairdneri*), and juvenile coho salmon (*Oncorhynchus kisutch*) were sampled during the low-flow period of summer to compare population biomass in western Washington streams flowing through old-growth forests with those in areas recently clearcut. In paired logged and unlogged sites, total salmonid biomasses averaged 1.5 times greater after logging than in adjacent unlogged sections. Among all sites (paired plus unpaired locations), total salmonid biomasses were 2.0 times greater, on average, in clearcuttings. Streams in logged watersheds contained higher percentages of age-0+ steelhead and age-0+ cutthroat trout, and lower percentages of age-0+ coho salmon and age-1+ and -2+ cutthroat, compared to streams in old-growth forests. Shifts in species and age composition were related to habitat changes that resulted from timber harvesting and debris removal from the channels. Large, stable organic debris declined and unstable debris increased after passage of forest practices legislation that mandated immediate debris removal following logging. Pool volumes decreased and riffle volumes increased after streambank disturbances and channel clearance, although the frequency (number per km) of both pools and riffles was lower in streams flowing through clearcut sites. Riffles in streams that underwent extensive debris removal were elongated and in many cases extended through former pool locations. Increases in the proportional abundance of underyearling steelhead and cutthroat trout after clearcutting is possibly explained by the preference of these fishes for riffle habitat, while the relative decline of coho and older cutthroat may have resulted from the loss of pool volume and large, stable debris for cover.

77. **Black, T.A. and D.L. Spittlehouse.** 1981. Modeling the water balance for watershed management. *In* Proc. Symp. on Interior West Watershed Management. D.M. Baumgartner (editor). April 8-10, 1980, Spokane, WA. Wash. State Univ., Coop. Ext., Pullman, WA, pp. 117-129.

The use of evapotranspiration and drainage relationships in developing practical water balance models for forested watersheds during the growing season is briefly reviewed. Two models of forest evapotranspiration currently being evaluated on 25-year-old Douglas-fir stands on Vancouver Island are described. One uses a semi-empirical relationship between evapotranspiration rate and net radiation, while the other uses stomatal resistance characteristics of the trees and the understory vegetation. As part of a two-layer root zone water storage model, the unity gradient approximation is used to drain water from the bottom layer. The possible application of the evapotranspiration models to assess the impact of silvicultural treatments on the stand water balance is discussed.

78. **Blockstein, D.E.** 1988. U.S. legislative progress toward conserving biological diversity. Conserv. Biol. 2(4):311-313.

The National Biological Diversity Conservation and Environmental Research Act (H.R. 4335) was introduced in March 1988 and approved in August, 1988. The author briefly describes the key provisions of the bill, its development, and reactions to its introduction. **

79. ——————— 1989. Toward a federal plan for biological diversity. Issues Sci. Tech. 5(4):63-67.

Protection of human health depends on environmental health which in turn depends on biological diversity. This paper points to the necessity for a federal conservation strategy to protect biological diversity, and discusses the role of science, seminatural areas, ecological recovery, international initiatives, and actions under way in the U.S. **

80. **Blondin, A.R.** 1989. The Owl complex. J. For. (Aug.):37-40.

The plight of the northern spotted owl has become a focal point to the greater issue of land use conflicts. If the owl makes it onto the endangered species list, high economic losses will result for the Pacific Northwest timber industry. At this time, a compromise plan to protect the owl while continuing harvesting has been rejected by preservation groups. **

81. **Boecklen, W.J.** 1986. Optimal design of nature reserves: consequences of genetic drift. Biol. Conserv. 38:323-338.

Computer simulations were used to compare rates of genetic drift and allele fixation in intact populations with those in subdivided populations with the same total numbers of individuals. Subdivided populations with occasional inter-subpopulation migrations typically preserve more heterozygotes over the long term and preserve allelles longer than do corresponding intact populations. Intact populations typically exhibit a short-term (50 generations) advantage over subdivided populations in maintaining heterozygosity. Rates of genetic drift are influenced by population size, inter-subpopulation migration rate, and degree of population subdivision. Archipelagos of refuges with occasional inter-refuge migration appear to be the optimal design strategy for genetic conservation.

82. **Bonan, G.B.** 1990. Carbon and nitrogen cycling in North American boreal forests. II. Biogeographic patterns. Can. J. For. Res. 20:1077-1088.

A model of carbon and nitrogen cycling developed with ecological relationships from upland boreal forests in interior Alaska was tested with forest structure and forest floor data from several bioclimatic regions of the North American boreal forest. Test forests included black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce (*Picea glauca* (Moench) Voss), white birch (*Betula papyrifera* Marsh.), balsam fir (*Abies balsamea* (L.) Mill.), and jack pine (*Pinus banksiana* Lamb.) stands located in five different bioclimatic regions. Test comparisons of simulated and actual data included aboveground tree biomass, basal area, density, litter fall, and moss and lichen biomass as well as forest floor biomass, turnover, thickness, nitrogen concentration, and nitrogen mineralization. The model correctly simulated 60 (76%) of the 79 variables tested. Approximately 42% of the incorrectly simulated variables occurred in one forest. The major recurring errors included inaccurate moss and lichen biomass and low moss nitrogen concentrations. These tests indicated that ecological relationships from interior Alaska can be extended to other boreal forest regions and identified the factors controlling vegetation in different bioclimatic regions of the North American boreal forest.

83. **Bonan, G.B.** and **H.H. Shugart.** 1989. Environmental factors and ecological processes in boreal forests. Ann. Rev. Ecol. Syst. 20:1-28.

The boreal forest is a mosaic of vegetation types that reflects a combination of environmental factors unique to high-latitude forests. Climate, solar radiation, soil moisture, soil temperature and the presence of permafrost, the forest floor organic layer, nutrient

availability, insect outbreaks, and wildfires interact to contribute to the mosaic pattern of forest types and the wide range in stand productivity characteristic of boreal forests. Our model of boreal forests is on a circumpolar scale, and one should not infer that the full model will apply to all boreal forests. Rather, this review has identified the critical processes and parameters required to understand the ecology of boreal forests. In doing so, it has provided a framework for a circumpolar comparison of boreal forests and a mechanistic context for climatic biogeographic classifications of boreal forest regions. (From authors' summary)

84. **Bonan, G.B., H.H. Shugart,** and **D.L. Urban.** 1990. The sensitivity of some high-latitude boreal forests to climatic parameters. Climatic Change 16:9-29.

A gap model of environmental processes and vegetation patterns in boreal forests was used to examine the sensitivity of permafrost and permafrost-free forests in interior Alaska to air temperature and precipitation changes. These analyses indicated that in the uplands of interior Alaska, the effect of climatic warming on the ecology of boreal forests may not be so much a direct response to increased air temperature as it may be a response to the increased potential evapotranspiration demands that will accompany climatic warmings. On poorly-drained north slopes with permafrost, the drier forest floor reduced the flux of heat into the soil profile. This was offset by increased fire severity, which by removing greater amounts of the forest floor increased the depth of soil thawing and converted the cold black spruce forests to warmer mixed hardwood-spruce forests. On well-drained south slopes, the increased potential water loss reduced available soil moisture, converting these mesic sites to dry aspen forests, or if too dry to steppe-like vegetation. Increases in precipitation offset the effects of increased potential evapotranspiration demands and mitigated these forest changes.

85. **Booth, W.** 1989. New thinking on old growth. Science 244:141-143.

This article discusses the state of old-growth forests in the Pacific Northwest. The following topics are addressed: 1) the conflicts between loggers and ecologists involving old-growth harvest; 2) old-growth forests and the greenhouse effect; 3) the amount of old-growth remaining in the Pacific Northwest; 4) habitat fragmentation resulting from old-growth harvest; and 5) old-growth dependant wildlife species. **

86. **Bosatta, E.** and **F. Berendse.** 1984. Energy or nutrient regulation of decomposition: implications for the mineralization-immobilization response to perturbations. Soil Biol. Biochem. 16(1):63-67.

A model developed previously to describe the turnover of forest soil nitrogen is modified here to explain the effects of carbon and nitrogen additions on their dynamics. The model, which is structurally very simple, seems to explain correctly, among other phenomena, the negative correlation between N mineralization and CO_2 evolution observed in many experimental situations. An important variable used to explain this behaviour is the deficiency factor, which is related to the critical C-to-nutrient ratio and which gives a measure of the C or nutrient deficiency in the substrate with respect to the needs of the decomposers. Ways are discussed in which the model output can be used to explain the observed retention in the soil of fertilizer N added to mature forest soils.

87. **Bosatta, E.** and **H. Staaf.** 1982. The control of nitrogen turn-over in forest litter. Oikos 39:143-151.

A "semi-empirical" model for describing the nitrogen dynamics of decomposing forest litter in a medium-long time perspective is presented. Derived results indicate the strong regulating influence of decomposition rate and initial nitrogen concentration of the litter on its retention and release of N. An increased decomposition rate tends to reduce the rate of N release per unit of carbon mineralized. This makes the "critical" C/N ratio of a litter, below which a net N mineralization takes place, lower the higher the decomposition rate. For a litter of low initial N concentration a faster decomposition generally also means a greater immobilized amount of N but a shortened immobilization phase. The peak of mineralized N is more marked and comes earlier the lower the C/N ratio and the higher the decomposition rate. Furthermore, in all litter types the C/N ratio becomes narrower and decomposition

proceeds, but the change levels out earlier and on a lower level the higher the decomposition rate. The possible role of these features as regulating factors for N distribution in soil and in secondary succession of forest ecosystems is discussed.

88. **Brackett, L.** 1988. Sustainable old growth. Am. For. (Sept./Oct.):15-16.

This letter from the Board of Directors of the Timber Framers Guild of North America, addressed to "those responsible for the National Forests and Bureau of Land Management timberlands of the United States," offers old-growth management recommendations from another arm of industry. Members of the Timber Framers Guild use old-growth timber in the construction and manufacture of their "goods": building frames, furniture, boats, pattern making, etc. Continued availability of old-growth timber is required for the continuation of these industries.

The authors recommend a scheme for sustaining the yield of old-growth timber. The scheme includes: 1) drastically reducing allowable harvest through rationing; 2) setting aside existing areas for future generations and using selective harvesting to allow maturation of young trees; 3) ending "below cost" sales by leaving harvesting until the timber becomes a valuable commodity; 4) conserving certain species for domestic use, and establishing a policy on export of logs; and 5) giving small and medium sized sawmills, which are most capable of handling selectively logged timber, greater priority in management and decision making. **

89. **Bramryd, T.** 1983. Human impact on the biogeochemical cycling of carbon between terrestrial ecosystems and the atmosphere. Ecol. Bull. 35:301-313.

Increased combustion of fossil fuels and an accelerated exploitation of terrestrial ecosystems have increased the atmospheric CO_2 concentration by over 20 ppm during the last decades. Replacement of virgin forests with intensively managed forests with fertilization, earlier cuttings, etc., in boreal and temperate areas can result in a net release of CO_2 to the atmosphere of up to 123 x 10(6) Tg C. Utilization of logging slash as fuel also in industrialized countries results in a decreased input of organic matter to the soil and thus decreases the pool of long-term accumulated soil organic carbon. Soil probably acts as one of the most significant sinks for organic carbon in terrestrial ecosystems.

Increased exploitation of peatlands may have significant effects on the carbon cycle. Burning of peat as fuel in an increasing number of countries rapidly releases the organic carbon accumulated in the peat layers.

Accumulation of organic carbon in urban ecosystems may be of much more importance than has been realized before. New estimates of pools and man-made fluxes of carbon in these areas are presented.

In addition to accumulation of organic carbon in the oceans, many of the processes in terrestrial ecosystems, like peat accumulation and formation of soil organic matter, act as feedback mechanisms for increased atmospheric CO_2 concentrations.

90. **Brayshaw, T.C.** 1970. The dry forests of southern British Columbia. Syesis 3:17-43.

The dry forest comprises the lower zones of the Montane Forest. It lies in a rainshadow that is most pronounced at low altitudes. The lowest, driest fringe of this forest, bordering the steppe, is a discontinuous, parklike zone dominated by Ponderosa pine (*Pinus ponderosa*) and with a ground cover of plants of the steppe vegetation. At higher altitudes is found a denser Douglas fir (*Pseudotsuga menziesii*) forest where ponderosa pine is a pioneer dominant only, following fire, being succeeded by Douglas fir as the climax stage is approached, if fire does not intervene. The ground cover here is dominated by typical forest species. The altitudinally modified climate, further modified locally by aspect, determines the limits of vegetation zones within which soil textural differences determine zonal associations, and topography determines azonal associations. Subassociations, bearing secondary successional relationships to the associations, are determined by historical events

superimposed on the natural environment. The influences of fire and grazing livestock on vegetation are to some extent complementary—fire favouring grassy, and grazing favouring woody vegetation components. The adaptations of ponderosa pine, the most important tree species, to its environment are discussed and its growth in various associations compared.

91. **British Columbia Ministry of Environment.** 1977. Wildlife resources of the Northeast Coal study area, 1976-1977. Resource Anal. Br., Anal./Interpret. Div., Victoria, BC. 58 p.

The objectives of the wildlife study were to collect historical data on the resource; to review existing information; to conduct an inventory of wildlife resources; to evaluate the impacts of coal development; to recommend ways of minimizing impacts; and to attempt an assessment of the values associated with the resource. Studies were focused on the "core area" of proposed coal development, which encompasses 4,300 square miles of extremely varied terrain, including parts of the Rocky Mountain Trench, the Rocky Mountains and foothills, and the Alberta Plateau Benchlands and Plains. (From the introduction)

92. **British Columbia Ministry of Forests.** 1989. Managing wilderness in provincial forests: a policy framework, December, 1989. Integrated Resources Br., Recreation Sect., Victoria, BC. 22 p.

The purpose of this document is to establish current Forest Service wilderness policy. Forest Service policy is set out in terms of a comprehensive policy framework as well as providing policy direction on a number of specific issues. This document is based on the discussion paper Managing Wilderness in Provincial Forests: a Proposed Policy Framework (1988) and the comments and responses generated by the public review of that discussion paper.

93. ————————. 1990. B.C. Forest Service assessment of land use for the Carmanah Valley. Integrated Resource Branch, Victoria, BC.

This report summarizes the technical background of the Carmanah Valley. It includes a brief history of the management process between MacMillan Bloedel Ltd. and the Ministry of Forests, M&B's management plan, and a summary of comments and opinions from the public. The major issues discussed are the protection of the Sitka spruce stands, provision of opportunities for sustainable harvest, provision for recreation, and management for wildlife. Aware of the consensus of opinion regarding protection of the spruce stand as well as the risks which uncontrolled harvesting directly adjacent to the stand would have on the long-term survival of the stand, the Ministry settled on a compromise whereby the lower half of the valley which includes the stand of Sitka spruce along the creek would be preserved and the upper half of the Valley would be available for harvesting (providing that this harvesting did not adversely affect the protection of the spruce stand). The division of the responsibility and further action for the preservation of the area is specified for both the Ministry and MacMillan Bloedel Ltd. (This report is accompanied by the News Release following the Ministry's decision, and a number of maps and color photographs of the area.) **

94. **Brockie, R.E., L.L. Loope, M.B. Usher,** and **O. Hamann.** 1988. Biological invasions of island nature reserves. Biol. Conserv. 44:9-36.

The effects of invading plants and animals on six island reserves, and measures taken to control them, are reviewed as case studies. On many European and North American island reserves the effects of invading plants and animals are negligible, or at least manageable. Tropical and southern oceanic islands are vulnerable to invaders of continental origin for many reasons, often with disastrous consequences to the native biota. Severity of island invasion increases, in general, with increasing isolation from continents. Successful and unsuccessful control measures on several island reserves are reviewed and prospects for managing these reserves evaluated. With limited resources to finance such active management strategies, long-range plans must be carefully developed and supported by research and monitoring to rank problems in order of severity and tractability so as to ensure that realistic conservation goals can be achieved.

95. **Brooke, R.C., E.B. Peterson,** and **V.J. Krajina.** 1970. The subalpine mountain hemlock zone. Ecol. West. N. Am. 2(2):153-349.

This volume describes, in detail, the Subalpine Mountain Hemlock Zone. The main sections of this monograph are devoted to: 1) a regional description of the zone; 2) subalpine microclimates and climate; 3) subalpine soils; and 4) the influences of vegetation on environment. All these topics are considered within the conceptual framework of the ecosystem. An appendix provides a list of plant species and environment and vegetation tables for this zone. **

96. **Brown, A.H. D., M.T. Clegg, A.L. Kahler,** and **B.S. Weir.** 1989. Plant population genetics, breeding, and genetic resources. Sinauer Assoc. Inc., Sunderland, MA. 449 p.

A collection of papers from the International Symposium on Population Genetics and Germplasm Resources in Crop Improvement, held August 11-12, 1988, at the University of California. The topics covered include genetic diversity, evolutionary processes, and applications in plant breeding and genetic resources. **

97. **Brown, E.R.** (technical editor). 1985. Management of wildlife and fish habitats in forests of Western Oregon and Washington: Part 1 - chapter narratives. U.S. Dep. Agric. For. Serv., Pac. NW Reg. and U.S. Dep. of Int. Bur. Land Manage., Portland, OR. Publ. No. R6-F&WL-192-1985. 332 p.

The chapters presented in this report follow the same sequence as that of Thomas (1979). The first chapters describe the relationship between wildlife habitat and the variety of plant communities and stand conditions. Specific habitat types such as riparian areas, freshwater wetlands, estuaries, snags, woody debris, caves, cliffs, and talus are discussed in individual chapters. Some high profile wildlife species—salmonids, deer and elk, northern spotted owls and bald eagles—are also discussed under separate chapters. This work is background to the recommendations made in the chapter, "Silvicultural Options", in which the concepts and principles of using silvicultural activities to protect or enhance wildlife habitat are discussed. These principles are illustrated using one type of plant community under one intensive timber management system. Five silvicultural variables are discussed here: stand conditions, size of area, scheduling of treatments, arrangement of stands, and topography. Relationship of these variables to featured species and diversity management is also discussed. The final chapter, "Impacts on Wood Production", describes two methods for evaluating the costs of timber/wildlife trade-offs. **

98. **Brown, T.C.** 1982. Monetary valuation of timber, forage, and water yields from Public Forest Lands. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn. Ogden, UT. Gen. Tech. Rep. RM-95. 26 p.

This paper describes methods for deriving monetary values for three market products of the forest: timber, forage, and water. Elements of the theory are reviewed and applied to actual forest conditions in central Arizona using available data. The paper should aid analysts with microeconomics training in understanding economic studies of resource values and in conducting valuations during the public land management planning process.

99. **Brownlee, M.J., B.G. Shepherd,** and **D.R. Bustard.** 1988. Some effects of forest harvesting on water quality in the Slim Creek watershed in the central interior of British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1613. 41 p.

The effects of forest harvesting practices on water quality were examined within a watershed 80 km east of Prince George in the central interior of British Columbia between 1971 and 1975. Suspended sediment loading in the study stream, Centennial Creek, increased 4 to 12 times over corresponding levels in an adjacent control stream. Mainline road development was the main source of increased levels of sediment which persisted for the duration of the three years of study. At associated tributaries, erosion from skid trails,

landings, road crossings and streambank damage occurred during and after logging, but in contrast, it did not persist beyond the first summer after logging. Mean water temperatures increased 1 to 3°C following logging to the edge of small tributary streams. Diurnal fluctuations more than doubled. Although maximum water temperatures in these small streams increased up to 9°C they remained within tolerance levels for salmonids. When instream nutrients were at high levels, logged areas had 1-2 times the orthophosphate concentrations, 2-3 times the total phosphate concentrations, and up to 5 times the nitrate concentrations present in the unlogged watershed.

The implications of this study's results to forest harvesting operations in the interior of British Columbia are discussed.

100. **Brubaker, L.B.** 1980. Spatial patterns of tree growth anomalies in the Pacific Northwest. Ecology 61(4):798-807.

Regional patterns of ring width anomalies in Washington, Oregon, and Idaho, USA, forests are examined using eigenvector (principal component) techniques. The first two eigenvectors, accounting for nearly 50% of the total variance, represent large-scale spatial patterns. Eigenvector I represents a pattern in which growth anomalies are positively correlated among all sites, and Eigenvector II one in which growth anomalies are negatively correlated between sites located on opposite sides of the Cascade Mountains crest.

These patterns most likely result from two types of tree growth responses to climate variations that extend uniformly across the study area. Common responses to spring-summer rainfall probably cause the positive, region-wide correlations identified by Eigenvector I, and opposite east-west responses to summer temperature and winter precipitation may account for the negative correlations identified by Eigenvector II. No evidence supports the idea that the tree growth eigenvectors directly reflect two distinctive patterns of climate anomalies.

The spatial patterns of these tree growth anomalies have remained essentially constant during the past 300 (possibly 400) yr.

101. **Bryant, M.D.** 1980. Evolution of large organic debris after timber harvest: Maybeso Creek, 1949-1978. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-101.

The Maybeso Creek valley was logged from 1953 to 1960. Stream maps showing large accumulations of debris and stream channel features were made in 1949 and updated to 1960. The objectives of this paper are to document the effects of natural and logging debris on channel morphometry and to examine the fate of logging debris during and after logging. Map sections from 1949 through 1963 are examined and compared with a ground survey in 1978 of debris accumulations.

Natural conditions before logging revealed sparse accumulations of large debris scattered throughout the stream; these accumulations increased in number and density during logging. Natural material appeared to be well controlled and stable; whereas, logging debris was floatable. Year-to-year changes in accumulations were noted throughout the period of logging from 1953 to 1969. Fewer accumulations were observed in 1978 than in 1949, before the start of logging. Further studies are needed to quantify physical changes and to relate these changes to salmon habitat.

102. ————. 1983. The role and management of woody debris in west coast salmonid nursery streams. N. Am. J. Fish. Manage. 3:322-330.

Debris removal is a frequently used management technique for small streams in logged watersheds, but many stream-cleaning techniques overlook important habitat requirements of juvenile salmonids. Reviews of some past management practices show little systematic evaluation or monitoring of physical or biological effects. A review of several studies (most

of them not associated with debris removal) shows the importance of woody debris as salmonid habitat. The role of organic debris in a small stream system is discussed and a set of criteria for debris removal is proposed.

103. ——————. 1985. Changes 30 years after logging in large woody debris, and its use by salmonids. *In* Proc. 1st N. Am. Riparian Conf. on Riparian Ecosystems and Their Management: Reconciling Conflicting Uses, Tuscon, AZ. R.R. Johnson *et al.* (editors). U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-120.

Changes in large woody debris in fourth- and fifth-order salmon streams with logged, unlogged, and partially logged riparian zones are documented from maps for 1949 to 1960 and from field surveys done in 1983 and 1984. Over the 30-year period, most changes in the amount of large woody debris occurred in the logged systems. During and immediately after logging large increases were noted, but in 1984 the amount of large woody debris in the logged systems was less than that observed before logging in most categories. Amounts of large woody debris in the other streams remained relatively stable. Thirty years after logging, habitat formed as a result of large debris provides important rearing areas for juvenile salmonids. Results from this study emphasize the importance of managing riparian zones as a source of large organic debris.

104. **Buchanan, J.B., R.W. Lundquist,** and **K.B. Aubry.** 1990. Winter populations of Douglas' squirrels in different-aged Douglas-fir forests. J. Wildl. Manage. 54(4):577-581.

We counted Douglas' squirrels (*Tamiasciurus douglasii*) along established transects in naturally regenerated old-growth and younger Douglas-fir (*Pseudotsuga menziesii*) forests in the Cascade Range of southern Washington State during 3 consecutive winters beginning in 1983-84. Squirrel populations were generally higher in old-growth forests and varied dramatically from year to year in synchrony with variations in the annual production of conifer cones. Old-growth forests appear to provide higher-quality habitat for Douglas' squirrels than younger forests due to greater and more reliable quantities of conifer seeds. Converting old-growth Douglas-fir forests to even-aged plantations of younger Douglas-fir would probably result in lower Douglas' squirrel populations. Alternative silvicultural strategies designed to provide increased levels of cone production over time may be an effective means of improving the habitat quality of young forests for Douglas' squirrels.

105. **Bunnell, F.L.** 1990a. Biodiversity: what, where, why, and how. *Paper presented at* Wildlife Forestry Symp. and Workshop, March 6-8, 1990, Prince George, BC. 22 p.

Subspecies are convenient units for assessing biodiversity because they are recognizable and represent real genetic diversity. Species are less controversial, and at the species level Canada contains high diversity for a north temperate nation. Larger species (1 kg) are better represented in Canada than elsewhere and most of the wildlife are forest-dwelling (60% of the breeding birds and 76% of the terrestrial mammals). Many of the species use cavities in trees to breed (52 birds and 28 mammals) and a large portion require mature or old-growth forests. Because of its diverse topography and vegetation, British Columbia contains the richest wildlife diversity in Canada, 70 and 72% of the nation's native breeding birds and terrestrial mammals, respectively. Eight major reasons for maintaining wildlife diversity are reviewed, as are the three approaches that will permit maintenance of wildlife diversity in forested ecosystems: 1) integrated management in individual stands; 2) allocation of silvicultural and harvesting practices through time and space; and 3) preserving areas free of forestry practices. Integrated forestry-wildlife management has produced success stories and will help maintain many wildlife species. The theory addressing size and shape of preserves provides guidelines but is not universal and has inherent uncertainties. Impacts on wildlife of the allocation of forestry practices through time and space are poorly understood, but we are defining the problem more clearly.

106. ——————. 1990b. Wild vs. managed forests: forestry wildlife: w(h)ither the future? *In* Proc. Conf. on Forests - Wild and Managed: Differences and Consequences. A. Pearson and D.A. Challenger (editors). Jan. 19-20, 1990, Univ. B.C., Vancouver, BC. Univ. B.C., Fac. For., Students for Forestry Awareness, Vancouver, BC, pp. 163-176.

The diverse topography and vegetation of the Pacific Northwest houses a great diversity of terrestrial wildlife species—generally greater than 400 species, with B.C. showing greater diversity than Washington or Oregon. A large portion of these species reside in forests. In Washington and Oregon the proportion is 26 to 30%, differing east and west of the Cascades; in B.C. it is about 50%. The portion of these forest-dwellers reproducing in old growth ranges from about 45% in Washington and Oregon to about 85% for mammals on Vancouver Island. The portions reproducing in grass-forb or shrub-seedling stages decrease from 45% east of the Cascades in Oregon, to about 35% west of the Cascades in Washington and Oregon, and to about 11% for mammals on Vancouver Island. Some species do better in deciduous or mixed conifer-deciduous forests. The areal extent and duration of all broad habitats—old-growth, early seral, and deciduous—will be reduced by intensive forest management.

Options exist for creating or maintaining most of these habitats while still harvesting timber. Of these habitats, old growth is the most difficult because it is impossible to create quickly. Those species preferring old growth do so for three reasons: heterogeneity, large "piece size", or age (e.g., rot, substrate for arboreal lichens). The first two attributes can be created in managed forests by appropriate silviculture. The approach is easier in forest types encouraging uneven-aged management, but appears possible even in coastal Douglas-fir. Two broad tactics appear necessary to maintain wildlife diversity: habitat preservation where the habitat cannot be readily created and innovative forestry over larger areas.

107. **Bunnell, F.L.** and **A. Allaye-Chan.** 1984. Potential of winter-range reserves for ungulates as habitat for cavity-nesting birds. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T. A. Hanley (editors). April 12-15, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 357-365.

Two old-growth stands reserved as winter-range for ungulates, one old-growth riparian forest, and one second-growth forest in the same community were sampled for snag density. Height, dbh, limb, twig and top condition, percentage bark loss, and species were recorded. Total snag density did not differ significantly between old- and second-growth, and ranged from 33.9 to 117/ha. Snags with cavities (active) were less abundant in second-growth (0.4/ha compared to 2.2 to 14.8/ha). In old-growth, active snags had significantly greater dbh and height than inactive snags ($P \leq 0.05$); second-growth snags had smaller dimensions than inactive old-growth snags ($P \leq 0.01$) and only 1.3% were active. Cavities of different sizes generally occurred in snags of different sizes ($P \leq 0.05$). Proposed forestry practices would greatly reduce the ability of forests to provide cavity sites. Minimum dimensions were demonstrated to be inadequate as snag retention guidelines. Old-growth winter-range reserves provided suitable habitat for cavity-nesters.

108. **Bunnell, F.L.** and **D.S. Eastman**. 1976. Effects of forest management practices on wildlife in the forests of British Columbia. *In* Proc. of Div., XVIth IUFRO World Congress. Oslo, Norway. Norwegian IUFRO Congress Committee, Norway, pp. 631-689.

In British Columbia, a wide variety of mammals, birds, amphibians and fish are directly or indirectly influenced by the nature of the forest cover present. The diversity of forestry types and wildlife precludes specific analysis of the influence of each forestry management practice on each wildlife species. Acknowledging this diversity, a general model of the changes in major resources required by any wildlife species following complete removal of the tree over-story is presented. The resources considered are energy, nutrients, water, temporary shelter, habitation, escape cover and space. The general model is evaluated for specific resources required by selected species and its applicability and limitations are documented. Because it presents a general pattern resulting from autogenic, secondary succession, the model can be used as a framework to examine influences of particular forest management practices on relating scattered observations on many wildlife species in many forest types and offers a vehicle for extrapolating generalities to areas that have not been studied extensively. It thus provides a forest manager with a convenient device for evaluating the potential impacts of proposed management practices.

109. **Bunnell, F.L., R. Ellis,** and **S. Stevenson.** 1978. Evaluating ungulate populations and range in British Columbia. Trans. N. Am. Wildl. Nat. Resour. Conf. 43:311-322.

This paper presents an approach for evaluating ungulate populations and their range in British Columbia. It provides an overview as well as case histories. Focus of this discussion is given to the decision-making process related to acquisition of information on ungulate populations and range. Flowcharts illustrate 1) the relationships of a manager's acquisition of information to the overall management system and 2) questions addressed and investments made when ungulates and their range are evaluated. **

110. **Bunnell, F.L.** and **G.W. Jones.** 1984. Black-tailed deer and old-growth forests: a synthesis. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 411-420.

In regions of high snowfall in the Pacific Northwest old-growth forests provide better winter habitat for black-tailed deer (*Odocoileus hemionus columbianus* and *O.h. sitkensis*) than do immature stands. The value of old growth to deer increases with the frequency of deep snowfalls. In more northerly areas, abundance of important winter browse species in immature stages is only 5-55 percent of that in old-growth stands. Nutrient contents are generally about 10 percent lower in immature stages, and highly digestible arboreal lichens are absent. When deer have access to both clearcuts and old growth they maintain a daily intake of digestible energy of about 1.6 BMR, even in severe winters. When snow conditions restrict deer to old-growth forest, energy intake falls to 1.4 BMR, but would approximate 0.0 for deer in clearcuts under deep snow. Heterogeneous old-growth canopies intercept significant snowfall and increase snow density, thereby reducing costs of deer movement significantly while still permitting abundant understory vegetation. Thus, energy input is sustained while energy costs are reduced. These relationships are examined in a simple model, and management guidelines are offered.

111. **Bunnell, F.L.** and **D.R. Klein.** 1984. Relationships between deer and old-growth forests on Vancouver Island: case study. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 385-390.

In the mountainous interior of Vancouver Island, British Columbia, snow was the greatest single factor influencing habitat selection by black-tailed deer in winter. The tree canopy of old-growth forests intercepted falling snow, and consequently snow was much shallower than in adjacent logged habitats. The deep, soft snow in cut-over areas prevented deer movement and restricted deer to old-growth winter ranges during a severe winter. Deer were more widely distributed in a mild winter having less snow. The severe winter restricted diets, worsened the condition of the deer, caused mortality, reduced juvenile recruitment, and reduced production of fawns the following summer. Identification of the necessity of old growth as winter habitat resulted in efforts to protect important winter ranges from logging watersheds having periodic severe winters.

112. **Bunnell, F.L.** and **L.L. Kremsater.** 1990. Sustaining wildlife in managed forests. N.W. Environ. J. 6(2):243-270.

For decades, foresters in North America have been grappling with the issue of maintaining wildlife while practicing forestry. This paper examines broad principles and patterns relevant to sustaining wildlife in the forests of the Pacific Northwest. In this review the authors distinguish between silvicultural practices applied to single stands. They note the special features of the Pacific Northwest, then present a simplified approach for defining the problems. Finally they address sustainability of forest-dwelling wildlife at the level of stands and larger management areas, concentrating on species associated with old growth because their habitat is the most difficult to re-create. The authors suggest the practical approach of selecting reserves, then managing a long-rotation buffer zone around them. Maintaining corridors of habitats, particularly around riparian areas, also will increase effective patch sizes and allow for movement of animals and some genetic mixing. For preservation of many species, firm control of access around reserves will be necessary. The major task is to learn how to distribute management practices through space and time.

113. **Bunnell, F.L., R.S. McNay, and C.C. Shank.** 1985. Trees and snow: the deposition of snow on the ground: a review and quantitative synthesis. B.C. Min. Environ. and Min. For., Victoria, BC. IWIFR-17. 440 p.

A thorough review of the effects of forest cover on the distribution and deposition of snow on the ground. The review is process-oriented, and focuses on snow fall and snow deposition in the coastal Pacific Northwest. The report is divided into 2 sections: processes affecting delivery of snow to a surface, and those affecting the manner in which forests modify snow deposition on the ground. A summary chapter summarizes the implications on wildlife, derived from the literature review. **

114. **Bureau of Governmental Research and Service**, Univ. Oreg. 1982. Old growth forests. A balanced perspective. Proc. Conf. Feb. 12-14, 1982, Eugene, OR. Eugene, OR. 147 p.

The objectives of this conference, sponsored by the League of Women Voters of Central Lane County and the Bureau of Governmental Research and Service, University of Oregon, were: 1) to educate interested public and land managers; 2) to provide a forum for transfer of current scientific knowledge; 3) to provide a comparative study; 4) to elucidate status of wildlife populations; and 5) to improve relations between polarized groups by providing the opportunity for dialogue. Papers are presented on the ecological (J. F. Franklin), sociological (R. P. Gale), management (J. Sirmon), and economic (D. Cox and R. O'Toole) aspects of old-growth forests, with particular reference to the Pacific Northwest. **

115. **Bury, R.B.** 1988. Habitat relationships and ecological importance of amphibians and reptiles. *In* Streamside management: riparian wildlife and forestry interactions. K.J. Raedeke (editor). Univ. Wash., Seattle, WA. Contrib. No. 59, pp. 61-76.

Amphibians and reptiles are often abundant in aquatic and streamside zones in the Pacific Northwest, and most have distinct habitat preferences. Stream size determines the characteristics of the adjacent riparian zone and associated wildlife. Along small headwaters the herpetofauna consists primarily of amphibians; as creeks and streams become larger, both amphibians and reptiles occur, with reptiles being found mostly along rivers. Many amphibians and reptiles use the riparian zone for cover and breeding habitat. The riparian zone along smaller streams is functionally an extension of the aquatic habitat and adjacent streambank. Eight to 12 species found along small streams include about 30 to 60 percent of the herpetofauna. Along larger streams and rivers, there is riverine habitat consisting of gravel bars (or beaches) and streamside plant communities, but we know little about the associated herpetofauna. The ecological significance of the riparian and riverine herpetofaunas in the Pacific Northwest is due to high population densities attained by several species. Moreover, in headwater reaches, amphibians can be the dominant vertebrate predators. These riparian and riverine species occur in limited stretches of habitat that are sensitive to perturbations.

116. **Bury, R.B.** and **P.S. Corn.** 1988. Douglas-fir forests in the Oregon and Washington Cascades: Relation of the herpetofauna to stand age and moisture. *In* Proc. Symp. on Management of Amphibians, Reptiles and Small Mammals in North America. R.C. Szaro, K.E. Severson, and D.R. Patton (technical coordinators). July 19-21, 1988, Flagstaff, AZ. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-166, pp. 11-22.

Pitfall traps effectively sampled amphibians but not reptiles in Douglas-fir (*Pseudotsuga menziesii*) forests. The abundance of only one amphibian species varied across an age gradient or a moisture gradient. Salamanders and frogs that breed in ponds or streams were captured in large numbers in some stands, likely due to the presence of nearby breeding habitat rather than forest conditions. Lizards occurred mostly in dry stands and clearcuts. Time-constrained searches showed different use of downed woody debris among terrestrial salamanders. The occurrence and abundance of species in naturally regenerated forests markedly differed from clearcut stands.

117. **Byers, H.R.** 1953. Coast redwoods and fog drip. Ecology 34(1):192-193.

The author debates the role that fog drip plays in providing moisture to redwood groves along the California coast. Those spending a great deal of time in these forests find it difficult to recall examples of fog drip in the better redwood stands in the summer. This is supported by meteorological data. The effect of the so-called fog-belt is attributed to factors other than fog drip. These factors are associated with decreased evapotranspiration and include: 1) reduction of the number of hours of sunshine and 2) reduction of daytime temperature. Dew plays a more important role than fog drip in the provision of moisture to redwoods in valley locations in the summer, as redwoods are seldom found at higher elevations exposed to fog. **

118. **Campbell, R.E., M.B. Baker,** and **P.F. Ffolliott.** 1977. Wildfire effects on a ponderosa pine ecosystem: an Arizona case study. U.S. Dep. Agric. For. Serv., Fort Collins, CO. Res. Paper RM-191. 12 p.

A wildfire of variable severity swept through 717 acres (290 ha) of ponderosa pine forest in north-central Arizona in May 1972. Where the fire was intense it killed 90% of the small trees and 50% of the sawtimber, burned 2.6 in (6.5 cm) of forest floor to the mineral soil, and induced a water-repellent layer in the sandier soils. The reduced infiltration rates, which greatly increased water yield from severely burned areas during unusually heavy fall rains, caused soils to erode and removed some nutrients which had been mineralized by the fire. Water yields have declined each year toward prefire levels. Soluble nutrients leached into the surface soil during fall rains were subsequently removed by a record snowmelt. Successional changes provided up to 1,650 lb/acre (1,850 kg/ha) of herbage production compared to about 515 lb/acre (577 kg/ha) in unburned forest.

119. **Campbell, R.K.** 1979. Genecology of Douglas-fir in a watershed in the Oregon Cascades. Ecology 60(5):1036-1050.

To gain insight into genetic microstructure of subregional populations of coastal Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco var. *menziesii*), genetic variability in a population found on a 6100 ha, central Oregon watershed is described. Genotypic values of 193 parent trees located throughout the watershed were estimated from progeny grown in a common garden. Then, genetic variation was partitioned into components attributable to parent-tree location and to differences among trees within locations. Within-location variation appeared to be homogeneous in the watershed; between-location variation was related to topography, but the patterns of trait variation differed depending on the trait measure. Growth traits exhibited strong gradients with elevation, but the relationship varied depending on position within the watershed. Based on estimates of proportions of nonadapted seedlings in hypothetical transfers of seed from one part of the watershed to another, genetic

differentiation within the watershed was surprisingly large. In one transfer of 3.5 km between north- and south-facing slopes at the same elevation, ≅ 80% of seedlings were estimated to be poorly adapted.

Although other possibillities exist, the topoclinal variation in traits probably results from selection as does the large within-location variation. Both kinds of variation are due to high selection intensities in the seedling stage, the former to selection by average environmental differences along gradients, the latter to microenvironmental heterogeneity. The combination of high within- and between-habitat variation is suited to a species which episodically colonizes an environment that is extremely heterogeneous in time and space.

120. **Canham, C.D., J.S. Denslow, W.J. Platt, J.R. Runkle, T.A. Spies,** and **P.S. White.** 1990. Light regimes beneath closed canopies and tree-fall gaps in temperate and tropical forests. Can. J. For. Res. 20:620-631.

Light regimes beneath closed canopies and tree-fall gaps are compared for five temperate and tropical forests using fish-eye photography of intact forest canopies and a model for calculating light penetration through idealized gaps. Beneath intact canopies, analyses of canopy photographs indicate that sunflecks potentially contribute 37-68% of seasonal total photosynthetically active radiation. In all of the forests, potential sunfleck duration is brief (4-6 min), but the frequency distributions of potential sunfleck duration vary because of differences in canopy geometry and recent disturbance history. Analysis of the photographs reveals that incidence angles for photosynthetically active radiation beneath closed canopies are not generally vertical for any of the forests, but there was considerable variation both among and within sites in the contribution of overhead versus low-angle lighting. Calculations of light penetration through idealized single-tree gaps in old growth Douglas-fir - hemlock forests indicate that such gaps have little effect on understory light regimes because of the high ratio of canopy height to gap diameter. However, single-tree gaps in the other four forest types produce significant overall increases in understory light levels. There is also significant spatial variation in seasonal total radiation in and around single-tree gaps. Our results demonstrate that there can be significant penetration of light into the understory adjacent to a gap, particularly at high latitudes. As gap size increases, both the mean and the range of light levels within the gap increases, but even in large gaps (ca. 1000 m^2) the potential duration of direct sunlight is generally brief (4 h). The major differences in gap light regimes of the five forests are largely a function of canopy height and latitude. The effects of latitude should also result in differences in gap light regimes across the geographic range of individual forest types.

121. **Carey, A.B.** 1983. A critical look at the issue of species-habitat dependency. *In* New Forests for a Changing World: Proc. 1983 SAF National Conven. K.A. Sabol (editor). Oct. 16-20, 1983, Portland, OR. Soc. Am. For., Bethesda, MD. SAF Publ. 84-03, pp. 28-33.

Federal regulations require forest managers to maintain viable populations of all species of wildlife that occur on National Forests. Managers must be able to determine the minimum biological requirements of species that may be jeopardized by multiple-use forest management. But attempts to determine minimum requirements can result in oversimplification of a species' ecology and failure to meet regulations. Thus there is a need for a concept of dependency that consists of a set of procedures that will aid managers in determining minimum requirements. The concepts must include several basic ecological concepts: ecotype, metapopulation, viable population, carrying capacity, niche and habitat. The effects of season, variation among years, and random events on the species and its environment must be considered. A newly emerging discipline, landscape ecology, can provide a framework for applying a concept of dependency to forest management. The subject of this paper is the dependency of wildlife on various types of environments. As with the concepts of diversity and variable populations, dependency is arising as a management concept through attempts by wildlife managers to integrate ecological concepts and regulations into management principles. A working concept of dependency has yet to be formulated. I will discuss dependency under the heading of regulations and ecological concepts. Much of my discussion is toward research on and management of old-growth Douglas-fir forests in National Forests in the Pacific Northwest.

122. ——————. 1989. Wildlife associated with old-growth forests in the Pacific Northwest. Nat. Areas J. 9(3):151-162.

Old-growth Douglas-fir forests provide habitat for many species. Prior to 1982, information on which species might actually depend on old growth for their continued existence in the Douglas-fir forests of western Washington and Oregon was lacking. The U.S. Forest Service instituted a program of studies of amphibian, bird, and mammal communities in young (around 50 years old), mature (around 100 years old), and old-growth (more than 200 years old) forests in the southern Washington Cascades, the Western Cascades of Oregon, and the Oregon Coast Ranges. I conclude that the Olympic salamander, the Oregon slender salamander, the spotted owl, Vaux's swift, and Myotis bats depend on old growth. Cavity-nesting birds, conifer seed-eating birds, stream-dwelling amphibians, and the northern flying squirrel are closely associated with old growth. The need for research on the stream-dwelling amphibians, bats and red tree voles is urgent.

123. **Carey, A.B., J.A. Reid,** and **S.P. Horton.** 1990. Spotted owl home range and habitat use in southern Oregon coast ranges. J. Wildl. Manage. 54(1):11-17.

We radiotracked 9 adult spotted owls (*Strix occidentalis*) in the southern Oregon Coast Ranges for 6-12 months. Owls selected home ranges that emphasized old growth within the landscape. Minimum convex polygon home ranges of 4 pairs were 1,153-3,945 ha and contained 726-1,062 ha of old growth. The percentages of the home ranges in old growth were 25-73%. Home-range size expanded significantly ($P<0.05$) with decreasing proportions of old growth ($r = 0.83$). The amount of old growth in the pair home ranges was less variable than was home-range size. Old growth was selected by the owls for foraging and roosting ($P<0.05$); clearcuts and other nonforested areas were not used. Early to middle stages of forest development were used either less than or in proportion to their availability within the home ranges, even where old growth was scarce.

124. **Carleton, T.J.** 1982. The pattern of invasion and establishment of *Picea mariana* (Mill.) BSP. into the subcanopy layers of *Pinus banksiana* Lamb. dominated stands. Can. J. For. Res. 12:973-984.

Stand age-structure analysis is used to determine whether establishment of *Picea mariana* (Mill.) BSP. in the subcanopy of *Pinus banksiana* Lamb. dominated stands takes the form of a gradual influx or a sudden event. Twenty-six *P. banksiana* dominated stands were investigated of which 15 contained *P. mariana* trees at moderate to high densities. Postfire ages ranged from 46 years to 132 years for the oldest *P. banksiana* cohort in each stand. The 26 stands were subjectively assigned to one of seven groups on the criterion of age-structure histogram appearance. A multivariate test of the hypothesis that such age-structure differences could be due to soil differences was not significant. Three patterns of *P. mariana* influx were indicated: 1) Gradual influx over a long time span in the oldest stands; 2) Contemporaneous postfire reestablishment of both *P. banksiana* and *P. mariana* on a site; and 3) Invasion of *P. mariana* cohorts following surface fire activity as evidenced by fire scar dates. Results from a *P. mariana* seedling survival experiment indicated that depth of burn is of critical importance for black spruce seedling establishment in these stands. However, circumstantial evidence suggests that *P. mariana* seed supply may also be limiting to establishment success. These observations are discussed briefly in relation to models of forest succession.

125. **Caulfield, C.** 1990. Reporter at large (The Ancient Forest). The New Yorker (May 14, 1990):46-84.

This article presents a broad overview of the controversy surrounding what the author calls the Pacific Forest, essentially the coastal forests extending from northern California to southeastern Alaska. Major topics of this article include the ecology of this forest, the history of its exploitation, a description of the current crisis, environmental management policies, a description of the environmental movement's efforts to conserve these forests, legal and political considerations, and the future of the Pacific Forest. **

126. **Chazdon, R.L.** 1988. Sunflecks and their importance to forest understorey plants. Adv. Ecol. Res. 18:1-63.

Sunfleck activity has profound effects on ecological processes ranging from photosynthesis to microsite distributions. Sunflecks occur when predominantly direct-beam radiation passes through openings in the forest canopy. In the forest understorey, sunflecks foster a high degree of spatial and temporal variation in light availability. Sunflecks may contribute more than 50% of the daily photon flux density in the understorey of temperate and tropical forests. Although understorey species are usually able to maintain positive carbon balance in the absence of sunflecks, photosynthesis during sunflecks may account for 30-60% of daily carbon gain.

Photosynthetic responses to sunflecks involve both short-term (dynamic) and longer-term (induction) responses. Following induction, leaves respond more rapidly to sunflecks. Carbon gain and photosynthetic efficiency during sunflecks depend strongly on sunfleck duration. When sunflecks are shorter than 40 s, measured carbon gain is often greater than predicted carbon gain based on steady-state photosynthetic responses. This enhancement of photosynthesis has been attributed to post-illumination CO_2 fixation, which contributes a large proportion of total carbon gain during brief sunflecks, but only a small proportion during longer sunflecks. Under natural conditions, photosynthetic utilization of sunflecks may be hindered by a variety of factors including loss of induction during low-light periods, restricted stomatal opening to conserve water loss, photoinhibition, wilting, and high leaf temperatures. There is no evidence that the photosynthetic characteristics responsible for efficient utilization of sunflecks impose any constraint on efficient utilization of low light. Some evidence does indicate, however, that photosynthetic adaptation to high light limits photosynthetic efficiency during sunflecks.

At light levels below 20% of full sun, light usually limits growth of understorey species. Accordingly, variation in sunfleck activity among understorey microsites has been correlated with differences in plant growth rates, size, sexual reproduction, and vegetative reproduction. The patchy distribution of some understorey species has, in some cases, been linked to microsite differences in light availability. Integrated organismal responses to changing light conditions make it exceedingly difficult to quantify the significance of sunflecks *per se* for growth, survivorship, and reproduction of forest understorey plants.

127. **Cherry, J.** and **R.L. Beschta.** 1989. Coarse woody debris and channel morphology: a flume study. Water Resour. Bull. 25(5):1031-1036.

In recent years, logs and other structures have been added to streams for the purposes of altering channel morphology to improve fish habitat. This flume study was conducted to evaluate the effects of coarse woody debris on local channel morphology. Wooden dowels were used to simulate the effects of individual logs in a stream, and scour depth and surface area were determined at the end of each test run. The maximum scour depth was significantly correlated (90 percent confidence level) with both the vertical orientation of the dowels and the channel opening ratio; the scour surface area was significantly correlated (90 percent confidence level) with both the flow depth and the vertical orientation. Upstream-oriented dowels caused relatively large streambed scour and also deflected flows toward the streambank. Downstream-oriented dowels generally caused less bed scour and appeared to provide better bank protection because flow was generally deflected from the bank. In conjunction with data from field studies, these results provide information on the effects of orientation, hydraulic function, and relative stability of coarse woody debris in streams.

128. **Christensen, N.L.** 1988. Succession and natural disturbance: paradigms, problems, and preservation of natural ecosystems. *In* Ecosystem management for parks and wilderness. J.K. Agee and D.R. Johnson (editors). Univ. Wash. Press, Seattle, WA, pp. 62-86.

The author considers four key questions relating to the preservation of natural ecosystems: What should be preserved? How much should be preserved? In what state should reserves be maintained? How should reserves be maintained? These topics are discussed from a plant ecology viewpoint and in terms of the desire to manage and preserve natural plant communities. The author asserts that these questions are more difficult to answer today because of changes in our understanding of the role of disturbance and succession in determining ecosystem structure and function. A discussion of the classical paradigms of succession is provided, including an examination of how diversity, biomass, production, and nutrient cycling change through succession. The author then describes how this paradigm is being reassessed, paying particular attention to the role of natural disturbance. Finally, the author dicusses how answers to the four questions posed at the outset are influenced by the new understanding of natural disturbance and succession. **

129. **Christy, E.J.** and **R.N. Mack.** 1984. Variation in demography of juvenile *Tsuga heterophylla* across the substratum mosaic. J. Ecol. 72:75-91.

(1) Recruitment and survival of juvenile *Tsuga heterophylla* were followed on different substrata on the west slope of the Cascade Range, central Oregon, U.S.A.

(2) Whilst seeds fell mainly from October to March, some were shed in all but six of thirty-two consecutive months.

(3) Almost all juveniles occurred on decaying logs even though fallen timber may cover only 10-30% of the forest floor.

(4) Recruitment on all substrata varied widely from year to year, as expected in a conifer with most years of seed production.

(5) Cohorts emergent in different months during one calendar year often showed greatly different survivorship curves even on the same rooting substratum.

(6) Mortality was much higher for juveniles during the first 2 yr after emergence than in subsequent years. Microtine rodents probably account for most seed and seedling deaths.

(7) The extent of decay of woody rooting-substrata does not influence percentage emergence, although survival of juveniles was most prolonged on *Pseudotsuga menziesii* logs with rotten heartwood.

(8) The age-class structures of juvenile populations were functions of the fraction of the forest floor covered by fallen wood in each decay class.

130. **Church, J.E.** 1912. The conservation of snow: its dependence on forests and mountains. Sci. Am. Suppl. 74:152-155.

An early classic which has had tremendous impact on U.S. snow studies. The greatest depth of snow occurs in openings to the lee of trees. Gathering quantitative data on this phenomena led Church to develop the Mt. Rose snow sampler in 1908. The sampler is described. Forests "anchor" the snow and protect it from erosion and sun. Interception is proportional to the density and width of the crowns and the closeness of the trees. A forest may be too dense to permit the maximum quantity of falling snow to reach the ground. Data are given illustrating this principle.

Greatest accumulations were found in fir forests containing numerous open glades, intermediate accumulations in the more uniform pine and fir forests, and the least under dense fir stands. Rates of depletion of the snowpack ("snowmelt") were greatest in open meadows, intermediate in the more open forest stands, and least in those most dense. The

now famous statement is presented that the best forest for snow conservation is one which, viewed from above, would resemble a gigantic honeycomb with forest glades being proportioned so that the height of the trees would screen the sun.

131. ———————. 1942. Interception of snow by tree crowns. Report of Committee on Snow, 1941-1942. Trans. Am. Geophy. Union 23:411.

Less snow than rain is intercepted by tree crowns but it remains longer in the crown. Wind is particularly effective in shaking snow down. Insolation causes wet snow to slip off. Only in sunless weather does snow cling for long.

132. **Cline, S.P., A.B. Berg,** and **H.M. Wight.** 1980. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. J. Wildl. Manage. 44(4):773-786.

We studied snags in 30 stands, 5-445 years old, of unmanaged and managed Douglas-fir (*Pseudotsuga menziesii*) in western Oregon to gain information about snag populations and status after logging. As snag production rates (snags/ha/year) declined from about 100 to 1, mean snag density decreased from 190 to 18/ha in age-classes 35 and 200+, respectively; remnant snags (formed in previous stands) represented 5-14% of current densities. Meanwhile, average snag dbh increased from 13 to 72 cm, and as dbh increased, snags stood longer. Douglas-fir was the dominant species among snags in all forest age-classes. Linear regression analysis showed a correlation ($P < 0.001$) between snag age and deterioration; populations consisted of fewer young (sound) and old (highly decayed) than middle-aged (partially decayed) snags. Cluster analysis revealed 5 stages of deterioration based upon snag size and decay condition. In unmanaged stands, most (62%) snag populations were distributed randomly, but patches of snags were found in all age-classes. Fewer snags ($P < 0.001$) remained after thinning and clear-cutting unmanaged forests, and natural snag production was disrupted. Large snags should be retained within forests managed over long (200-year) rotations; in riparian forests; in extensively managed, slow-growing forests; and within intensively managed forests, safety permitting.

133. **Cline, S.P.** and **C.A. Phillips.** 1984. Coarse woody debris and debris-dependent wildlife in logged and natural riparian zone forests—a western Oregon example. *In* Proc. Symp. on Snag Habitat Management, June 7-9, 1983, Flagstaff, AZ. U.S. Dep. Agric., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-99, pp. 33-39.

We conducted a reconnaissance study to determine some structural aspects of riparian zone forests and the effects of logging upon woody debris wildlife habitat. We also conducted a literature search to gather information upon the debris-dependent wildlife in riparian zone forests, and how they are influenced by timber management. This information was synthesized in a hypothetical example of snag management in the Coast Range of Oregon. We found that snag habitat of the larger woodpeckers was reduced by clearcutting and we predicted that shortened rotations in the future will reduce or even locally extirpate 20 bird and 5 mammal species. We calculated that the snag requirements of hole-nesting birds are not met using only snags in riparian zone buffer strips. An active program of dead tree management on upland areas is also necessary.

134. **Cohn, J.P.** 1990. Genetics for wildlife conservation. BioScience 40(3):167-171.

This article underscores the value of genetic studies in understanding the basic biology of wild animals. Genetic work is helping to resolve taxonomic issues, explain reproductive problems, assess the risk of disease epidemics, and suggest conservation strategies. Some examples of recent work are included. **

135. **Cole, D.N.** 1990. Wilderness management: has it come of age? J. Soil Water Conserv. 45(3):360-364.

This article describes the progress to date, or lack of it, in preserving the wilderness system since the inception of the Wilderness Act by the U.S. Forest Service in 1964. Progress in wilderness management is discussed, with specific reference to fire management, programs designed to minimize ecological impacts of recreation, and opportunities for solitude in wilderness. Movement towards better wilderness management is necessary and may need to begin with changes to internal agencies responsible for management. Such changes should include: 1) expanding of research programs; 2) encouragement of careful planning and monitoring; 3) improvement of the qualification of wilderness personnel; and 4) increased accountability by wilderness managers. Wilderness management would also benefit from the following external changes: 1) pressure from the conservation community for better wilderness management; 2) more contributions to wilderness management, particularly by the academic community; and 3) public involvement in debates concerning objectives for wilderness areas. **

136. **Coleman, B.B., W.C. Muenscher,** and **D.R. Charles.** 1956. A distributional study of the epiphytic plants of the Olympic Peninsula Washington. Am. Midl. Nat. 56:54-87.

This study examined the distribution of epiphytic plants of the Olympic Peninsula, Washington. The hosts selected from the 20 stations observed were the dominant trees of the associations found at these stations. Each of the 20 stations varied in biotic and climatic factors, conveying six environment types. On 43 species of hardwoods, conifers, and shrubs, 195 species, varieties, and kinds of epiphytes were observed: 105 lichens, 36 liverworts, 48 mosses, 1 lycopsid, and 5 ferns. The 11 gymnosperms of this study were more receptive to epiphytes than the 32 angiosperms. Some hosts were more receptive to one type of epiphyte than another. Host differences in receptivity to lichens (the only group examined in this context) were due chiefly to climatic factors. The author cites four factors responsible for the presence of a particular epiphyte on a particular host at a given station in this study: 1) the surface conditions of the host; 2) climatic conditions; 3) the presence of at least one suitable host at a given station; and 4) previous opportunity for a particular epiphyte to arrive at a particular station. **

137. **Conner, R.N.** 1979. Minimum standards and forest wildlife management. Wildl. Soc. Bull. 7(4):293-296.

Wildlife scientists have presented minimum standards of selected habitat factors to be provided for wildlife on lands designated for multiple use. However, in some instances, provision of only minimum habitat factors may be biologically unsound and for some species may lead to a gradual decline in abundance. Much of this paper focuses on minimum tree diameter required for cavity-nesting birds. The author uses stabilizing selection theory to show that provision of minimum-sized trees for woodpecker species may be detrimental to nesting success. If forest managers provide only minimum-sized trees, they may be providing a suboptimum habitat. The author recommends that managers provide habitat as close to optimum as possible for each important habitat variable for threatened and endangered species. In managing multiple-use areas for species that are not endangered or threatened, the author suggests that a habitat may be provided in the range between the species' mean and 1 standard deviation below the mean for important habitat factors. **

138. **Connor, E.F.** and **E.D. McCoy.** 1979. The statistics and biology of the species-area relationship. Am. Nat. 113(6):791-833.

The authors discuss the theory of the species-area relationship by examining three basic aspects of the theory. The first point addressed is that of a unique theoretical basis for the species-area relationship. Three mechanisms examined here are the hypotheses of habitat diversity, of area, and of sampling method. A positive correlation between species number

and area is virtually always observed, but the mechanism by which this is observed is not quantitatively or qualitatively different. Thus, the authors consider their results to be inconclusive.

Second, the authors ask if there is a best-fit model of the species-area relationship. After analysing 100 species-area curves, they conclude that there is no single best-fit model. They examined only linear models and found that the power function and untransformed models provide good fits most frequently. They suggest continued use of these types of models because they can be compared with relative ease and are used extensively now, as they were in the past.

In examining the interpretation of a particular model, the authors found that, in general, published predictions and interpretations related to intercept and slope parameters are not supported by the available evidence. Consequently, they suggest that these parameters be considered simply as fitted constants without any specific biological meaning.

The authors continue with a discussion of the implications of the species-area relationship to conservation practices, addressing the question of conservation of numerous small reserves or single large reserves. They conclude that both strategies can be effective and that the planning of conservation areas include consideration of the particular habitat requirements of the species under study.

Species-area curves are, ultimately, most useful in comparing diversities between taxa, habitats, or geographic regions, and over a range of sample sizes. The models used will have a biological significance only through indirect comparisons of these species-area curves and must be accompanied by *a priori* theoretical bases for predictions. **

139. **Connor, E.J., W.J. Trush,** and **A.W. Knight.** 1988. Effects of logging on pacific giant salamanders: influence of age-class composition and habitat complexity. Bull. Ecol. Soc. Am. 69(suppl):104-105.

Habitat requirements of stream dwelling pacific giant salamanders, *Dicamptodon ensatus*, were studied over a four year period (1982-1986) within three unlogged and four logged watersheds in northwestern California. Densities, standing crops, and age-class compositions of salamanders were measured at 135 sites using a backpack electrofisher. Salamander densities and standing crops were highly correlated with substrate cover and complexity, and were greatly reduced in logged watersheds as a consequence of sedimentation. Densities of year 0+ and 1+ salamanders were up to 20 times higher within stream sections in which older age classes of salamanders and steelhead trout (*Salmo gairdneri*) were absent. Salamanders appeared to reside for only two years as juveniles in logged streams before transforming into adults. However, the presence of six juvenile year classes in the unlogged streams studied suggest that Pacific giant salamanders assume a neotenous life history strategy in these undisturbed habitats.

140. **Conservation International.** 1989. Ecosystem conservation and the strategic vision of Conservation International. Conservation International, Washington, DC. 17 p.

Conservation International (CI) was incorporated in 1987 as a private, non-profit conservation organization whose purpose is "To help sustain biological diversity and the ecosystems and ecological processes that support life on earth." The emphasis of their conservation strategy is on systems, processes, and, ultimately, local capacity building. Initially, CI has established three multi-faceted Ecosystem Programs: 1) the Chimane Ecosystem Program in the Beni Department of north central Bolivia; 2) La Talamanca highlands on the border between Costa Rica and Panama; and 3) the islands and waters of Mexico's Sea of Cortes. Each of these areas is characterized by extraordinary biological and cultural richness, a bond between ecological systems and the human economy, contact of indigenous and modern cultures, and the signs of imminent change. In each of these places, ecosystem conservation is bringing together what was once considered two antithetical

processes, biological conservation and regional economic development. The long range plans of CI are to develop ecosystem programs in Africa and Asia, and eventually to include tundra, prairie, boreal forest, and steppe in worldwide programs. **

141. **Cooley, J.L.** and **J.H. Cooley.** 1984. Natural diversity in forest ecosystems. Proc. of a Workshop. Nov. 29-Dec. 1, 1982, Athens, GA. Inst. Ecol., Univ. Georgia, Athens, GA. 290 p.

This workshop provided a forum for a number of issues associated with the diversity of forest ecosystems. Papers were grouped and presented under the following subject areas: 1) measures of natural diversity in forest ecosystems; 2) forest genetics; 3) forest recreation and cultural resources; 4) forest wildlife; 5) forest range and rangelands; and 6) timber management. **

142. **Cooper, C.F.** 1961. Pattern in ponderosa pine forests. Ecology 42(3):493-499.

Four types of pattern can be identified in the ponderosa pine forests of northern Arizona: (1) differences in density, growth, and species composition, the result of microenvironmental variation; (2) a mosaic pattern of even-aged groups, averaging about 1/5 acre in size and maintained largely by fire; (3) variations in stand density within a single even-aged group, primarily due to chance factors in early stand development; (4) the spacing pattern of individual trees in an even-aged stand.

Trees in young stands are randomly distributed, with a slight tendency toward a uniform distribution as the stands mature. No tendency toward clumping of individuals was detected. Average tree diameter in uniform stands is largely determined by stand density, but little of the variation in tree diameter within a single stand is accounted for by differences in spacing distance among the individual trees in the stand. Even less of the variation is accounted for by the differences in size of neighboring trees.

The clearly identifiable pattern in ponderosa pine forests is the result of the intolerance of the species to shade, the harsh environment which restricts the number of species present, and periodic natural fires that serve as the force that opposes the natural tendency of vegetation to take in a random distribution. (Author's summary)

143. **Corn, P.S.** and **R.B. Bury.** 1989. Logging in western Oregon: responses of headwater habitats and stream amphibians. For. Ecol. Manage. 29:39-57.

We compared occurrence and abundance of four species of aquatic amphibians in 23 streams flowing through uncut forests to 20 streams flowing through forests logged between 14 and 40 years prior to the study. Species richness was highest in streams in uncut forests. Eleven streams in uncut forests contained all four species, and only two of these streams had fewer than three species present. Eleven streams in logged stands had one or no species present, and only one contained all four species. Density and biomass of all four species were significantly greater (2-7x) in streams in uncut forests. Physical comparisons between types of streams were similar, except that streams in logged stands had generally smaller substrata, resulting from increased sedimentation. Densities of Pacific giant salamanders (*Dicamptodon ensatus*) and Olympic salamanders (*Rhyacotriton olympicus*) were positively correlated with stream gradient in logged stands, but not in uncut forests, suggesting that the disruptive effects of increased sedimentation are greatest in low-gradient streams. Tailed frogs (*Ascaphus truei*) and Dunn's salamanders (*Plethodon dunni*) occurred more often in streams in logged stands when uncut timber was present upstream, but neither density nor biomass of any species were related to either presence of uncut timber upstream or years since logging. Logging upstream from uncut forests also had no effect on the presence, density or biomass of any species. Tailed frogs and Olympic salamanders may be extirpated from headwaters traversing clearcuts; these streams should be afforded some protection in plans for managed forests.

144. **Corn, P.S., R.B. Bury, and T.A. Spies.** 1988. Douglas-fir forests in the Cascade Mountains of Oregon and Washington: is the abundance of small mammals related to stand age and moisture? *In* Proc. Symp. on Management of Amphibians, Reptiles, and Small Mammals in North America. R.C. Szaro, K.E. Severson, and D.R. Patton (technical coordinators). July 19-21, 1988, Flagstaff, AZ. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-166, pp. 340-352.

Red tree voles (*Arborimus longicaudus*) were the only small mammal strongly associated with old-growth forests, whereas vagrant shrews (*Sorex vagrans*) were most abundant in young forests. Pacific marsh shrews (*S. bendirii*) were most abundant in wet old-growth forests, but abundance of this species in young (wet) forests needs further study. Clearcuts had a mammalian fauna distinct from young forest stands. Abundance of several species was correlated to habitat features unique to naturally regenerated forests, indicating an urgent need to study the long-term effects of forest management on nongame wildlife.

145. **Corns, I.G.W. and G.H. La Roi.** 1976. A comparison of mature with recently clear-cut and scarified lodgepole pine forests in the Lower Foothills of Alberta. Can. J. For. Res. 6:20-32.

Mature, even-aged lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) forests on upland sites with Orthic Gray Luvisols in the Lower Foothills of Alberta have been clear-cut for pulpwood and scarified by bulldozer since 1958. Undisturbed stands had weak shrub strata, well developed herb - dwarf shrub strata, and continuous feather moss strata.

In 25 clear-cut stands 6-12 years old, the average cover of vascular plants was 54% and did not change significantly during the sampled age interval. Cover of tree "regeneration" (immature size classes) was 5%, increasing slowly, and codominated by lodgepole pine and aspen (*Populus tremuloides* Michx.). Shrub cover was also 5% and dominated by prickly rose (*Rosa acicularis* Linl.). Herb - dwarf shrub cover was 44% and dominated by nine species of the mature forest. Bryoid cover was 13%.

The density of young trees stabilized within 6 years after clear-cutting, and the above-ground biomass of both pine and aspen increased rapidly during the sampled age interval.

An ordination of the clear-cut stands showed that the distribution and abundance of several important plant species were well correlated with soil moisture on two gravimetric sampling dates in summer.

A comparison of dominance-diversity curves and indices for mature and clear-cut stands revealed that the clear-cut community was richer in vascular species (100 cf. 57) and had a more even distribution of cover among species.

The early stages of secondary succession after clear-cutting and scarification of lodgepole pine forest are discussed.

146. **Cross, S.P.** 1988. Riparian systems and small mammals and bats. *In* Streamside management: riparian wildlife and forestry interactions. K.J. Raedeke (editor). Univ. Wash., Seattle, WA. Contrib. No. 59, pp. 93-112.

This paper presents an overview of the knowledge of the importance of riparian zone habitat to small mammals and bats. The author notes that, especially in arid regions, small mammal fauna in riparian zones tend to be different from those found in neighboring upland areas. In general, small mammals are more abundant and their communities are more diverse in riparian areas. There is much less information available for bats, but it is likely that bats are more abundant and their communities are richer and more diverse in riparian zones than in adjacent upland areas. The species of small mammals and bats most commonly found in riparian, open forest and continuous forest habitats are given. Finally, the author identifies some of the areas where more research and information is needed for management purposes. **

147. **Cummins, K.W.** 1974. Structure and function of stream ecosystems. BioScience 24(11):631-641.

This paper identifies some practical and theoretical questions confronting stream ecologists where they examine methods for qualifying and quantifying functional groups involved in stream processes. The authors speculate how process-function investigations have affected the evolution of stream ecosystem theory, and examine the implications of this approach to stream management strategies. Stream ecosystem structure and function are discussed, as is the processing of functional groups and organic matter. Topics addressed include: 1) heterotrophy-autotrophy and import-export of organic matter in streams; 2) primary producers; 3) microconsumers; and 4) macroconsumers. Three general strategies for management to maintain water quality are listed and briefly discussed. **

148. **Cummins, K.W.** and **M.J. Klug**. 1979. Feeding ecology of stream invertebrates. Ann. Rev. Ecol. Syst. 10:147-172.

Classification of functional feeding groups among stream invertebrates provides a useful means for describing the morpho-behavior capacity of stream invertebrates to consume available food resources. It does not define what portion of an ingested food resource is assimilated; this may depend on short- or long-term physiological adaptations.

Invertebrates that are facultative in their morpho-behavioral feeding have a wider niche breadth (i.e. they can ingest a wider array of substrates) and inhabit a greater diversity of stream habitats. Species with cellulase can grow in a wide range of habitats because they are able to utilize a greater array of detritus and algal types.

A variety of feeding strategies are used by stream macroinvertebrates to compensate for the changing dietary sufficiency of ingested substrates. Shredders, and possibly some collectors, feed preferentially on particulate organic detritus colonized by microorganisms, utilizing the associated microorganisms and partially hydrolyzed (microbially digested) substrate. Collectors, scrapers, and facultative shredders increase the consumption of low quality food to compensate for its decreased nutritional benefit.

Animals that eat materials inadequate to support their growth may harbor microbial symbionts that compensate for the dietary deficiency. They are thus analogous to ruminant animals, which take in food of high C:N ratio (>17) and absorb through their gut wall material with a lower C:N ratio (<17) produced by intestinal microbiota that break down polymers and supply essential amino acids. (From authors' conclusion)

149. **Cummins, K.W., M.A. Wilzbach, D.M. Gates, J.B. Perry**, and **W.B. Taliaferro**. 1989. Shredders and riparian vegetation. BioScience 39(1):24-30.

Leaf litter falling into streams influences stream invertebrate communities. Shredders are one functional group of invertebrates that feed off plant litter in freshwater environments. Shredders include a wide range of taxa and one of their major roles is the conversion of leaf litter into smaller particles. These smaller particles; as well as feces produced by shredders, are a significant food source for other stream invertebrates, most notably for the functional group known as collectors. In this paper the authors propose the formation of a conceptual model linking riparian plant communities (and their litter) with stream shredders. A number of topics related to such a model are discussed, including: 1) timing of litter inputs; litter-processing categories; 3) relationships between canopy cover and litter retention; 4) litter-processing rates; 5) shredder response to variables in litter input; and 6) vegetation and climate influences. The model proposed categorizes litter as fast, medium and slow on the basis of how fast it breaks down, and identifies different shredder species as autumn-winter or spring-summer shredders. **

150. **Cundiff, B., C. Wallis, and D. Dodge**. 1990. Vanishing old growth. Borealis 2(2):16-21.

One of the most serious environmental issues confronting us today is our vanishing old-growth forests. Many people do not understand this issue despite the fact that many of today's major environmental conflicts surround old-growth issues. This paper discusses the current situation and importance of old-growth forests in Canada.

Modern forestry practices prescribe that harvesting should occur when tree growth begins to diminish. However, environmentalists and ecologists point out that harvesting of these complex old-growth communities will result in, most importantly, species loss and diminished biological diversity. The survival of hundreds of species of wildlife depends on old-growth forests; some are mentioned in this publication.

The authors emphasize that old-growth communites are dynamic ones, containing not only old, dead, and dying trees but also young trees. As well as providing a diverse array of wildlife habitats, these decadent forests also play a large role in nutrient recycling and produce nutrient-rich soils and clean, clear water. The old-growth situation of Carmanah Valley, British Columbia, is briefly addressed. Some discussion is directed toward strategies and policies designed for old-growth conservation. **

151. **Cunningham, J.B., R.P. Balda,** and **W.S. Gaud**. 1980. Selection and use of snags by secondary cavity-nesting birds of the ponderosa pine forest. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Res. Exp. Stn., Fort Collins, CO. Res. Paper RM-222. 15 p.

One factor limiting the population size of secondary cavity-nesting birds in ponderosa pine is the number of suitable nesting cavities. Snags in the pine forest provide a large number of species with nesting and roosting sites. To maintain secondary cavity nesters at their natural population level, a density of 5.2 snags per ha is recommended for mature ponderosa pine.

152. **Currie, D.J.** and **V. Paquin**. 1987. Large-scale biogeographical patterns of species richness of trees. Nature 329(24):326-327.

Biologists have long recognized the striking geographical variablilty of species richness. A primary goal of contemporary ecology is to identify the factors responsible for this variability. We have examined the spatial distributions of trees in North America to determine which characteristics of the environment are most closely related to the species richness of different regions. Realized annual evapotranspiration, which is correlated with primary production and is therefore a measure of available energy, statistically explains 76% of the variation in species richness. Topography and proximity to the sea are significantly related to the residual variation, whereas seasonal climatic variability and glacial history are not. Tree richness in Great Britain and Ireland can be accurately predicted from these North American patterns. Our data are best explained by the hypothesis that contemporary available energy limits species richness.

153. **Cwynar, L.C.** 1987. Fire and the forest history of the North Cascade Range. Ecology 68(4):791-802.

Postglacial vegetation changes are often ascribed to the direct effects of climate change. I studied pollen, plant macrofossils, and sediment charcoal in order to determine the potential role of changes in the disturbance (fire) regime in the postglacial development of local vegetation at Kirk Lake in the foothills of the North Cascade Range in northwestern Washington. Five pollen assemblage zones are recognized: a *Pinus - Populus* zone 12 000 BP, a *Picea - Alnus sinuata* zone from 12 000 to 11 030 BP, an *Alnus rubra - Pteridium* zone from 11 030 to 6830 BP, a Cupressaceae zone beginning at 6830 BP, and a late Holocene *Pinus - Alnus rubra* zone from 2400 to 900 BP.

The first forests (12 000 BP) were an open mixture of conifers and deciduous trees, chiefly *Tsuga mertensiana, Abies, Pinus contorta,* and *Populus* on a landscape subject to erosion. Just before 12 000 BP, the pioneer species *Picea sitchensis, Alnus rubra,* and *A. sinuata* became important constituents of the forest. Although pollen accumulation rates were high, the abundance of *Alnus sinuata* indicates an open-canopy forest. Beginning ≅ 11 200 BP, climatic warming initiated major changes in forest composition and the fire regime. *Tsuga heterophylla* migrated into the region, rapidly expanded, then declined shortly thereafter, while *Pseudotsuga menziesii, Alnus rubra,* and *Pteridium* expanded, and *Pinus contorta, Picea sitchensis, Populus,* and *Alnus sinuata* declined. The abundance of *Pseudotsuga, Alnus rubra,* and *Pteridium* between 11 030 and 6830 BP corresponds with increased influxes of charcoal into the sediment; this zone is interpreted as a closed forest with a relatively high fire frequency and composed of a mosaic of postfire successional communities in which fire-adapted *Pseudotsuga* and *Alnus rubra* predominated over fire-sensitive *Tsuga heterophylla. Pinus monticola* became locally important ≅ 8000 BP. Between 6800 and 6400 BP *Thuja plicata* arrived, *Tsuga heterophylla* expanded, and *Alnus rubra, Pseudotsuga,* and *Pteridium* declined. These changes are accompanied by a reduced fire frequency, inferred from lower charcoal accumulation rates, and they indicate a shift to wet-temperate climate similar to today's. The late Holocene fossil record shows the development of the adjacent peatland, which *Pinus contorta* eventually invaded.

154. **Dale, V.H., M.A. Hemstrom,** and **J.F. Franklin**. 1984. The effect of disturbance frequency on forest succession in the Pacific Northwest. *In* New Forests for a Changing World: Proc. 1983 SAF National Convention. K.A. Sabol (editor). Oct. 16-20, 1983, Portland, OR. Soc. Am. For., Bethesda, MA. SAF Publ. 84-03, pp. 300-304.

A computer model of forest succession has been adapted for the Pacific Northwest to include fire, windstorms, and clearcut logging. The simulation experiment consists of having each of these disturbances occur at different frequencies to a 500 year old stand on the western Olympic Peninsula. The model is run for 480 years, and leaf area, basal area, diameter distributions and Douglas-fir biomass are compared. Each disturbance results in unique patterns of stand development. The model is a useful tool for examining long-term stand dynamics.

155. ————————. 1986. Modeling the long-term effects of disturbances on forest succession, Olympic Peninsula, Washington. Can. J. For. Res. 16:56-67.

A model of forest development has been adapted for the Pacific Northwest. The regeneration, growth, and death of individual trees are tracked for simulated 0.2 ha plots and tree attributes are aggregated to provide stand measures. The model includes the influence of temperature, soil moisture, light tolerance, and competition on tree growth. Long-term simulations for Douglas-fir dominated forests on the western Olympic Peninsula show that the stand is eventually dominated by western hemlock with silver fir being codominant. Even after 1200 years of subsequent stand development, silver fir fails to replace western hemlock indicating that this is a self-replicating and stable community. Fire, windthrows, insect disturbance, and clear-cut logging followed by replanting are incorporated into the model as single-event disturbances to a 500-year-old forest. For those cases where large Douglas-fir survive the disturbance, stand biomass and leaf area patterns are not significantly impacted until the death of the last large Douglas-fir. The projections were all carried out to the time when the forest is dominated by western hemlock and silver fir. At that time, the differential effect of the earlier disturbance is not apparent from the forest composition, biomass, or leaf area patterns except for the insect disturbance. Following the removal of all Douglas-fir by an insect, leaf area fluctuates regularly with a period of 600 years.

156. **Davis, G.D.** 1984. Natural diversity for future generations: the role of wilderness. *In* Proc. Workshop on Natural Diversity in Forest Ecosystems. J.L. Cooley and J.H. Cooley (editors). Nov. 29-Dec. 1, 1982, Athens, GA. Inst. Ecol., Univ. Georgia, Athens, GA, pp. 141-154.

The National Wilderness Preservation System offers opportunities to protect samples of the nation's basic ecosystems for future scientific, educational, and recreational use. To date, however, only 81 of the nation's 233 ecosystems, as defined by the Bailey-Kuchler method, are represented in the National Wilderness Preservation System. The potential to diversify the system exists within 102 additional ecosystems. No federally owned, undeveloped lands exist within the remaining 50 ecosystems.

157. **Davis, M.B.** 1981. Quaternary history and the stability of forest communities. *In* Forest succession: concepts and application. D.C. West, H.H. Shugart, and D.B. Botkin (editors). Springer-Verlag, New York, NY, pp. 132-153.

A record of geographical distribution of trees, particularly the changes in pollen influx for a given area within eastern North America, is interpreted through the use of pollen analysis. The author describes forest communities at the time of the last glacial maximum, the Wisconsin ice sheet. It is commonly thought that warming climate resulted in a northward migration of boreal trees and temperate deciduous forest. However, maps illustrating migration patterns for individual tree species indicate otherwise. Rates and direction of movement vary greatly among species. Seedling survival potential and the availability of propagules also affects migration patterns. The author concludes that all of the above factors have contributed to the current distribution of tree species and suggests that this evidence demonstrates that forest communities in temperate regions are the result of chance combinations of species, and do not have an evolutionary history. **

158. **Day, J.C.** and **D.B. Gamble.** 1990. Coastal zone management in British Columbia: an institutional comparison with Washington, Oregon, and California. Coastal Manage. 18:115-141.

The basis for coastal zone management in the United States is established in legislation. In comparison, Canadian federal and provincial governments have adopted a piecemeal approach for managing a variety of concerns examined here: water quality, ecological protection, public access, aesthetics, natural hazards, and water dependency. As a result of this approach, which is characterized by a minimum of federal, provincial, and interjurisdictional coordination, the British Columbia coastal zone is showing signs of stress. For example, major shellfish harvesting areas are being lost to water pollution; ecologically sensitive habitats are being consumed by urban, commercial, and industrial expansion; recreation and tourism opportunities are being impaired by clear cutting and other inappropriate developments; and infrastructure is allowed in flood- and erosion-prone areas. Recommendations to improve the approach to coastal management in British Columbia include a variety of innovations. New federal and provincial policies, legislation, institutions, and experimentation with local and regional integrated resource planning are required to better govern the coastal zone. Increased support for existing agencies, public involvement, and access to information as well as more common use of environmental impact studies are needed to justify proposed coastal developments.

159. **Day, J.C.** and **R. Stace-Smith.** 1982. British Columbia land for wildlife: past, present, future. Proc. Conf. Oct. 23-24, 1981, Simon Fraser Univ. B.C. Min. Environ., Fish Wildl. Br., Victoria, BC. 181 p.

This proceedings contains several papers that address the management of British Columbia land for wildlife. Topics include: 1) a global, national, and provincial overview of wildlife habitat, diversity, and land use; 2) government policies and programs directed toward the preservation of wildlife habitat; 3) wildlife habitat management and land use—the race for space; 4) problems involving effects of current land use on wildlife habitat; and 5) strategic wildlife habitat management. **

160. **Day, R.J.** 1972. Stand structure, succession, and use of southern Alberta's Rocky Mountain forest. Ecology 53(3):472-478.

Structural analysis of the subalpine forest in southern Alberta shows that the old-growth *Picea/Abies* forest has succeeded even-aged stands of *Pinus contorta* var. *latifolia* that became established after fire 150-200 or more years ago. Because *P. contorta* regeneration fails beneath its own canopy, an irregular- to uneven-aged understory of *Picea engelmannii*

Parry x *P. glauca* (Moench) Voss, and *Abies lasiocarpa* (Hook) Nutt. becomes established. As the even-aged *P. contorta* overstory ages, sporadic death of overmature trees permits an irregular- to all-aged *Picea - Abies* forest to emerge and dominate, unless fire re-initiates the succession to even-aged *P. contorta*. Extensive and frequent fires in the past, mainly initiated by "dry" electrical storms, have prevented long-term successional development and have maintained most of the forest in the early *P. contorta*-dominated phase of the succession. Introduction of effective fire protection is now permitting progress toward the late successional phases. Widespread development of the *Picea - Abies* phase and the decadent *Abies-Picea* phase that follows are forecast. The ecological effects of such fire-protection policies are questioned. A silvicultural program of fire prescription is suggested for the maintenance of the fauna and wilderness value of the mountain national parks. Silvicultural alternatives in harmony with the ecology of the forest are suggested for the implementation of multiple-use policies in the Rocky Mountain Reserve.

161. **DeBell, D.S.** 1990. Silvicultural practices and "New Forestry". *In* Proc. Conf. on "New Forests" in the 90's. April 19, 1990, Coos Bay, OR. Sponsored by Coos Chap., Soc. Am. For. and Southwestern Oreg. Community Coll. 5 p.

A discussion on silvicultural practices and "New Forestry." Thė author believes that the development of New Forestry has stemmed from a national desire for consensus on forest land management objectives and the practices by which these objectives are achieved. New Forestry suggests many ideas useful in achieving consensus in management and in enhancing the productivity of our forest lands. Society seems to focus on three major desires: 1) the desire for multi-purpose or multi-resource forest management; 2) the desire for a wide range of silviculture practices to be used in attaining the forest land management objectives; and 3) a desire for participating in the setting of these objectives and selecting management tools, especially on public lands. The author briefly discusses development and testing of silviculture prescriptions being carried out by silviculturists with the aim of meeting a wide range of forest management objectives. These silviculture practices are aimed at providing greater stand structure diversity in managed stands and maintaining diverse wildlife habitat by retaining mixed species stands. **

162. **DeBell, D.S.** and **J.F. Franklin.** 1987. Old-growth Douglas-fir and western hemlock: a 36-year record of growth and mortality. West. J. Appl. For. 2(4):111-114.

Growth and mortality were measured at 6-year intervals in a 1,180-acre old-growth stand in southwestern Washington. Principal tree species were Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), Pacific silver fir (*Abies amabilis*), western redcedar (*Thuja plicata*), and western white pine (*Pinus monticola*). They composed 59, 27, 6, 6, and 1%, respectively, of the total cubic volume (13,290 ft^3) in 1947. Gross volume growth averaged 94 ft^3 per acre per year, and mortality averaged 96 ft^3 per acre per year. Net growth was therefore minimal, and total stand volume remained nearly constant for 36 years. Douglas-fir, which accounted for only one-third of the gross growth and nearly one-half of the mortality, is losing dominance to western hemlock, which provided nearly one-half the gross growth and only 28% of the mortality. Pacific silver fir increased in importance in the lower canopy and composed 60% of the in-growth. Thus, although net gain in timber volume was nil, substantial changes occurred in stand characteristics during the 1947-1983 period.

163. **DeGraaf, R.M.** 1978. Proc. of the workshop on nongame bird habitat management in the coniferous forests of the western United States, Feb. 7-9, 1977, Portland, OR. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-64. 100 p.

This collection comprises the following papers: Maser, C., Thomas, J.W. Ecosystems, habitats, wildlife, and management; DeGraaf, R.M. The importance of birds in ecosystems; Meslow, E.C. The relationship of birds to habitat structure - plant communities and successional stages. Wiens, J.A. Nongame bird communities in northwestern coniferous

forests; Rotenberry, J.T., Wiens, J.A. Nongame bird communities in northwestern rangelands; Black, H., Jr., Thomas, J.W. Forest and range wildlife habitat management: ecological principles and management systems; Edgerton, P.J., Thomas, J.W. Silvicultural options and habitat values in coniferous forests; Kindschy, R.R. Rangeland management practices and bird habitat values; Miller, R. Guidelines for wildlife management in western coniferous forests; Bull, E.L. Specialized habitat requirements of birds: snag management, old growth, and riparian habitat; Canutt, P.R., Poppino, J.H. Accounting for bird habitat needs in land use planning; Thomas, J.W., Maser, C., Rodiek, J.E. Edges—their interspersion, resulting diversity and its measurement. **

164. **Del Moral, R.** and **R.S. Fleming.** 1979. Structure of coniferous forest communities in Western Washington: diversity and ecotope properties. Vegetatio 41(3):143-154.

The vegetation of the central Cascades of Washington is dominated by coniferous forests that have been a major focus of study by the Coniferous Forest Biome Project of the International Biological Program. The authors' goal is to describe, in three regions along a longitudinal gradient across the central Washington Cascades, the following aspects of coniferous forest community structure: species richness and diversity; growth-form complexity; and habitat breadth overlap.

The contrasts between the maritime western study region and the more continental eastern study region imply that ecotope differentiation increases from west to east. The following responses to decreasing maritime influence were noted: all aspects of species diversity increase; growth-form complexity increases; habitat heterogeneity increases; species habitat breadths decrease; and habitat overlaps decrease. The enhanced structural complexity of the eastern region results from climatical limitation of the dominant tree species. Reduced canopy dominance produces greater within-habitat heterogeneity with respect to moisture, light and soil properties. Contrasts between the extremes of the topographic-moisture gradient increase toward the east. These factors combine to increase *alpha, beta* and *gamma* diversities in the eastern study region above those of the western study region. Corresponding to these diversity trends are decreasing mean relative niche, habitat and ecotope breadths of species toward the east. (From Summary)

165. **Denison, R., B. Caldwell, B. Bormann, L. Eldred, C. Swanberg,** and **S. Anderson**. 1977. The effects of acid rain on nitrogen fixation in western Washington coniferous forests. Water, Air, and Soil Pollution 8:21-34.

Both the current status of N_2 fixation in western Washington forests, and the potential effects of acid rain on this vital process were investigated. Even the low concentrations of SO_2 presently found in the Northwest are thought to have an adverse effect on N_2 fixation by limiting the distribution of the epiphytic N_2-fixing lichen, *Lobaria pulmonaria*, which is found mainly in deciduous forests. A close relative, *L. oregana*, was found to be the major N_2 fixer in old-growth coniferous forests. It fixes less N_2 following exposure to H_2SO_4 of pH 4 or less.

A more serious threat to N_2 fixation than acid rain is the practice of deliberately suppressing red alder to keep it from competing with Douglas fir. Also, *L. oregana* is a late successional species and does not develop in forests where short cutting cycles are practiced.

166. **Denison, W.C.** 1973. Life in tall trees. Sci. Am. 228(6):74-80.

A study was conducted to examine the community of plants and animals in the canopy of a 450-year-old stand of *Pseudotsuga menziesii* in western Oregon. The canopy community formed a unique ecosystem of considerable complexity (comparable in many respects to communities found on the forest floor). The variety of life reflected a variety of habitats that differed widely in amount of available light, moisture, and temperature. The diversity of habitat and the number of species of epiphytic plants increased higher in the canopy. In old-growth Douglas-fir, the nitrogen-fixing plant life of the canopies can serve as the main

pathway for the introduction of new nitrogen, an element required by all life forms. The N pathways and N contribution by these old-growth stands to the forest ecosystem are illustrated and discussed. The contribution of N by the epiphyte *Lobaria oregana* is cited as an example. Some of the epiphytic lichens were found to be very susceptible to poisoning by atmospheric pollutants. How the form of a tree is related to its ability to thrive in specific conditions is also briefly addressed. **

167. ————————. 1979. *Lobaria oregana*, a nitrogen-fixing lichen in old-growth Douglas fir forests. *In* Symbiotic nitrogen fixation in the management of temperate forests. J.C. Gordon, C.T. Wheeler, and D.A. Perry (editors). Oreg. State Univ., Corvallis, OR, pp. 266-275.

Lobaria oregana (Tuck.) Mull. Arg. occurs on the branches of old-growth Douglas firs in amounts estimated at 10-15 kg dry weight per tree, or approximately 500 kg/ha. This is roughly 5% of the weight of foliage on the Douglas firs. Other nitrogen-fixing lichens occur in much smaller quantities; usually less than 1% of the weight of *L. oregana*. We found no nitrogen-fixing bacteria or blue green algae on the surfaces of foliage or twigs.

Two methods gave estimates of nitrogen fixed by *L. oregana* in the range 3-4 kg/ha/yr. Annual growth of the lichen, measured by sequential photographs, averaged 30%, or 150 kg/ha/yr. The nitrogen content of the lichen is 2.1%, amounting to 3.15 kg/ha of nitrogen in each year's new growth. Assuming that all of the nitrogen required for growth is fixed by the lichen, this is a rough estimate of annual fixation. Another method used the acetylene reduction technique to estimate rates of fixation. The average rate of fixation during the wet season (15 September - 15 June) when the lichens are active was 78 nanomoles of nitrogen per gram of dry lichen per hour. Assuming that all fixation occurs during the wet season this amounts to 3.5 kg/ha/yr.

The principal factors influencing the rate of fixation were the moisture content of the lichen and the temperature. Light only affects the rate indirectly. Fixation continues undiminished in the dark, presumably until stored food is exhausted. Transfer of nitrogen from *L. oregana* to the forest floor occurs by litter-fall and decomposition and by leaching from intact lichens. Grazing by invertebrates could not be demonstrated.

168. **Denison, W.C., D.M. Tracy, F.M. Rhoades,** and **M.A. Sherwood.** 1972. Direct, nondestructive measurement of biomass and structure in living, old-growth Douglas-Fir. *In* Proc. Symp. on Research on Coniferous Forest Ecosystems. J.F. Franklin, L.J. Dempster, and R.H. Waring (editors). March 23-24, 1972, Bellingham, WA. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR, pp. 147-158.

Previous studies of biomass and structure of Douglas-fir have examined trees less than 100 years old. This paper describes methods for measuring older trees, illustrated by data from a tree 60 m tall and 450 years old.

Rock climbing techniques, modified for use on trees, are employed to climb the main trunk. A movable spar provides access to lateral branches. The trunk is measured, the position of each branch system is located on it, and the branch systems are scored for 10 variables related to biomass and structure. An importance value, calculated for each branch system, is used in selecting a set of branch systems for detailed measurement. The data permit diagramatic reconstruction of the tree, or estimates of the distribution or total amount of component parts.

169. **Dennis, J.V.** 1975. The climax forest of the Congaree Swamp. Sierra Club Bull. 60:31-34.

This is a naturalist's account of the climax forest of the Congaree swamp of Southern Carolina, USA. The author cites progress made in attempts to designate this swamp a national preserve area despite bitter resistance from timber interests. Discussed is the exceptional circumstance in which loblolly pines, some more than 300 years old, have not

yielded to competition with hardwood trees. An extensive list of rare and endangered species of the Congaree is also provided. The role that the ancient forests of the Congaree swamp play in flood control and removal of sediment and pollutants is emphasized. **

170. **De Vries, J.** and **T.L. Chow.** 1978. Hydrologic behavior of a forested mountain soil in coastal British Columbia. Water Resour. Res. 15(5):935-942.

Inferences with respect to the hydrologic behavior of a West Coast forested mountain soil are based on measurement of the water potential field during the wetting and drainage phases of simulated rainfall events. The field was measured as a continuous function of time with an array of 13 tensiometers in combination with pressure transducers and a data collection system. Measurements were carried out with the forest floor intact, partly disturbed, and totally removed. Inferences were made by interpreting the water potential fields as "fingerprints of hydrologic behavior." It was concluded that during a simulated rainfall event, water flow through the profile was partitioned between root channels and the soil matrix which is transversed by the channels. The proportion of the flow conducted by the channels was at its maximum during the non-steady state phase of the event, decreasing to a minimum as steady state was approached. During the drainage phase of the event the channels did not contribute to downward flow. The process of internal infiltration is discussed. It causes the soil matrix to wet up both from the surface of the H horizon of the forest floor and from the wetted periphery of the root channels. Results indicated that simulated disturbance of the forest floor down to the mineral soil caused a shift in the water flow pathway from the channels to the soil matrix. It was speculated that this shift was due to closure of the channel openings. It was speculated that the flash response of streams to rainfall events is related to rapid subsurface storm flow through root channels. Also, because water flow through the soil matrix is much slower than that through root channels, it is likely that forest floor disturbance on a watershed-wide scale would result in an increase in the time lag between the rainfall event and the corresponding streamflow event.

171. **Deyrup, M.** 1981. Deadwood decomposers. Nat. Hist. 90(3):84-91.

The author began his study of insects in dead Douglas-fir, expecting to find a relatively simple grouping of a few specialized well-known insect species. The search resulted in a complex array of more than 300 species which follow an even more complicated pattern of population changes, changes in species combinations and changes in specific deadwood habitat. Early invaders prepare the habitat for later occupants and there are numerous examples of phytophagous insects and their accompanying group of parasitoids, predators, and associates. These last "associates" consist of scavengers and species whose ecological roles remain yet to be discovered. The author describes some of the known species and their roles in decomposition, nutrient cycling, forest regeneration, and the food chain. **

172. **Diamond, J.M.** 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. Biol. Conserv. 7:129-146.

A system of natural reserves, each surrounded by altered habitat, resembles a system of islands from the point of view of species restricted to natural habitats. Recent advances in island biogeography may provide a detailed basis for understanding what to expect of such a system of reserves. The main conclusions are as follows:

The number of species that a reserve can hold at equilibrium is a function of its area and its isolation. Larger reserves, and reserves located close to other reserves, can hold more species.

If most of the area of a habitat is destroyed, and a fraction of the area is saved as a reserve, the reserve will initially contain more species than it can hold at equilibrium. The excess will gradually go extinct. The smaller the reserve, the higher will be the extinction rates. Estimates of these extinction rates for bird and mammal species have recently become available in a few cases.

Different species require different minimum areas to have a reasonable chance of survival.

Some geometric design principles are suggested in order to optimise the function of reserves in saving species.

173. ——————. 1976. Island biogeography and conservation: strategy and limitations. Science 193:1027-1029.

The author points out the fallacies in Simberloff and Abele's arguments favoring the use of several small reserves as species conservation strategy. Different species react differently to changes in habitat and must be managed according to these differences. Biologists are encouraged to familiarize themselves with the theory of island biogeography in order to provide managers with valid and convincing arguments for large reserves. **

174. ——————. 1988. Red books or green lists? Nature 332:304-305.

The author discusses why using green lists (listings of species definitely known to be secure) will give a much more realistic indication of the extinction crisis than the red books (listings of species definitely known to be threatened). **

175. **Dickman, A.** 1978. Reduced fire frequency changes species composition of ponderosa pine stand. J. For. 76:24-25.

In the Umpqua National Forest, Oregon, a .35-acre ponderosa pine (*Pinus ponderosa* Laws.) stand situated in the midst of a Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) forest is being invaded by Douglas-fir seedlings as a result of reduced fire frequency within the last 50 years. In earlier times frequent ground fires kept Douglas-fir at a minimum.

176. **Donnelly, D.M., J.B. Loomis, C.F. Sorg,** and **L.J. Nelson**. 1985. Net economic value of recreational steelhead fishing in Idaho. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Resour. Bull. RM-9. 23 p.

Average willingness to pay in addition to actual expenditure for steelhead fishing in Idaho was estimated at $27.87 per trip with the Travel Cost Method and at $31.45 per trip with the Contingent Value Method. Willingness to pay was greater for increased catch or fish size. Average actual expenditure was $72 per trip.

177. **Donnelly, D.M.** and **L.J. Nelson**. 1986. Net economic value of deer hunting in Idaho. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Resour. Bull. RM-13. 27 p.

Average net willingness to pay in addition to actual expenditure for deer hunting in Idaho was estimated with the Travel Cost Method at $50.23 per trip and with the revised 1983 Contingent Value Method at $40.09.

178. **Dorcy, A.J.** 1987. The management of super, natural British Columbia. B.C. Studies 73:14-42.

In this paper the author examines the environmental conflicts which have emerged in British Columbia and assesses the public policies that have been developed to resolve them. The evolution of the provincial environmental policy is discussed in the first section with an emphasis on major initiatives introduced by the New Democratic Party in the period from 1972 to 1975 and the modification of these by subsequent Social Credit governments. The second section of the report deals with the influences of federal environmental policies. The author then provides an evaluation of provincial environmental management based on three criteria: 1) opportunities for participation by interested groups; 2) information available relevant to interested groups; and 3) cost-effectiveness. Recommendations to improve environmental management in British Columbia are provided. The main recommendations are to strengthen political leadership and accountability and to improve the generation of information. Means of achieving these are provided. **

179. **Dudley, T.** and **N.H. Anderson**. 1982. A survey of invertebrates associated with wood debris in aquatic habitats. Melanderia 39:1-21.

A field survey was undertaken to examine the community of invertebrates associated with wood debris in freshwater systems, with an emphasis on forested streams of the western states. Fifty-six taxa representing 5 orders of insects and other invertebrates are identified as closely associated with wood, while 129 taxa are listed as facultative users. The methods of utilization range from the opportunistic use of the wood surface for refuge, resting and feeding, to ingestion of wood tissue, including sub-surface boring. Wood debris is found most abundantly in headwater streams, where the low streamflows cause less abrasion and displacement of the material, and allow more extensive conditioning by decomposers. Obligate xylophages occurred predominantly in these low-order streams.

180. **Duever, L.C.** and **R.F. Noss**. 1990. A computerized method of priority ranking for Natural Areas. *In* Ecosystem management: rare species and significant habitats. R.S. Mitchell, C.J. Sheviak and D.J. Leopold (editors). N. Y. State Museum, Albany, NY. Bull. No. 471, pp. 22-33.

The Nature Conservancy has developed an efficient system for ranking the relative merits of different sites for preservation of particular species and communities, but there is no universally accepted systematic method for comparing the composite values of complex sites. We addressed this issue in preparing a natural area preservation priority list for Alachua County, Florida. Our system involves scoring sites on a ten-point scale according to each of six criteria: vulnerability, rarity, connectedness, completeness, manageability, and nature-oriented human use potential. The scores are derived from expert consensus on carefully defined qualitative ratings, then entered into a Lotus 1-2-3 program. This program permits the criteria to be weighted differently for evaluating sites taking into consideration different types of planning objectives (e.g., recreation area vs. wildlife sanctuary planning).

181. **Dunlap, T.R.** 1988. That Kaibab myth. J. Forest History 32(2):60-68.

A history of wildlife management in the United States, citing the famous management disaster of Kaibab National Park. In the late 19th and early 20th centuries, management of deer populations in this park began, and consisted of measures encouraging reproduction, based on the assumption that population size was self regulating. In an attempt to help preserve deer populations, all natural predators were removed by government hunters between 1906 and 1923. The result was incredible increases in the deer populations and over-browsing of the range, which led to death of many deer by starvation and disease. Wildlife managers then realized the need for some type of control on population sizes. This article follows the development of ecological thought and emphasizes the need for understanding population dynamics for successful wildlife management. **

182. **Dunwiddie, P.W.** 1986. A 6000-year record of forest history on Mount Rainier, Washington. Ecology 67(1):58-68.

Sediments in three ponds between 1300-1500 m on the south side of Mt. Rainier were examined for plant macrofossils and pollen. Macrofossils of seral species such as *Abies lasiocarpa, Pseudotsuga menziesii, Pinus monticola, Abies procera*, and *Pinus contorta* were conspicuous from 6000 to 3400 BP. These species suggest a climate that was warmer/drier than today and favored frequent fires. Neoglacial cooling may have begun 3700-3400 BP, as species typical of higher elevations became prominent; a decline in seral species after 3400 BP suggests less frequent fires. In the last 100 yr, *Tsuga heterophylla* became abundant and then declined at the highest elevation site. General trends in pollen percentages are similar to the macrofossil curves. Tephra deposition from Mt. Rainier and Mt. St. Helens did not produce conspicuous changes in forest composition. Few major fires are evident from charcoal and macrofossils at these sites.

183. **Edmonds, R.L.** 1982. Analysis of coniferous forest ecosystems in the western United States. US/IBP Synthesis Series. Hutchinson Ross Publishing Co., Stroudsburg, PA. 419 p.

This analysis of coniferous forest ecosystems in the western United States is addressed in 11 chapters: 1) R.L. Edmonds, Introduction; 2) G.M. Hawk, J.N. Long, and J.F. Franklin, Relations between vegetation and environment; 3) W.H. Emmingham, Ecological indexes as a means of evaluating climate, species distribution, and primary production; 4) K.L. Reed and S.G. Clark, The niche and forest growth; 5) J. N. Long, Productivity of western coniferous forests; 6) J.P. Lassoie, Physiological activity in Douglas-fir; 7) D.W. Johnson, D.W. Cole, C.S. Bledsoe, K. Cromack, R.L. Edmonds, S.P. Gessel, C.C. Grier, B.N. Richards, and K.A. Vogt, Nutrient cycling in forest of the Pacific Northwest; 8) F.J. Swanson, R.L. Fredriksen, and F.M. McCorison, Material transfer in a western Oregon forested watershed; 9) F.J. Swanson, S.V. Gregory, J.R. Sedell, and A.G. Campbell, Land-water interactions: The riparian zone; 10) F.J. Triska, J.R. Sedell, and S.V. Gregory, Coniferous forests streams; 11) R.C. Wissmar, J.E. Richey, A.H. Devol, and D.M. Eggers, Lake ecosystems of the Lake Washington drainage basin. An appendix includes coniferous Forest Biome program publications. **

184. ————————. 1987. Decomposition rates and nutrient dynamics in small-diameter woody litter in four forest ecosystems in Washington, USA. Can. J. For. Res. 17:499-509.

Decomposition rates and nutrient dynamics in small-diameter woody litter (twigs, cones, and branches) were studied in four ecosystems in western Washington: high elevation Pacific silver fir (*Abies amabilis* [Dougl.] Forbes) and low elevation Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), and red alder (*Alnus rubra* Bong.). Conifer twigs decomposed faster (k = 0.14-0.24 year^{-1}) than cones (k = 0.09-0.12 year^{-1}) and branches (k = 0.03-0.11 year^{-1}). Decomposition constants were related better to initial lignin/initial N ratios (r = -0.64) than initial lignin concentrations. N was generally the least mobile nutrient while K was the most mobile. Many nutrients were strongly immobilized in conifer fine woody litter, including N, Mg, Mn, and Ca. There was little immobilization of N in red alder branches. N release from decomposing woody litter appears to be controlled by a critical C/N ratio. This critical C/N ratio, however, was not constant and increased as the substrate decomposition rate increased.

185. **Elliot, S.T.** 1986. Reduction of a Dolly Varden population and macrobenthos after removal of logging debris. Trans. Am. Fish. Soc. 115:392-400.

Logging debris resident for five or more years in small streams of southeastern Alaska is frequently removed to improve salmonid habitat. This practice was evaluated for its effects on juvenile anadromous Dolly Varden (*Salvelinus malma*) and macrobenthos populations in a small spring-fed stream during 1973-1981. Debris, consisting of limbs, needles, and fragmented logs, was removed by hand from the entire stream in July 1976. The surface area, number, and size of pools was reduced thereafter, and the water velocity increased. Macrobenthos density and invertebrate drift decreased 60-90% immediately after debris removal but returned to pretreatment levels in 1977. The Dolly Varden population decreased from 900 to less than 100 fish by 1978 and then fluctuated sharply between late 1978 and 1981. After 1978, Dolly Varden averaged 27 mm less in length and their biomass decreased from 12.5 to 3.9 g/m^2. Decrease in fish standing crop occurred in two stages: (1) an initial loss of larger fish due to reduced habitat; (2) loss of smaller individuals during November freshets thereafter. This study indicates that removal of old logging debris does not improve habitat and can result in smaller rearing populations. Old debris should not be removed unless a block to migrating adult spawners or impairment of water quality can be demonstrated.

186. **Englin, J.** 1990. Backcountry hiking and optimal timber rotation. J. Environ. Manage. 31:97-105.

This paper examines the effect of backcountry hiking on the optimal rotation periods of several species of trees. The paper begins by showing how theoretical models of timber rotation in the presence of externalities can be used to describe this situation. Following this,

empirical rules for harvesting timber based on common forest data are computed for five species of trees. The paper proceeds by simulating the optimal social forest management regime when both timber and amenity values can substantially alter the rotation period of timber.

187. **Environmental Law Institute.** 1977a. The conservation of endangered species. *In* The evolution of National Wildlife Law. Prepared for the Council of Environment Quality, Washington, DC, pp. 370-411.

This paper examines the many aspects of the United States federal program to conserve endangered species. The article begins by decribing the development of the Endangered Species Preservation Act since its inception in 1966. The act called for a program to be initiated to conserve, protect, restore, and propagate selected species of native fish and wildlife. It became apparent that conservation wildlife in the United States required a more comprehensive effort than that exemplified by the 1966 and 1969 endangered species preservation acts. The author concludes by discussing the many provisions of the Endangered Species Act of 1973, which was thought to be a truly comprehensive effort at wildlife preservation in the United States. **

188. ——————. 1977b. Wildlife conservation through mandating consideration of wildlife impacts. *In* The evolution of National Wildlife Law. Prepared for the Council on Environmental Quality, Washington, DC, pp. 192-218.

This paper examines a number of federal statutes developed to compel consideration of the impacts of various activities on wildlife not protected by sanctuaries. Emphasis is placed on 1) The Fish and Wildlife Coordination Act and 2) The National Environmental Policy Act. The protection of coastal and estuarine areas is also discussed. **

189. **Erdelen, M.** 1984. Bird communities and vegetation structure: I. Correlations and comparisons of simple and diversity indices. Oecolgia 61:277-284.

In order to investigate relations between bird community and vegetation structure indices, with a focus on methodological problems, 22 study plots ranging from grassland to old forests were selected. Breeding passerine birds were censused by means of the mapping method. Vegetation structure was assessed by measuring cover values at 12 different heights (0.25 to 32 m). Simple indices (e.g. number of bird species, NRSPEC, and number of layers with vegetation, NSTRAT) as well as diversity values (bird and plant species diversity, BSD and PSD, resp.; foliage height diversity, FHD, and other indices of structural diversity) were calculated. Vegetation structure diversity, but not floristic diversity (PSD) was found to be correlated with bird species diversity (BSD). However, vegetation structure indices differed in several respects. The much-discussed BSD/FHD correlation held only if structurally different plots (forests and low vegetation) were included in the analysis, but not if the evaluation was restricted to forests alone. The index DT, suggested by Blondel and Cuvillier (1977) proved to be more useful, being more highly correlated to BSD, and more robust as to study site selection. It also offers the advantage of discerning between a vertical (DV) and a horizontal (DH) component. Due to methodological divergencies, it was found virtually impossible to make detailed comparisons, in terms of biological concepts, of the results of other authors and those of the present study, the problem of comparability apparently deserving more discussion than it has received hitherto. The designation "FHD" especially, is used for numerical values arrived at by quite divergent field methods and computational procedures. It is concluded that simple indices (e.g. NRSPEC and NSTRAT), which are demonstrated to be good predictors of more complex ones (BSD and FHD, respectively), should be preferred as they permit better standardization and easier, more direct interpretation. (Author's summary)

190. **Fahey, T.J.** 1983. Nutrient dynamics of aboveground detritus in lodgepole pine (*Pinus contorta* ssp. *latifolia*) ecosystems, southeastern Wyoming. Ecol. Monogr. 53(1):51-72.

Storage and fluxes of N, P, Ca, Mg, and K in aboveground detritus were measured in six contrasting lodgepole pine (*Pinus contorta* ssp. *latifolia*) stands in southeastern Wyoming. Litterfall was predominantly leaves (67-80%) in 80-100 yr old stands, while woody litter was more important in an older stand (240 yr old). Leaf litter nutrient concentrations were very low compared with other pine forests, particularly for N (0.40% dry mass). Dry mass loss from decomposing leaf litter was slow (15%/yr in first 2 yr), and summer rates did not differ significantly from winter rates beneath the insulating snowpack. Significant amounts of N, P, and Ca were added to decomposing leaves during the first winter, and N and Ca addition continued for 2 yr. Potassium and magnesium were rapidly lost from decomposing leaves. Rates of mass and nutrient loss from decomposing bark, twigs, and cones were comparable to those observed in other studies of temperate-zone forests. Mass loss from decaying bole wood appeared to be exponential through 40 yr, with an average decay coefficient (k) of 0.016, which is comparable to that in other cold temperate forests. Nitrogen content of decaying boles doubled between 30 and 55 yr following tree death, while smaller additions of P, Ca, K, and Mg also were noted.

Relatively large accumulations of organic matter and nutrients were observed in the forest floor, leading to very high steady-state residence times for dry mass (mean = 18 yr), N (54 yr), P (39 yr), Ca (35 yr), Mg (21 yr), and K (18 yr). Deadfall contributed by the present forest generation was a minor component of the aboveground detritus except in an old-age stand and in a dense, self-thinning forest site. In contrast, dead wood inherited from the previous forest generation (killed by fire) was a major detrital storage component, exceeding forest floor mass by several-fold in 80-100 yr old stands. High nutrient immobilization in the dead wood led to storage values which were similar to those of the forest floor in these stands.

191. **Fahey, T.J., J.B. Yavitt, J.A. Pearson,** and **D.H. Knight**. 1985. The nitrogen cycle in lodgepole pine forests, southeastern Wyoming. Biogeochemistry 1:257-275.

Storage and flux of nitrogen were studied in several contrasting lodgepole pine (*Pinus contorta* spp. *latifolia*) forests in southeastern Wyoming. The mineral soil contained most of the N in these ecosystems (range of 315-860 g/m^2), with aboveground detritus (37.5-48.8 g/m^2) and living biomass (19.5-24.0 g/m^2) storing much smaller amounts. About 60-70% of the total N in vegetation was aboveground, and N concentrations in plant tissues were unusually low (foliage = 0.7% N), as were N input via wet precipitation (0.25 g/m^2/yr), and biological fixation of atmospheric N (0.03 g/m^2/yr, except locally in some stands at low elevations where symbiotic fixation by the leguminous herb *Lupinus argenteus* probably exceeded 0.1 g/m^2/yr^2).

Because of low concentrations in litterfall and limited opportunity for leaching, N accumulated in decaying leaves for 6-7 yr following leaf fall. This process represented an annual flux of about 0.5 g/m^2 to the 01 horizon. Only 20% of this flux was provided by throughfall, with the remaining 0.4 g/m^2/yr^2 apparently added from layers below. Low mineralization and small amounts of N uptake from the 02 are likely because of minimal rooting in the forest floor (as defined herein) and negligible mineral N (0.05 mg/L) in 02 leachate. A critical transport process was solubilization of organic N, mostly "fulvic acids". Most of the organic N from the forest floor was retained within the major tree rooting zone (0-40 cm), and mineralization of soil organic N provided NH_4 for tree uptake. Nitrate was at trace levels in soil solutions, and a long lag in nitrification was always observed under disturbed conditions. Total root nitrogen uptake was calculated to be 1.25 gN/m^2/yr with estimated root turnover of 0.37 gN/m^2/yr, and the soil horizons appeared to be nearly in balance with respect to N. The high demand for mineralized N and the precipitation of fulvic acid in the mineral soil resulted in minimal deep leaching in most stands (0.02 g/m^2/yr). These forests provide an extreme example of nitrogen behavior in dry, infertile forests.

192. **Fahrig, L.** and **G. Merriam.** 1985. Habitat patch connectivity and population survival. Ecology 66(6):1762-1768.

We constructed a patch dynamics model which can be used to simulate the changing sizes of resident populations in series of interconnected habitat patches. We applied the model to white-footed mice (*Peromyscus leucopus*) inhabiting patches of forest in an agricultural landscape. The model predicts that mouse populations in isolated woodlots have lower growth rates and are thus more prone to extinction than those in connected woodlots. Field data support this prediction.

193. **Falk, D.A.** 1990. The theory of integrated conservation strategies for biological diversity. *In* Ecosystem management: rare species and significant habitats. R.S. Mitchell, C.J. Sheviak, and D.J. Leopold (editors). N. Y. State Museum, Albany, NY. Bull. No. 471, pp. 5-10.

As the threats to biological diversity increase worldwide, conservation strategies (and programs based upon them) must be correspondingly strengthened. No single strategy sufficiently protects all levels of the biological hierarchy from the wide range of threats encountered. Moreover, the resources available to protect natural diversity are inherently limited. Because of the pervasiveness of environmental impacts and threats to species' survival, most conservation practice requires some active intervention into natural systems. Conservation decision-making should be approached as a question of optimal resource allocation, by protecting the greatest diversity for a given investment of conservation resources, with preference for strategies that are most cost-effective in protecting a desired biological entity. Thus, conservation has reached an era of diversity management, a significant change from the purist, preservation ideals of past centuries, and an approach requiring new kinds of information and programs.

194. **Farr, W.A.** and **A.S. Harris.** 1971. Partial cutting of western hemlock and Sitka spruce in southeast Alaska. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Res. Pap. PNW-124. 10 p.

This study of response to partial cutting over a 17-year period in a 96-year-old stand of western hemlock-Sitka spruce at Karta Bay, Alaska, showed that crop trees left after partial cutting were able to increase or maintain about the same rate of diameter growth as before thinning, but growth in diameter of trees in an unthinned stand followed the normal pattern of decline.

Opening the stand stimulated epicormic branching, thus reducing quality of trees in the future. Partially cut plots become well stocked with conifer regeneration, mostly western hemlock.

195. **Feller, M.C.** 1977. Nutrient movement through western hemlock-western redcedar ecosystems in southwestern British Columbia. Ecology 58(6):1269-1283.

A calibrated watershed study was established in a *Tsuga heterophylla - Thuja plicata - Pseudotsuga menziesii* forest in the Coastal Western Hemlock biogeoclimatic zone in southwestern British Columbia to study the effects of clearcut logging and broadcast slashburning on ecosystem biogeochemistry.

Water was sampled regularly at the following stages in its passage through a forest-watershed ecosystem: (1) Precipitation above the forest; (2) canopy throughfall; (3) surface runoff (overland flow); (4) forest floor leachate; (5) mineral soil leachate near the bottom of the rooting zone; (6) groundwater; and (7) stream water. All samples were analyzed for K^+, Na^+, Mg^{2+}, Fe^{2+}, Mn^{2+}, Al^{3+}, NH_4^+, Cl^-, PO_4^{3-}, NO_3, SO_4^{2-}, dissolved SiO_2, pH, alkalinity (as bicarbonate), and electrical conductivity.

There was a general increase in chemical concentrations as water entered and moved vertically down through the system to maximum values in forest floor leachate. This was followed by a decrease to minimum values in groundwater, with a slight increase again in stream water. The pH increased steadily from a low in throughfall to maximum values in stream water. These changes in solution chemistry are discussed in relation to ecosystem nutrient cycling processes.

Chemical concentrations, pH, and electrical conductivity were generally highest in late summer and early autumn and lowest in winter and early spring. This pattern generally occurred throughout the system and was attributed to seasonal cycles of geological and biological activity, and to rainfall patterns.

Data from this study are consistent with the current theory explaining the chemistry of solutions passing through soil.

196. **Feller, M.C.** and **J.P. Kimmins.** 1979. Chemical characteristics of small streams near Haney in southwestern British Columbia. Water Resour. Res. 15(2):247-258.

The hydrological, thermal, and chemical characteristics of two small streams flowing through relatively undisturbed, low-elevation mountain watersheds in southwestern British Columbia were investigated. All observations and chemical analyses of ecosystems were consistent with the hypothesis that stormflow originated mainly from flow of water through soil macrochannels to groundwater and thence to streams. Water budgets indicated unmeasured groundwater losses. The streams exhibited annual chemical cycles for most parameters, with maximum values in late summer and early autumn and minimum values in winter and early spring. Nitrate concentrations displayed no consistent seasonal variation, whereas potassium and sulphate concentrations were relatively uniform throughout the year. Most chemical parameters decreased with increasing discharge, whereas dissolved oxygen concentrations increased. Potassium concentrations exhibited some increases and some decreases, and chloride, nitrate, and sulphate concentrations were generally not significantly related to discharge. Concentration-discharge relationships were used to infer the origin of stormflow water. Differences in the chemistry of the two very similar streams have important ramifications for the design of watershed nutrient studies. Nutrient budgets were very similar to those of other watersheds in humid temperate regions, with net losses of calcium, sodium, magnesium, potassium, chloride, and sulphur. Nitrogen and phosphorus exports in dissolved or particulate organic form were not measured. Based on dissolved inorganic measurements, nitrogen was accumulated, while any gains or losses of phosphorus were extremely small.

197. **Ffolliott, P.F.** 1980. Impact of man's activities on spruce forest ecosystems in the southwestern United States. *In* Proc. Symp. on Stability of Spruce Forest Ecosystems. E. Klimo (editor). Oct. 29-Nov. 2, 1979, Inst. For. Ecol. Brno, Czechoslovakia. Univ. Ariz., Tucson, AZ, pp. 251-260.

A status-of-knowledge report on the management of spruce-fir and mixed conifer forests in the southwestern United States is presented. Included is a description of the overstory and understory species, wildlife, climatic patterns, edaphic and physiographical characteristics, recreational uses, past land history, and ownership patterns. Responses of water, timber, forage, wildlife, soil, and aesthetics to forest management activities on the three experimental watersheds indicate that changes imposed by man can benefit man and, at the same time, the environment. By taking a holistic viewpoint, all the ecosystem products and uses can be obtained within a framework of stability and high environmental quality.

198. **Finklin, A.I.** 1986. A climatic handbook for Glacier National Park, with data for Waterton Lakes National Park. U.S. Dep. Agric. For. Serv., Intermtn. Res. Stn., Ogden, UT. INT-204. 124 p.

A climatic description of the Glacier-Waterton Lakes Park area; mainly covers Glacier. Contains numerous tables, graphs, and maps showing the year-round pattern of climatic elements and 10-day details during fire season. Data analysis includes frequency distributions in addition to average values. Examines relationship of averages to topography, weather correlations between stations, persistence of weather, and climatic trends during this century.

199. **Fischer, W.C.** and **B.R. McClelland.** 1983. A cavity-nesting bird bibliography — including related titles on forest snags, fire, insects, disease, and decay. U.S. Dep. Agric. For. Serv., Intermtn. For. Range Exp. Stn., Ogden, UT. Gen. Tech. Rep. INT-140. 79 p.

This report provides an index to the contents of more than 1,700 references pertaining to cavity-nesting birds and the related topics of forest snags, fire, insects, disease, and decay.

The list of titles is arranged alphabetically by author and each title is assigned a reference number. The reference number identifies the title in the indexes provided.

The indexes include a forest snag index; a fire, insect, disease, and decay index; a cavity-nesting bird index; and a geographic index.

The cavity-nesting bird index contains separate sections for each of 86 different bird species. Keywords used are: habitat management, habitat, foraging behavior, breeding, nesting, nest and roost trees, nest boxes and houses, biology, ecology, life history, relations with other fauna, territory, distribution, population density, status, identification, taxonomy, and damage.

200. **Fitzgerald, R.O.** 1984. Silvicultural practices can provide diversity in a managed forest. *In* Proc. Symp. on Natural Diversity in Forest Ecosystems. J.L. Cooley and J.H. Cooley (editors). Nov. 29-Dec. 1, 1982, Athens, GA. Inst. Ecol., Univ. Georgia, Athens, GA, pp. 263-266.

Silvicultural practices and land allocation can provide diversity of plants and animals on southern national forests. This diversity should be achieved on the planning area as a whole and not solely on a site-by-site basis. The National Forest System Land and Resource Management Plan is the document that guides the land manager.

201. **Fletcher, R.** 1989. Special forests for a special owl. For. Res. West (June):15-17.

Description and life history of *Otus flammeolus*, the flammulated owl, currently considered a new wildlife species indicator for healthy old-growth Douglas-fir and ponderosa pine forests. **

202. **Fogel, R.** 1975. Insect mycophagy: a preliminary bibliography. U.S. Dep. Agric., For. Serv. Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-36. 21 p.

Insects that feed on fungi are primary dispersal agents for many beneficial and pathogenic species. Nearly 300 references on the subject, published since the mid-19th century are listed in this bibliography. References are intended to provide an entry into the insect mycophagy literature. The most frequently reported insect mycophagists are either Diptera, mainly Mycetophilidae or Phoridae, and Coleoptera, separable into bark beetles and other beetles. Agarics and "bracket" fungi (Polyporaceae) encompass most of the commonly reported substrates.

Most literature records insects extracted or reared from fungal sporocarps rather than observations of actual feeding on fungi. Complete food chains are thereby concealed, since some insects in sporocarps may be predators or casual visitors. However, such insects can also serve as carriers of spores. Food consumption rates, chemical composition, species numbers, models of food webs, etc., have rarely been reported. (From author's introduction)

203. ——————. 1980. Mycorrhizae and nutrient cycling in natural forest ecosystems. New. Phytol. 86:199-212.

The widespread occurrence of mycorrhizae in nature and their importance in the mineral nutrition of almost all plants has been extensively documented but despite this mycorrhizae have not been included in nutrient cycling studies of forest ecosystems. This neglect may be due to a failure on the part of researchers to recognize the functional differences between mycorrhizae and roots and to the labour-intensive effort needed to study mycorrhizae.

Biomass or surface area of mycorrhizae must be measured before information on ion absorption by mycorrhizae can be applied to forest ecosystems. A full assessment of the importance of mycorrhizae in nutrient cycling also requires data on mycorrhiza production, senescence, and decomposition. Few mycorrhiza studies have provided such data. Consequently, our information on nutrient cycling is derived from fine root (≤ 5 mm in diameter) data which may or may not include mycorrhizae.

Recent studies have shown that most of the organic input to the decomposition process results from fine root production. Fine root mortality and decomposition is also more important than other mechanisms for returning nitrogen immobilized in vegetation to the soil in both deciduous and coniferous forests. A recently completed study indicates that mycorrhizae account for 50% of the annual throughput of biomass and for 43% of the nitrogen released annually in a Douglas fir ecosystem. These transfers are five times larger than the releases from litterfall or litter decomposition. Clearly, the study of mycorrhizal nutrient cycling is in an embryonic state and considerable additional research is needed.

204. **Fogel, R.** and **G. Hunt**. 1979. Fungal and arboreal biomass in a western Oregon Douglas-fir ecosystem: distribution patterns and turnover. Can. J. For. Res. 9:245-256.

The allocation of biomass and the turnover time of various components were measured from August 1976 to August 1977 in a young, second-growth Douglas-fir stand in the Oregon Coast Range. Allocation of biomass among the tree components was 14,732 kg foliage ha^{-1}, 30,455 kg branches ha^{-1}, 212,941 kg boles ha^{-1}, 49,289 kg nonmycorrhizal roots ha^{-1}, and 15,015 kg host portion of mycorrhizae ha^{-1}. Biomass allocation of fungal components was 10,009 kg mycorrhizal mantles ha^{-1}, 2,785 kg *Cenococcum geophilum* sclerotia ha^{-1}, 65 kg sporocarps ha^{-1}, 369 kg litter hyphae ha^{-1}, and 6666 kg coarse (2-25 mm) litter ha^{-1}, and 5500 kg log (25 mm) litter ha^{-1}. Soil organic matter (0.494 mm) was 87,600 kg ha^{-1}. Total annual stand throughput was 30,324 kg ha^{-1}, excluding soil organic matter throughput. Of this total, 50.5% was accounted for by fungal throughput, 39.5% by tree throughput, and 10.0% by forest floor throughput.

205. ———————. 1983. Contribution of mycorrhizae and soil fungi to nutrient cycling in a Douglas-fir ecosystem. Can. J. For. Res. 13:219-232.

The allocation of biomass and nutrients (N, P, K, Ca, Mg) was measured from August 1976 to September 1978 in a young, second-growth Douglas-fir (*Pseudotsuga menziesii* [Mirb.] *Franco*) stand in the Oregon Coast Range. Tree biomass comprised 78-79% of the total standing crop of organic matter with the remainder allocated as follows: soil organic matter, 17%; forest floor, 4%; and fungi, 2%. Bole biomass accounted for 64-66% of the total tree standing crop; the remainder was apportioned among: nonmycorrhizal roots, 17-18%; branches, 7-8%; mycorrhizae, 6%; and foliage, 4%. Nutrient stocks in aboveground tree components exceeded those in belowground components by one to nine times. For all nutrients except Ca, roots and mycorrhizae contained larger stocks than either the forest floor or fungi; amounts of Ca in the forest floor and in fungi were twice those in roots and mycorrhizae. Return of organic matter to the soil by fine roots and mycorrhizae ranged from 84 to 78% of total tree return. About 73% of total net primary production was invested in growth and maintenance of roots and mycorrhizae. Return of N, P, and K to the soil by mycorrhizae comprised 83-87% of total tree return and 25-51% of Ca and Mg return. Return by mycorrhizae of N, P, and K was four to five times greater than that of roots, nearly equal for Ca, and three times less for Mg.

206. **Fogel, R.** and **J.M. Trappe.** 1978. Fungus consumption (mycophagy) by small animals. Northwest Sci. 52(1):1-31.

A review of the natural history literature of small mammal feeding habits, based on many fortuitous field observations, some analysis of stomach contents, and a few feeding experiments, shows that diverse animals feed on similarly diverse fungi. The interdependence of animals and fungi has evolved to a high degree in some cases, e.g., the loss of alternative spore dispersal mechanisms by some fungi and the strong reliance of some mammals on fungi as a primary food. Consequently, adaptation for mycophagy and the effects of mycophagy of habitat, fungal toxicity, and the food value of fungi have implications in the interpretation of ecosystem structure and function.

207. **Fonda, R.W.** 1974. Forest succession in relation to river terrace development in Olympic National Park, Washington. Ecology 55:927-942.

The floodway zone of the Hoh River exhibits four terrace levels of different ages, formed by erosional activity of the river on valley fills. The vegetation in this valley is in a long-term seral sequence as shown by the zonal pattern in relation to aging and development of these land surfaces. Succession starts on gravel bars, which are dominated by *Alnus rubra* and *Salix scouleriana*. The following sequential forest communities, and associated ages of land surfaces, are found: 1) *Alnus rubra* on alder flats (80-100 yr); 2) *Picea sitchensis - Acer macrophyllum - Populus trichocarpa* on first terraces (400 yr); 3) *Picea sitchensis - Tsuga heterophylla* on second terraces (750 yr); and 4) *Tsuga heterophylla* on third terraces. The latter represents the climax community for the river terrace sere, and it occurs on surfaces exposed by retreating Pleistocene alpine glaciers. The first tree terraces are derived from Neoglacial alluvial fills.

There is a strong correlation among zonation patterns, forest succession, age of terraces, soil moisture, and soil profile development. Available soil moisture is an important factor governing the zonal sequence. The younger land surfaces are significantly drier than the older terraces. Plants on alder flats and first terraces must withstand greater moisture stress than those of second and third terraces. As the land surface ages, the soil profile develops; deeper, more mature soils are found away from the river.

The term "Olympic rain forest" is inappropriately applied to this vegetation; "temperate moist coniferous forest" is more appropriate not only for forests in the Hoh Valley, but also for the rest of the Olympic Mountains and vegetation along the northern Pacific coast.

208. **Food and Agriculture Organization of the United Nations.** 1962. Forest influences. FAO For. and For. Products Studies, Rome, Italy. No. 15., 307 p.

Land use problems urgently require the development of an integrated approach to a sound land use policy. This study was undertaken: to clarify the importance of considering of forest influences in land use and management; to aid land administrators in their assessments of forests and land-use policies; and to emphasize the need for further research on forest influences. The six chapters include discussions on: 1) forest influences on climate, soils, and water supplies; 2) water action and water movement in the forest; 3) the influence of the forest on the weather and other environmental factors; 4) trees outside the forest; 5) land use and watershed protection and management; and 6) evaluation of the utility of forest influences. **

209. **Forman, R.T.T.** and **M. Godron**. 1981. Patches and structural components for a landscape ecology. BioScience 31(10):733-740.

Landscapes as ecological units with structure and function are composed primarily of patches in a matrix. Patches differ fundamentally in origin and dynamics, while size, shape, and spatial configuration are also important. Line corridors, strip corridors, stream corridors, networks, and habitations are major integrative structural characteristics of landscapes.

210. **Forsman, E.D., E.C. Meslow,** and **M.J. Strub**. 1977. Spotted owl abundance in young versus old-growth forests, Oregon. Wildl. Soc. Bull. 5(2):43-47.

A survey to determine the relative abundance of spotted owls (*Strix occidentalis*) in second-growth and old-growth forests in western Oregon was conducted between 12 July and 11 August 1976. In old-growth, 17 pairs were located in 47 linear km, for an average density index of 0.36 pairs/km. Five pairs were located in 167 linear km of second-growth survey, for an average density index of 0.03 pairs/km. The 12-fold difference in owl

numbers in second-growth indicates that such forests provide, at best, marginal spotted owl habitat. Information on production of young by spotted owls in second-growth forests is needed before the owl's status in such forests can be fully evaluated.

211. **Foss, T.** 1990. New forestry: a state of mind. Inner Voice 2(1):4-6.

This discussion of New Forestry—a paradigm contrary to traditional forestry practices—focuses on ecosystems rather than just trees. According to the author, Dr. Jerry Franklin's concept of New Forestry, directed specifically to the Pacific Northwest, is based on the way a natural forest recovers from fire. Franklin's concept, consisting of several parts, is reviewed in further detail. Views of New Forestry by Chris Maser and Larry Harris are also considered. The place that selection harvest or uneven-aged management holds in modern forestry is discussed in some detail. The author follows with observations of how forest managers are dealing with several problems of selection harvesting in the Pacific Northwest. The need for a movement toward holistic forestry practices is emphasized. **

212. **Foster, J.R.** and **W.A. Reiners**. 1986. Size distribution and expansion of canopy gaps in a northern Appalachian spruce-fir forest. Vegetatio 68:109-114.

Canopy gap area/age distributions and growth mechanisms were examined in a virgin subalpine forest in the White Mountains, New Hampshire, USA. The gap area distribution was negative exponential in form. Within gap tree ages varied widely in response to stepwise gap expansion caused by windthrow of peripheral trees or death of standing mature *Picea rubens* at gap edges. As a consequence, the density of small gaps may have been underestimated and the density of large gaps overestimated. The estimates of canopy turnover time, 303 yr, and of patch birth rate on an area basis, 3.3 x 10^3 ha new patches/ha land area/yr, were not affected by the gap expansion phenomenon. However, any estimate of patch birth rate as numbers of new patches formed per year would have been too low. Because of increasingly widespread *Picea* death, the patch area/age distribution of this forest may not currently be in steady-state.

213. **Foster, R.E.** and **G.W. Wallis**. 1974. Common tree diseases of B.C. 2nd ed. Can. For. Serv., Ottawa, ON. Publ. No. 1245. 116 p.

This report describes the infectious and non-infectious diseases known to affect the trees of British Columbia. Infectious diseases included here are mistletoes, root and butt rots, rusts, cankers, heart rots, sap rots, blights and casts, needle and cone rusts, foliage diseases of broadleaved trees as well as witches broom, cork-bark, and burls and galls. Non-infectious diseases include cedar flagging, pole blight, terminal injury, forest lesions, sunscald, top killing basal and trunk scars, sapsucker damage, winter kill and fume injury.

214. **Fowler, W.B.** and **H.W. Berndt**. 1971. Efficiency of foliage in horizontal interception. Proc. West. Snow Conf. 39:27-33.

A description of how foliar characteristics affect rime and hoarfrost collection in Washington. Cylinders of various sizes, branches of alpine fir and lodgepole pine, and a 7 ft lodgepole pine were continuously weighed. The surface area of needles on the tree was 223,000 cm^2. Within the first 12 hours, there was no species effect on rime collection. Many aspects of the process remain to be investigated.

215. **Fowler, W.B., J.D. Helvey,** and **E.N. Felix**. 1987. Hydrologic and climatic changes in three small watersheds after timber harvest. U.S. Dep. Agric. For. Serv., Pac. NW Res. Stn., Portland, OR. Res. Paper PNW-RP-379. 13 p.

No significant increases in annual water yield were shown for three small watersheds in northeastern Oregon after shelterwood cutting (30-percent canopy removal, 50-percent basal area removal) and clearcutting. Average maximum air temperature increased after harvest and average minimum air temperature decreased by up to 2.6°C. Both maximum and

minimum water temperatures decreased slightly in two streams as compared with the control stream. Wind passage and velocities increased dramatically with removal of the forest cover. Both snow depth and snowpack water content increased in clearcuttings.

216. **Fox, J.F.** 1989. Bias in estimating forest disturbance rates and tree lifetimes. Ecology 70(5):1267-1272.

Intervals between fires, tree blowdowns, and other large and small forest disturbances are often estimated by dating tree rings. Dates are taken from living trees, fallen logs or stumps, or other indicators such as peaks in tree age distributions and ages of understory plants damaged by treefalls. Such indicators disappear gradually over time; this will bias estimates of disturbance recurrence times or tree lifetimes. Models and simulations employing plausible rates of disturbance and indicator disappearance show that the bias can be substantial. Comparison of a realistic simulation with simpler models suggests that it may not be difficult to correct the bias, given estimates for indicator survival rate. I recommend that investigators estimating forest-disturbance recurrence times also estimate survival rates for their indicators, and collaborate with statisticians (about estimating survival times with censored data) before designing field studies.

217. **Fox, J.L., C.A. Smith,** and **J.W. Schoen**. 1989. Relation between mountain goats and their habitat in southeastern Alaska. U.S. Dep. Agric. For. Serv., Pac. NW Res. Stn., Portland, OR. PNW-GTR-246. 25 p.

Mountain goats in southeastern Alaska occupy habitats providing abundant areas of high-quality forage during summer but only limited feeding areas during winter because of deep snow. Winter is a period of severe nutritional deprivation, and goats converge into areas with available forage, often within old-growth forest where relatively low snow depths and litterfall enhance food availability. Goats are further restricted in their habitat use to sites within and near steep and rugged terrain, which provides escape areas from predation by wolves. Because goat winter habitat is limited, even small areas of habitat alteration that impinge on these sites can have a disproportionally large effect on the goat populations concentrated there. Removal of old-growth forest would decrease available forage and thus lower the quality of goat wintering sites when snow-packs are present. Whereas the effects of forest management might be locally important for goats, the total amount of goat habitat subject to this or other habitat alteration is likely to be small and should not greatly affect goat carrying capacity in southeastern Alaska. But, where forest management or other human land use occurs within goat habitat, the limited areas of actual conflict may make avoidance of critical goat habitat practical. Research is needed on digestive physiology of goats, habitat use by goats within the critical areas surrounding escape terrain, and the relations of forest management to goat populations.

218. **Fox, R.J.** 1988. The wildlife of northern British Columbia: past, present and future. Proc. Symp., Nov. 1987. Spatsizi Assoc. Biolog. Research, Smithers, BC. 159 p.

The symposium, organized as part of Canada's 1987 Wildlife Centennial celebrations, was designed to increase public awareness and appreciation of the wildlife of northern British Columbia. Included in Part I of the symposium are papers on wildlife prehistory and northern British Columbia's diversity of habitat, big-game mammals, furbearing mammals, small non-game mammals, grizzly bears, and the bird and marine life of the Queen Charlotte Islands. Part II focuses on the future conservation of British Columbia's wildlife and the roles of both government agencies and the public in effective conservation practices. **

219. **Frankel, O. H.** and **E.M. Soulé**. 1981. Conservation and evolution. Cambridge Univ. Press, Cambridge, England.

The conservation of genetic diversity is the central theme of this book. The authors stress that conservation must mean the retention of natural communities under conditions which provide the potential for continuing evolution. In keeping with the central theme, a major portion of the publication is devoted to a discussion of the underlying biological and genetic principles for the conservation of all life forms. The genetic basis of conservation is explored in terms of fitness, population size, and genetic diversity. This book may superficially be divided into three major sections: the first deals with wild biota; the second with the role of zoological and botanical gardens; and the third with domesticated species. Other topic areas include: the process of extinction, the role of population and evolutionary genetics in conservation, and the role of nature reserves in conservation. **

220. **Franklin, J.F.** 1977. Effects of uneven-aged management on species composition. *In* Proc. Workshop on Uneven-aged Silviculture and Management in the Western United States. Oct.19-21, 1976, Redding, CA. U.S. Dep. Agric. For. Serv., pp. 64-70.

This article is part of an in-service workshop designed to consider the effects of uneven-aged management on species composition. Two questions are addressed: 1) Will selection forestry lead to undesirable shifts in stand composition? and 2) Is uneven-aged management for a preferred species in a given forest type possible? The author describes the potential for uneven-aged management without disruption of species composition, and identifies generalities that are relevant to the consideration of management alternatives. The conclusion is that it is technically possible to practice some form of uneven-aged management with western forests, without undergoing unacceptable changes in species composition. The autecology of a species and its succesional role on a specific habitat type must be considered. The strongest tendencies towards shifts in composition of forest stands come on evironmentally moderate to favorable sites where a preferred intolerant species is subject to succesional pressures from aggressive tree (or shrub and herb) competitors. **

221. ————. 1981. Vegetation of the Douglas-fir region. *In* Forest Soils of the Douglas-fir Region. P.E. Heilman, H.W. Anderson, and D.M. Baumgartner (editors). Wash. State Univ., Coop. Ext. Serv., Washington, DC, pp. 93-112.

The Douglas-fir region of western Washington and Oregon and northwestern California is one of the most densely forested areas of the world. It represents maximal development of the temperate coniferous forest. The region is well known for the extensive areas dominated by Douglas-fir, with climax forests of western hemlock and western redcedar, and coastal "rain forests" of coast redwood and Sitka spruce. In this chapter I will attempt to outline major compositional, structural, and successional features of these varied and productive forests. More thorough accounts of the forest zones and communities that make up the Douglas-fir region are found in Franklin and Dyrness (1973).

222. ————. 1984. Comments on natural diversity. *In* Proc. Symp. on Natural Diversity in Forest Ecosystems. J.L. Cooley and J.H. Cooley (editors). Nov. 29-Dec. 1, 1982, Athens, GA. Inst. Ecol., Univ. Georgia, Athens, GA, pp. 31-34.

This paper discusses old-growth forests and biodiversity in the Pacific Northwest. The author addresses four points: 1) our current interest in diversity; 2) uncommon species and specialized habitats; 3) diversity versus successional stage; and 4) maintenance of structural diversity within forest stands. In his concluding comments, the author emphasizes that snags and down logs are important characteristics to forests of all ages and cannot be eliminated without numerous ecological consequences. He urges that structural diversity, including snags and logs, be recognized in guidelines for considering diversity in national forest and land use planning. **

223. ———————. 1987. Scientific use of wilderness. *In* Proc. on National Wilderness Research: Issues, State-of-Knowledge, Future Directions. R.C. Lucas (compiler). July 23-26, 1985, Fort Collins, CO. U.S. Dep. Agric. For. Serv., Intermtn. Res. Stn., Fort Collins, CO. Gen. Tech. Rep. INT-220, pp. 42-46.

Relatively little scientific use has been made of wilderness areas despite the outstanding opportunities they provide for research. Examples are given of the applicability of wilderness-based research to solution of problems outside wilderness areas, such as those on commodity lands. Deterrents to research include attitudes of scientists and managers, restrictions on equipment and sampling techniques, and conflicting human activities. Suggestions are made for increasing the level of wilderness research.

224. ———————. 1988. Structural and functional diversity in temperate forests. *In* Biodiversity. E.O. Wilson (editor). National Academy Press, Washington, DC, pp. 166-175.

This chapter contains the author's views on some major needs in preserving and enhancing biotic diversity in temperate forest regions. These needs are to maintain or, where absent, to create a complete array of forest successional stages, including old-growth forest conditions; to maintain structural and functional diversity throughout the forest landscape (e.g., by retaining standing dead trees and fallen logs); to protect aquatic diversity in the streams, lakes, and rivers associated with temperate forests; and to develop effective stewardship programs that can maintain (and create, when necessary) natural area preserves within intensively used landscapes. There is also a critical need to integrate biodiversity objectives into management of all our landscapes because preservation of selected tracts of land, even on the largest scale possible, will not by itself achieve the desired goal of maintaining Earth's biodiversity. **

225. ———————. 1989. A kinder, gentler forestry in our future: the rise of alternative forestry: remarks from Oregon's Forests 2010 Conf. Trumpeter 6(3):99-100.

The author calls for the need to develop a new approach to forestry that is probably less efficient per unit, but which accommodates a range of ecological values while yielding economic benefits. Leaving green trees at time of harvesting, allowing for continued input of woody debris, and managing for stands with variable composition and structure are some basic elements of the new forestry. At the landscape level, patch size and orientation, consideration of cumulative effects of treatments, and use of semi-natural areas provide management alternatives. The author maintains that silvicultural systems that incorporate diversity are essential to the maintenance of biological diversity, as protected areas become increasingly fragmented and vulnerable to pollution and global climatic change. **

226. **Franklin, J.F.** and **T. Blinn**. 1988. Natural vegetation of Oregon and Washington: commentary and bibliographic supplement. Oreg. State Univ. Press, Corvallis, OR.

The authors have compiled a bibliography of articles and reports relevant to the natural vegetation of Oregon and Washington, which have been published since Franklin and Dyrness's original work in 1973. Areas of research include plant community analysis and classification, disturbance ecology, ecosystem processes, and scientific reserves. **

227. **Franklin, J.F., K. Cromack, Jr., W.C. Denison, A. McKee, C. Maser, J.R. Sedell, F.J. Swanson,** and **G.P. Juday**. 1981. Ecological characteristics of old-growth Douglas-fir forests. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-118. 48 p.

Old-growth coniferous forests differ significantly from young-growth forests in species composition, function (rate and paths of energy flow and nutrient and water cycling), and structure. Most differences can be related to four key structural components of old growth:

large live trees, large snags, large logs on land, and large logs in streams. Foresters wishing to maintain old-growth forest ecosystems can key management schemes to these structural components.

228. **Franklin, J.F., N.D. Davis, F.J. Swanson,** and **S. Eubanks**. 1989. Toward a new forestry. Am. For. (Nov/Dec):37-44.

This article summarizes Franklin's revolutionary forest management theory of maintaining the forest ecosystem and not just producing wood. It includes biographical notes on Franklin and the developmental process which led to his current theory. **

229. **Franklin, J.F.** and **D.S. DeBell**. 1988. Thirty-six years of tree population change in an old-growth *Pseudotsuga-Tsuga* forest. Can. J. For. Res. 18:633-639.

Tree populations exhibited considerable individual plant mortality and replacement over a 36-year period in a 500-year-old *Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii* (Douglas-fir) - *Tsuga heterophylla* (Raf.). Sarg. (western hemlock) forest in the Cascade Range of southern Washington, USA. Nearly 22% (113/ha) of the original stems died at an annual rate of 0.75%. This was balanced by recruitment (117/ha) of *Tsuga, Abies amabilis* Dougl. ex Forbes (Pacific silver fir), and *Taxus brevifolia* Nutt. (Pacific yew) saplings. Diameter distributions and relative species composition were nearly identical at the beginning and end of the 36 years. Compositional changes were slow despite the high turnover; extinction of *Pseudotsuga* is predicted in 755 years at its current mortality rate. Mortality was generally caused by wind (45.5%) or suppression and unknown causes (39.4%). Additional long-term studies of old-growth forests are needed to understand the direction and rate of successional change.

230. **Franklin, J.F., L.J. Dempster,** and **R.H. Waring.** 1972. Research on coniferous forest ecosystems: first year progress in the Coniferous Forest Biome, US/IBP. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. 322 p.

This report presents the papers from a symposium held in Bellingham, Washington, in March 1972. The symposium was organized to summarize and report on the first year's efforts of the U.S. International Biological Program's integrated ecosystem research in the coniferous forest biome of the Pacific Northwest. Papers were presented under five general sections. The first section provided an overview of the coniferous forest biome and the organization of the program as well as papers on modelling and classification of ecosystems. The movement of water and nutrients through the ecosystems was discussed in the second section. Papers on the measurement and techniques of estimating biomass and populations were included in the third section. Section four consists of terrestrial process studies and section five cover saquatic process studies.

231. **Franklin, J.F.** and **C.T. Dyrness.** 1973. Natural vegetation of Oregon and Washington. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-8. 417 p.

Major vegetational units of Oregon and Washington and their environmental relationships are described and illustrated. After an initial consideration of the vegetation components in the two States, major geographic areas and vegetation zones are detailed. Descriptions of each vegetation zone include composition and succession, as well as discussion of variations associated with environmental gradients. Three chapters treat the forested zones found in the two States. Major emphasis is on the distinctive mesic temperate forests found in western Washington and northwestern Oregon. The interior valley forests, shrub lands, and prairies found between the Coast and Cascade Ranges in western Oregon are treated in a single chapter as are subalpine and alpine mosaics of tree-dominated and meadow communities. Unusual habitats, such as areas of recent vulcanism, serpentines, and ocean strand, are individually described. Soils, geology, and climate are considered in broad outline in an early chapter and in greater detail within discussions of individual geographic areas and

vegetation zones. Appendices are included for definition of the various soil types, scientific and common plant names, and a subject index. An extensive bibliography is included to direct the reader to other references.

232. **Franklin, J.F.** and **R.T.T. Forman**. 1987. Creating landscape patterns by forest cutting: ecological consequences and principles. Landscape Ecol. 1(1):5-18.

Landscape structural characteristics, such as patch size, edge length, and configuration, are altered markedly when management regimes are imposed on primeval landscapes. The ecological consequences of clearcutting patterns were explored by using a model of the dispersed patch or checkerboard system currently practiced on federal forest lands in the western United States. Thresholds in landscape structure were observed on a gradient of percentages of landscape cutover. Probability of disturbance, e.g., wildfire and windthrow, and biotic components, e.g., species diversity and game populations, are highly sensitive to these structural changes. Altering the spatial configuration and size of clearcuts provides an opportunity to create alternative landscapes that differ significantly in their ecological characteristics. Both ecosystem and heterogeneous landscape perspectives are critical in resource management.

233. **Franklin, J.F.** and **M.A. Hemstrom**. 1981. Aspects of succession in the coniferous forests of the Pacific Northwest. *In* Forest succession: concepts and applications. D.C. West, H.H. Shugart, and D.B. Botkin (editors). Springer-Verlag, New York, NY, pp. 212-229.

This chapter explores aspects of succession in the coniferous forests west of the Cascade Range in the Pacific Northwest of the U.S. The authors' objectives are fourfold: 1) to contrast succession in the above forest type with temperate deciduous forests and with conifer forests in boreal and arid regions; 2) to detail recent advances in the understanding of succession in Pacific Northwest forests; 3) to examine the role of coarse woody debris in succession; and 4) to explore some of the successional modeling problems posed by Northwest forests. The authors conclude that Pacific Northwest coastal forests differ from the above-mentioned forest types in several respects, most notably in that trees grow very large and old; above-ground biomass values are much greater, sometimes exceeding 1500 metric tons/ha; and leaf areas are very high, reaching 20 m^2/m^2. The authors also note that Northwest forests recover slowly after disturbance. Canopy closure may take 40 years or more and early seral intolerant trees can live over 100 years. Other findings: when early seral, intolerant trees are important in the initial stand, climax conditions occur only rarely; climax species are often an important influence in future stand composition and structure; and northwestern forests are difficult to model using FORET-type successional models. **

234. **Franklin, J.F., W.H. Moir, M.A. Hemstrom, S.E. Greene,** and **B.G. Smith**. 1988. The forest communities of Mount Rainier National Park. U.S. Dep. Int., National Park Serv., Washington, DC. Sci. Monogr. Ser. No. 19. 194 p.

The forests of Mount Rainier National Park are a major natural resource. They extend up the mountain slopes to an elevation of about 1800 m (5,800 ft) and occupy 60% of the Park landscape. This phytosociological study, conducted during 1975-80, has provided a detailed description and classification of these forests for the use of park managers and visitors. The forests lie within three zones based upon the major climax tree species: *Tsuga heterophylla, Abies amabilis*, and *Tsuga mertensiana*. A total of 14 plant associations and 5 community types were recognized across the range of environmental conditions represented within the Park. The moist forest types have rich understories that include numerous herbaceous species and shrubs such as *Oplopanax horridum*. The *Abies amabilis/Vaccinium alaskaense* association is typical of modal environments and the most extensive formation within the Park. Dry associations are typified by *Gaultheria shallon*- and *Berberis nervosa*-dominated understories. High-elevation forest types belong to the cold grouping and are typified by herbaceous understories on better drained sites and by dense understories of ericaceous shrubs on wet sites. Forest types show strong relations with elevation and landform,

although details vary in the four Park quadrants. Moisture, temperature, and duration of snowpack appear to be the primary environmental variables. Wildfire has been the major forest disturbance; approximately 90% of the forests have arisen after fire, 7% after avalanche, and 2% after lahars. The natural fire rotation was calculated as being 465 years before white settlement of the region. Climatic episodes appear to have been important in creating conditions for wildfire. Uses of the forest type classification by managers include interpretations of the potential value of sites for development, productivity and resilience, value for wildlife, and visitor interest. Large color-keyed maps (Plates 1 and 2) are included on the inside back cover to show the distribution of the plant associations and major forest age classes within the park. (Authors' summary)

235. **Franklin, J.F., D.A. Perry, T.D. Schowalter, M.E. Harmon, A. McKee,** and **T.A. Spies**. 1989. Importance of ecological diversity in maintaining long-term site productivity. *In* Maintaining the long-term productivity of Pacific Northwest forest ecosystems. D.A. Perry, R. Meurisse, T.B. Miller, J. Boyle, J. Means, C.R. Perry, and R.F. Powers (editors). Timber Press, Portland, OR, pp. 82-97.

Long-term site productivity is ultimately dependent upon ecosystem resilience—an ability to absorb stress or change without significant loss of function—and not simply soil properties. Forest ecosystems are faced with dramatic changes in climate, pollutants, pests and pathogens. These uncertainties, coupled with our demonstrably inadequate knowledge of ecosystem function, strongly indicate management approaches which retain the genetic, structural, landscape, and temporal diversity critical to resilience. Current management emphases simplify forests. Alternative management programs that retain diversity, including schemes which accommodate early successional species, provide for coarse woody debris, create mixed stands, protect streamside habitats, and provide for diverse and functional landscapes, are suggested. Foresters must manage to retain greater ecological margins in order to sustain long-term productivity and buffer against uncertainties.

236. **Franklin, J.F., H.H. Shugart,** and **M.E. Harmon.** 1987. Tree death as an ecological process. BioScience 37(8):550-556.

In this paper, the authors discuss the causes, consequences and variability of tree death. Some common causes or contributors are such abiotic occurrences as fire, lightning, chemical pollution, environmental stress, wind damage, volcanic eruption, and climatic change. Biotic factors include old age, senescence, mechanical imbalance, inadequate photosynthesis, consumption by insects, ungulates, and humans, and tree disease. Tree death can result in a variety of ecological consequences such as altered tree population and community structure, a shift from biomass to necromass, and release of resources such as light, nutrients, and moisture. New resources are created by the death of a tree: habitat for wildlife and decomposer organisms, and synthesis of complex organic compounds. Uprooted dead trees also mix soil and falling trees kill other organisms by crushing. Spatial variation in tree death is influenced by abiotic causes such as windthrow and wildfires, as these events will occur at different frequencies over the landscape. Temporal variability is exemplified by the process of succession. High mortality occurs during a catastrophic disturbance and again with the colonizing of tree seedlings. As a forest canopy closes, competition becomes increasingly important in contributing to tree death. All of this illustrates how a seemingly simple process has many valid and useful perspectives and how the complex mechanisms which drive a single ecological process are still inadequately understood. **

237. **Franklin, J.F.** and **T.A. Spies**. 1984. Characteristics of old-growth Douglas-fir forests. *In* New Forests for a Changing World: Proc. 1983 SAF National Conven. K.A. Sabol (editor). Oct. 16-20, 1983, Portland, OR. Soc. Am. For., Bethesda, MD. SAF Publ. 84-03, pp. 328-334.

Old-growth forests in the Douglas-fir region are distinguished primarily by several structural characteristics including a wide range of tree sizes and ages, a deep multilayered crown canopy, large individual trees, and accumulations of coarse woody debris including snags and down logs of large dimension. Old-growth forests are compositionally diverse and include many species for which it is optimum habitat. Old-growth forests are productive although the bulk of the energy is used for respiration. Wood accumulations tend to be stable with growth at least balancing mortality. Nutrient losses and erosion are generally low in old-growth watersheds. The large trees, snags, and logs are the key structural features of old-growth; silviculturalists can use these as critical elements in developing and applying management schemes.

238. **Franklin, J.F., T.A. Spies, D.A. Perry, M.E. Harmon,** and **A. McKee**. 1986. Modifying Douglas-fir management regimes for nontimber objectives. *In* Proc. Symp. on Douglas-fir: Stand Management for the Future, Seattle, WA. C.D. Oliver, D.P. Henley, and J.A. Johnson (editors). Univ. Wash., Seattle, WA, pp. 373-379.

This paper deals with the values of non-timber resources in the Douglas-fir region. Concerns with current approaches to forest management are discussed. A general approach is suggested for the management of all forest resources for the future, the basic principle being to maintain or enhance complexity whenever possible, including genetic, structural and spatial variability. Non-timber management strategies are discussed for: 1) the accommodation of early successional species; 2) the management of large woody debris on commercial timberlands; 3) the development of mixed species and multi-structured stands; and 4) the protection of riparian habitats. Landscape issues are briefly mentioned. The authors conclude that once more ecologically prudent management approaches are adopted, there can be ecologically healthy ecosystems and many forest services and goods with relatively low penalties to wood production. **

239. **Franklin, J.F.** and **R.H. Waring**. 1980. Distinctive features of the Northwestern coniferous forests: development, structure and function. *In* Forests: Fresh Perspectives from Ecosystem Analysis. Proc. 40th Ann. Biol. Colloq. R.H. Waring (editor). April 27-28, 1979, Corvallis, OR. Oreg. State Univ., Corvallis, OR, pp. 59-86.

Our objective in this paper is to highlight some findings on the structure and function of coniferous forests of the Pacific Northwest. We also hope to transmit some sense of the progress and existing directions of current research and stimulate you to reexamine what you think you already know about these forests. We will cover: 1. biomass and productivity, 2. factors responsible for evergreen dominance and massiveness, 3. successionally oriented studies of age structure and coarse woody debris, and 4. aspects of old-growth systems. (From authors' introduction)

240. **Franson, R.T.** 1975. Ecological reserves legislation: a prescription for preservation. *In* Energy flow: its biological dimensions: a summary of the IBP in Canada. T.W.M. Cameron and L.W. Billingsley (editors). Roy. Soc. Can., Ottawa, ON, pp. 157-167.

A report of a project directed towards the development of ecological reserves to preserve a system of sites containing samples of the most naturally occurring ecosystems in Canada. The objective of the reported project was to discover the legal means that might be used to preserve these sites. Discussed are: 1) criteria for evaluating legislation; 2) existing legislation; 3) the B.C. Ecological Reserves Act; and 4) a description of recommended legislation. Advice for getting a program started for the creation of ecological reserves is offered. **

241. **Fraser, B.** 1990. Summary of the Old Growth Workshop: Towards an Old Growth Strategy. Nov. 3-5, 1989, Parksville, BC. B.C. Min. For., Integrated Res. Br., Victoria, BC.

This report summarizes the presentations made at the workshop, "Towards an Old-Growth Strategy." More than 80 delegates, representing the full range of groups associated with various resource and environmental issues in British Columbia, were invited to attend the workshop. The agenda included such topics as the definition of old growth, the social, economic, environmental, and scientific objectives for old growth, research and inventory requirements, criteria for selection of old-growth reserves, and a blueprint for an old-growth strategy. **

242. **Frear, S.T.** 1982. Ecological benefits of large organic debris in streams. For. Res. West (Feb.):7-10.

Researchers emphasize that the occurrence of large debris in streams is a natural process and vital to the river system. In small streams, large organic debris is the principal factor determining both their biological and physical characteristics. Large debris in streams increases the "roughness" of the stream channel, causing sediment and organic matter to be trapped and slowing its movement through the stream system.

Debris in streams also creates habitat for aquatic organisms both by serving as a substrate in the streambed and by modifying streamflow to form areas where material is deposited.

Management of the forests through which streams flow must neither create conditions that will place too much debris in streams nor attempt to clean them out in the belief of creating a better environment. Removal of large debris may reduce long-term productivity and increase the rate of sediment movement from headwater streams to the main river system. An outline of general guidelines to help minimize the impacts of human activity on the stream environment is also provided. **

243. **Fredriksen, R.L.** and **R.D. Harr**. 1981. Soil, vegetation, and watershed management. *In* Forest soils of the Douglas-Fir Region. P.E. Heilman, H.W. Anderson, and D.M. Baumgartner (editors). Coop. Ext. Serv., Wash. State Univ., Pullman, WA, pp. 231-260.

Timber harvesting alters the quality of water and the supply of soil and nutrients by changing the processes that control their movement from the land into streams. The loss of soil and nutrients from forests may be as detrimental to future productivity of forests as to present quality of stream water. The purpose of this chapter is to describe current knowledge about the impacts of forest management on streams and forests. The subjects covered here are hydrology, soil erosion, nutrient balance and stream temperature. (From authors' introduction)

244. **Fritschen, L.J.** and **P. Doraiswamy**. 1973. Dew: an addition to the hydrologic balance of Douglas fir. Water Resour. Res. 9(4):891-894.

The hydrologic balance of a 28-meter Douglas fir tree in a weighing lysimeter was determined for 2 clear days in May 1972. The results indicated dew accumulations of 6.4 and 10.9 liters, which represent 15 and 20% of 42.5 and 55.2 liters of evaporation from the tree. Since the dew was recorded as a weight increase, its source has to be the atmosphere. In the Pacific Northwest, conditions are favorable for dew formation during most of the summer and fall. Thus dew formation could represent a large part of the hydrologic balance of fir forests.

245. **Gaddy, L.L.** 1977. Notes on the flora of the Congaree River floodplain, Richland County, South Carolina. Castanea 42(2):103-106.

The Congaree River floodplain forest, part of which has been referred to as the only remaining virgin bottomland forest in the Southeast, harbors twenty-six State record-sized trees. Although a complete floristic study of the area is yet to be done, five county records, three of which are rare in the Carolinas (Radford *et al.* 1968), have been found in the Beidler Tract of the floodplain.

246. **Gadgil, M.** 1984. Conserving biological diversity: the Indian experience. *In* Ecology in Practice. Part 1: ecosystem management. F. di Castri, F.W.G. Baker, and M. Hadley (editors). Indian Inst. Sci., Bangladore, India, pp. 485-491.

The biological resources of India were greatly depleted during the period of British rule, a process that has accelerated since. Traditionally, conservation focused on the protection of species or ecosystems for religious purposes and the protection of the hunting reserves of rulers. These efforts focused on individual species such as the tiger, rather than on the overall biological diversity. Concern for India's biological diversity arose in earnest during the debate over the Silent Valley, a rich rainforest area threatened by a dam. Since then, the biosphere reserve program has progressed to where there are several areas in India being considered for protection. The success of the biosphere reserve program depends on the local population being guaranteed a living in the rejuvenation of devastated lands which surround the potential reserves, thereby taking pressure off the reserve core areas. **

247. **Gagnon, D.** and **G.E. Bradfield.** 1986. Relationships among forest strata and environment in southern coastal British Columbia. Can. J. For. Res. 16:1264-1271.

Data from coastal forests on west-central Vancouver Island were used to examine correlations between compositional variation in six forest strata among themselves (trees, saplings, tree seedlings, shrubs, herbs, and bryophytes) and with site environmental variables. These relationships were examined with data from three geographical areas: (i) a dry inland area dominated by *Pseudotsuga menziesii*, (ii) a wet coastal area dominated by *Thuja plicata*, and (iii) the entire study area including a few sites dominated by *Abies amabilis*. Principal component analysis was used to summarize the main compositional variation within the strata of each of the three areas. Canonical correlation analysis was then used to assess the degree of correlation among strata, as well as between strata and several environmental variables. Patterns of correlation among strata differed in the three geographical areas analysed. The most strongly correlated strata were commonly associated with similar environmental factors, although the total variance in the data explained by the correlations was low (<18%). Strata growing on rotting logs, in many parts of the study area (saplings, tree seedlings, shrubs, and bryophytes), tend to be highly intercorrelated. These same strata are weakly correlated with the herb stratum, which does not occur on rotting logs.

248. ————————. 1987. Gradient analysis of west central Vancouver Island forests. Can. J. Bot. 65:822-833.

The objective of this study is to describe the structure, composition, and ecological relationships of old-growth forests of west central Vancouver Island. Data were obtained by sampling 172 plots, at elevations up to 1000 m, located within 13 drainage areas. Relationships between vegetation and environmental variation were examined using indirect and direct gradient analysis. Successive reciprocal averaging ordinations using data from the tree, sapling, seedling, shrub, herb, and bryophyte-lichen strata led to the recognition of six vegetation groups (floodplain, subalpine, *Pinus contorta, Pseudotsuga, Thuja, Abies*) and 23 community types. Vegetation groups are differentiated along climatic and soil parent material gradients. The floodplain group occurs on alluvial terraces and the *Pinus contorta* group on rock outcrops. The vegetation of the *Pseudotsuga* group, dominant inland and influenced by fire disturbance, appears to respond to gradients of elevation and soil moisture. The *Thuja* group is found only near the coast, and its vegetation varies along gradients of soil nutrients and elevation, soil moisture having little effect. Wind is the strongest disturbance factor in this group. The vegetation patterns of the *Abies* group are correlated with elevation and soil moisture. Most community types of this group are associated with cool microclimates.

249. **Gary, H.L.** 1975. Airflow patterns and snow accumulation in a forest clearing. Proc. West. Snow Conf. 43:106-113.

An investigation of the question whether relatively large snow accumulation in clearings is due to theft from the surrounding forest or from interception and evaporation in the canopy. Windspeed in the forest was least where canopy biomass was greatest due to the larger number of frictional surfaces. Since this was in the mid-canopy region, windspeeds above and below the canopy were independent. Snow distribution under the canopy was more influenced by sub-canopy flow than by penetration of winds through the canopy. Clearing the strip one TH wide resulted in large snow buildups to the windward and depletion to the leeward. In total more snow was found in the clearing and less in the forest. Excess and deficit amounts were about equal. Airflow consisted of two regions: one a closed eddy extending from the middle of the clearing to 4 m downwind of the lee clearing edge; the other an upward flow on the windward side of the clearing. Maximum deposition was near the junction of the two airflows. Maximum depletion was in a slow air movement zone indicating that windscouring was not the cause of depletion.

250. **Geiger, Rudolf.** 1961. The climate near the ground. Harvard Univ. Press, Cambridge, MA. 611 p.

This book is a comprehensive review of microclimatology and is covered in nine chapters addressing ground level microclimate, heat budgets, the influence of topography on microclimate, man and animal relationships to microclimate, and techniques used in microclimatologic and micrometeorologic investigations. Chapter six discusses problems in forest meteorology and focuses on old stands. Radiation, heat balance and wind, air temperature and humidity, and dew, rain, and snow in old stands are discussed. **

251. **Geiszler, D.R., R.I. Gara, C.H. Driver, V.F. Gallucci,** and **R.E. Martin**. 1980. Fire, fungi, and beetle influences on a lodgepole pine ecosystem of South-Central Oregon. Oecologia 46:239-243.

Interactions between fire, fungi, bark beetles and lodgepole pines growing on the pumice plateau of central Oregon are described. Mountain beetle (*Dendroctonus ponderosae*) outbreaks occur mainly in forests that are 80-150 years old with a mean diameter of about 25 cm and weakened by a fungus, *Phaeolus schweinitzii*. The outbreak subsides after most of the large diameter trees are killed. The dead trees fuel subsequent fires which return nutrients to the soil, and a new age class begins. The surviving fire scarred trees are prone to infection by the slow fungal disease and about 100 years later these trees are then susceptible to bark beetle attack.

In preliminary surveys of lodgepole pine stands growing on the pumice plateau, we noted that (1) the older pines, ca. 80-150 years old, were being removed by an ongoing *D. ponderosae* outbreak; (2) a large percentage of the trees had fire scars; (3) a slow moving fungus, *Phaeolus schweinitzii* (Fr.) Pat., seemed to be associated with fire scarred trees. We wished to learn if these events were interrelated and associated with the persistence of lodgepole pine in the area.

252. **Gholz, H.L.** 1982. Environmental limits on aboveground net primary production, leaf area, and biomass in vegetation zones of the Pacific Northwest. Ecology 63(2):469-481.

Mature vegetation from eight of the 12 major vegetation zones in Oregon and Washington was sampled along a transect from the Pacific Coast to the east slopes of the Cascade Mountains. Six stands were in forests, one in woodland, and one in the shrub-steppe. Aboveground-overstory net primary production (NPP estimated as the sum of annual stem, branch, and foliage production) ranged from <1 to 15 Mg/ha/yr, aboveground biomass from 3 to 1500 Mg/ha, and area of all sides of leaves from 1 to 47 ha/ha; minima were in the shrub-steppe zone and maxima in the coastal forest zone.

Maximum leaf area index, biomass, and NPP were all strongly related both to a simple index of growing season water balance and to mean minimum air temperatures in January. In the subalpine conifer zone, though, cold winter temperatures apparently have a stronger influence than summer water availability. Of the water balance components, evaporative demand alone could account for >90% of the variation in leaf area index. Although annual precipitation ranged from 20 cm in the shrub-steppe to 260 cm at the coast, it was a relatively poor predictor of stand structure and production. Biomass and NPP increased linearly up to a leaf area of ≅ 30 ha/ha; above this point, biomass continued to increase while NPP decreased. Except in the coastal forest zones, NPP was less than maximum values reported for other mature systems elsewhere in the world for the same range in leaf area indices. Compared to other forested regions of the temperate zone with the same NPP, these systems receive more annual precipitation, and average twice the basal area and biomass.

253. **Gholz, H.L., F.K. Fitz, and R.H. Waring**. 1976. Leaf area differences associated with old-growth forest communities in the western Oregon Cascades. Can. J. For. Res. 6:49-57.

Total leaf area varied from 20 to 42 m^2/m^2 in 250- to 450-year-old forest communities developed under different temperature and moisture conditions. The largest values were in communities at midelevations where winter snowpack accumulated and growing-season temperatures were cool. Shrub and herb leaf area varied from 3% to 14% of the total. Equations for converting from foliage biomass to surface area are included for most species encountered.

254. **Gholz, H.L., G.M. Hawk, A. Campbell, K. Cromack, Jr.** and **A.T. Brown**. 1985. Early vegetation recovery and element cycles on a clear-cut watershed in western Oregon. Can. J. For. Res. 15(2):400-409.

Above-ground biomass and leaf area, net primary production, and nutrient cycling through vegetation were studied for 3 years after clear-cutting (stems only) a 10.24-ha watershed in the Oregon Cascade Mountains. The riparian zone and 4 main habitats were analysed separately. In 3 years, aboveground net primary production increased from 5 to 112 g/m^2/year in the ridgetop habitat; midsummer aboveground biomass increased from 8 to 196 g/m^2 in the riparian zone and from 198 to 327 g/m^2 on the ridgetop. Other values were intermediate to these. Litter fall of species with perennial above-ground parts averaged 20-27% of standing biomass. Native annuals, especially *Aralia californica* Wats., dominated the riparian zone. *Senecio sylvaticus* L., an introduced species, dominated most of the rest of the watershed, except for the ridgetop habitat, which was dominated by residual woody shrubs. Uptake of N exceeded losses in streamflow the 1st year and was six times greater in the 2nd; uptake of P and K in that year was 2.5 and 3 times greater than losses. In the 3rd year, total uptake of K (2.5 g/m^2) equaled the preclear-cutting level and uptake of N (1.3 g/m^2) and P (0.3 g/m^2) was about half that level. No correlation was found between plant uptake and nutrient loss in streamflow. Uptake of all elements exceeded return through leaching and litter fall by 16%, except that of Mg, which exceeded return by 44%. Because of early dominance by species with annuals, the proportion of elements redistributed internally by vegetation was generally low. The amount of nutrients in flux through vegetation, atmosphere, and stream was small in comparison to the amount lost in the removal of tree stems.

255. **Gibbons, D.R.** and **E.O. Salo** (compilers). 1973. An annotated bibliography of the effects of logging on fish of the western United States and Canada. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-10.

This bibliography is an annotation of the scientific and nonscientific literature published on the effects of logging on fish and aquatic habitat of the Western United States and Canada. It includes 278 annotations and 317 total references. Subject areas include erosion and sedimentation, water quality, related influences upon salmonids, multiple logging effects, alteration of streamflow, stream protection, multiple-use management, streamside

vegetation, stream improvement, and descriptions of studies on effects of logging. A review of the literature, a narrative on the state of the art, and a list of research needs determined by questionnaires are included.

256. **Giles, D.G., T.A. Black,** and **D.L. Spittlehouse.** 1985. Determination of growing season soil water deficits on a forested slope using water balance analysis. Can. J. For. Res. 15:107-114.

Coefficients for the calculation of soil water balance components at seven sites on a forested slope were determined using only measurements of daily solar irradiance, maximum and minimum air temperature and rainfall, and weekly root zone soil water content during a 2-year period. Site parameters required were root zone depth, soil water retention characteristics, and rainfall interception coefficients. Based on daytime net radiation, the Priestly-Taylor evapotranspiration coefficient (α) was found to be 0.73 ± 0.07, which is similar to values reported in other conifer forest studies. Growing season water deficit increased with decreasing root zone water storage capacity, which was mainly a function of root zone depth. A comparison between high and low elevations on the slope showed 100-year site indices ranging from 17 to 53 m corresponding to growing season soil water deficits during the driest year of the study, ranging from 79 to 4 mm. Basal area annual increments were found to be correlated with soil water deficits and growing season transpiration, both for the study period and when both variables were averaged over the last 18 years.

257. **Gillis, A.M.** 1990. The new forestry: an ecosystem approach to land management. BioScience 40(8):558-562.

This is an article on new forestry—a strategy designed to manage land to accommodate ecological values while allowing for the extraction of commodities. This strategy places emphasis on management of forests as complete ecosystems rather than just as tree factories. The main objectives of new forestry discussed in this article are management for long-term site productivity and maintenance of the natural complexity of ecosystems. New forestry in the Pacific Northwest is discussed with special reference to the northern spotted owl and its dependance on old-growth forests for habitat. According to some ecologists and forest engineers, several areas should be studied further before new forestry practices are put into widespread use. Seven areas that require greater research are listed and briefly discussed. The author closes with emphasis on the need for new forestry practices for a healthy future of our forests. **

258. **Gilpin, M.E.** and **M.E. Soulé.** 1986. Minimum viable populations: processes of species extinction. *In* Conservation biology: the science of scarcity and diversity. M.E. Soulé (editor). Sinauer Assoc. Inc., Sunderland, MA, pp. 19-34.

In this paper the authors take a conceptual and pluralistic overview of the process of extinction, aiming to integrate various models of population dynamics, ecology and population genetics. A general systems model, responsible for estimating minimum viable populations, is presented. This model is intended to be a guide for further work, not a solution towards the minimum viable population problem. Three topics are addressed within the framework of the model: 1) the dynamics of species viability; 2) deterministic and stochastic extinctions; and 3) four extinction vortices. **

259. **Glenn-Lewin, D.C.** 1977. Species diversity in North American temperate forests. Vegetatio 33(2/3):153-162.

Samples from temperate forest communities across the North American continent were analysed for correlations of plant species diversity with environment and community structure.

Alpha diversity relationships are complicated by different vegetation patterns and community history. The differences in community diversity patterns may be due to the independent evolution of communities in different regions.

Results of analyses were: 1) on a continental scale plant species diversity is related to mean annual temperature, but not precipitation; 2) diversity is substantially greater in continental climates than in maritime regions; 3) diversity-community structure relationships are generally weak; except 4) there is an inverse relationship between diversity and abundance of conifer tree species. Attempts to relate diversity to environmental parameters with multiple regression techniques met with only moderate success. (Author's summary)

260. **Goertz, J.W.** 1964. Habitats of three Oregon voles. Ecology 45:846-848.

Voles of the species *Microtus oregoni oregoni, M. townsendii townsendii*, and *M. montanus canicaudus* were collected from Coast Range and Willamette Valley habitats in western Benton County, Oregon, from June 1957 to January 1959, in an effort to determine habitat preferences.

Collecting results indicate that the Oregon vole is a species of the Coast Range mountains. It is found in all Coast Range (Douglas fir) habitats, but prefers grassy cutover areas.

Townsend voles are most closely associated with both Coast Range and Valley riparian situations especially where dense stands of sedge and grass occur.

The gray-tailed vole is found on all agricultural lands, especially in fields and pastures of grass and legumes and along fence rows. This species is not associated with Coast Range habitats. The gray-tailed vole is at all times a potential agricultural pest.

261. **Golding, D.L.** 1982. Snow accumulation patterns in openings and adjacent forest. *In* Proc. of the Canadian Hydrol. Symp. '82: Hydrological Processes of Forested Areas. June 14-15, 1982, Fredericton, NB. National Res. Counc. Can. NRCC No. 20548, pp. 91-112.

The influence of elevation, aspect, forest cover, and forest openings on snow accumulation is reviewed. Results of snow accumulation studies at Marmot Creek experimental watershed and James River, Alberta, are discussed.

At Cabin subbasin of Marmot Creek snow accumulation in 8-10 H clearcut blocks averaged 22 percent greater from adjacent forest so that calculated interception loss averaged 18.3 per cent for the three years. Twenty-one hundred 3/4 - 1 1/4 H circular openings on Twin subbasin averaged 28 per cent greater snow accumulation than the uncut forest.

At James River, 10 replications of nine opening sizes showed greatest snow accumulation in 2-3 H openings (43-45 per cent greater than in the uncut forest) and least in the uncut forest and the 1/4 H opening. Interception loss averaged 12.5 per cent for four years. Snow accumulation in 1 H openings was as great with 1 H leave strips as with 6 1/2 - 8 1/2 H leave strips, indicating that closely-spaced 1 H openings can attain maximum snow accumulation.

262. ———————. 1987. Changes in streamflow peaks following timber harvest of a coastal British Columbia watershed. *In* Forest Hydrology and Watershed Management: Proc. International Symp. held during the XIXth General Assembly of the International Union of Geodesy and Geophysics. R.H. Swanson, P.Y. Bernier, and P.D. Woodard (editors). Aug. 9-22, 1987, Vancouver, BC. International Assoc. Hydrol. Sci., Wallingford, Oxfordshire. IAHS Publ. No. 167, pp. 509-517.

The objective of this paper was to document the effects of clearcutting in a coastal British Columbia watershed on stream flow peaks for the late fall-winter and summer seasons. Jamieson Creek and Elbow Creek were treatment and control basins, respectively. Winter storm peaks, generated by rain on melting snow, showed a 13.5% increase during clearcutting of Jamieson basin. This effect was not limited to a particular storm size class. Summer storm peak streamflows were not affected during clearcutting but post-clearcut

peak streamflows in winter and summer showed significant increases, presumably because of changes in precipitation patterns which resulted in storms of increased total precipitation. Jamieson basin was 19.2% clearcut. Correlations between peak winter streamflows and snowmelt rates were high. Differences were not observed in the size of peak flow or lag time between peak snowmelt and peak streamflow, whether or not melt rates were greater in the forest than in clearcut areas. **

263. **Golding, D.L.** and **R.H. Swanson**. 1978. Snow accumulation and melt in small forest openings in Alberta. Can. J. For. Res. 8:380-388.

A study was carried out from 1973 to 1976 to determine snow-trapping efficiency and ablation rates in circular openings of 1/4-6 tree heights (H) in diameter, spaced 10 H between centers. The greatest snow accumulation was in 2-H and 3-H openings, closely followed by 1-H and 3/4-H openings. Below 3/4 H, accumulation dropped off rapidly, with the minimum being in the uncut forest. Ablation rates (expressed as centimetres water equivalent per day) were least in the 1 H, with maximum rates in 5-H and 6-H openings.

In 1977 and 1978 measurements were made in 14 closely spaced (2 H between centers) 1-H openings. Snow accumulation and ablation rate were the same as in the more widely spaced 1-H openings.

264. **Golley, F.B.** 1984. Changing anthropogenic land use patterns and diversity. *In* Proc. Workshop on Natural Diversity in Forest Ecosystems. J.L. Cooley and J.H. Cooley (editors). Nov. 29-Dec. 1, 1982, Athens, GA. Inst. Ecol., Univ. Georgia, Athens, GA, pp. 133-140.

An essay written to make three points: 1. when we expand our interest from restricted areas such as biological reserves or parks to landscapes, we encounter human dominated environments; 2. mankind creates as well as limits biological diversity in these environments; and 3. a characteristic of modern society is rapid changes in landscape patterns and relatively rapid shifts in diversity. The fundamental question coming from this analysis is that of optimization. Is there an optimum level of landscape diversity which maintains biological, cultural, and economic diversity? Is maximum diversity chaotic? Is the highest quality of life or productivity at an intermediate level of diversity? The author concludes that man creates diversity through his manipulation of landscape and construction of new environments. This activity can be positive or negative. Thus, it is possible for the designer to organize the use of space so that the highest quality of life can occur. That point seems not to be at maximum diversity, but rather at some intermediate level. (From author's comments)

265. **Goodell, B.C.** 1963. A reappraisal of precipitation interception by plants and attendent water loss. J. Soil Water Conserv. 18:231-234.

A theoretical investigation of the claim that precipitation interception, and attendant vaporization, cause a compensating reduction in transpiration yielding little or no net loss to the atmosphere. The technique of comparing snow depths in the forest and in openings is subject to criticisms that the differences are due to differential distribution rather than loss. There are theoretical reasons to suggest that there is insufficient energy available to vaporize large quantities of snow or water. The transpiration hypothesis is questioned on the basis of several theoretical considerations.

266. **Gosz, J.R., R.T. Holmes, G.E. Likens,** and **F.H. Bormann**. 1978. The flow of energy in a forest ecosystem. Sci. Am. 238(3):92-102.

A forest ecosystem runs on energy initially obtained by the sun. These ecosystems are composed of a number of living organisms and the chemical and physical environments in which they live. In this paper, the ecosystem includes plants, animals, nutrients, organic debris, water and gases, and soils and minerals which are all linked by flows of nutrients and energy and by food webs. Consuming and producing organisms usually regulate the

amount of energy available in a given ecosystem. This paper discusses the flow of energy in the forest ecosystem of Hubbard Brook Experimental Forest in New Hampshire. Basic pathways of energy flow through forest ecosystems are illustrated, as are the energy flow in hardwood forests. Grazing and detrital food webs are also considered. Energy budgets for five major above-ground consumers—chipmunks, salamanders, birds, mice and shrews—and a general model of energy budgets are presented and discussed. **

267. **Graham, R.L.** and **K. Cromack, Jr**. 1982. Mass, nutrient content, and decay rate of dead boles in rain forests of Olympic National Park. Can. J. For. Res. 12:511-521.

Analysis of dead boles of *Picea sitchensis* (Bong.) Carr. and *Tsuga heterophylla* (Raf.) Sarg. in open- and closed-canopy forests of the Olympic Peninsula, Washington, USA, revealed that hemlock mortality in both forest types was due mainly to windthrow, whereas spruce typically died upright. The open forest contained 120 t/ha of dead bole wood; the closed forest contained 161 t/ha. Hemlock boles decayed more rapidly than the larger spruce boles, although both showed considerable variability. On a per-hectare basis, 146-223 kg of N, 147-197 kg of Ca, 39-61 kg of K, 18-29 kg of Mg, 6-14 kg of Na, and 17-29 kg of P were contained in dead boles of the open- and closed-canopy forests, respectively. Except for N and Mg, the nutrient concentrations of the wood were not significantly different after 33-68 years of bole decay. The N:P ratios increased with increasing decay for both species.

268. **Graham, R.T.** and **R.A. Smith**. 1983. Techniques for implementing the individual tree selection method in the Grand fir-Cedar-Hemlock ecosystems of northern Idaho. U.S. Dep. Agric. For. Serv., Intermtn. For. Range Exp. Stn., Ogden, UT. Res. Note INT-332. 3 p.

Methodology in stands using the individual tree selection silviculture method includes selecting stands and desired diameter distributions, determining the cutting cycle, and marking the stands. However, some cautions should be heeded.

269. **Graumlich, L.J., L.B. Brubaker,** and **C.C. Grier**. 1989. Long-term trends in forest net primary productivity: Cascade Mountains, Washington. Ecology 70(2):405-410.

Estimates of annual net primary productivity since 1880 for four high elevation forest stands in western Washington indicated that productivity has increased 60% during the 20th century. Because these stands were separated by up to 200 km and differed in species composition, elevation, and time since establishment, the observed trends in productivity imply a response to regionwide changes in environmental factors rather than to site-specific stand dynamics. Annual production is significantly correlated with long-term variation in summer temperature and short-term variation in annual precipitation since 1893, the beginning of continuous local meteorological records. Production is uncorrelated with atmospheric CO_2 concentrations, suggesting that direct CO_2 fertilization is currently unimportant in these forests.

270. **Greene, S.** 1988. Research natural areas and protecting old-growth forests on federal lands in western Oregon and Washington. Nat. Areas J. 8(1):25-30.

Research natural areas in the Pacific Northwest have played a role in protecting old-growth forest ecosystems since the establishment of the Metolius Research Natural Area in 1931. Recent concerns about remaining old growth have led to an attempt to define old growth and to determine the extent of old-growth acreage. Research natural areas are discussed in the context of the old-growth definition, how well they actually protect existing old growth, and whether they can continue to play a useful role. Suggestions for managing old-growth research natural areas include integrating them into the surrounding landscape, doing a better job of protecting edges, and having on-site natural area professionals deal with management.

271. **Gregory, K.J.** and **A.M. Gurnell.** 1988. Vegetation and river channel form and process. *In* Biogeomorphology. H.A. Viles (editor). Basil Blakewell Ltd., New York, NY, pp. 11-43.

In this chapter it is argued that it is now time for more coordinated study of the significance of vegetation on river channel form and process. This is a prerequisite for the further development of river management procedures.

Vegetation influences the supply of water and sediment to the river channel network, the morphology of river channels, and the routing of water and sediment through the network of river channels. Examples are provided to indicate how recent research is clarifying the intricate way in which vegetation is encompassed within the pattern of variables in the drainage basin system.

Factors controlling the ecological component (i.e., in-stream use) are reviewed and relationships with discharge discussed. In future management of rivers, it is important to think not only of vegetation and the effect that it has directly and indirectly on the river, but also of the ways in which river management can provide habitats for fauna, and particularly for fish. **

272. **Gregory, K.J., A.M. Gurnell,** and **C.T. Hill.** 1985. The permanence of debris dams related to river channel processes. Hydrol. Sci. 30:371-381.

Vegetation debris dams occur on average every 27 m of channel in a drainage basin in the New Forest, Hampshire, England, and within less than 12 months 36% changed position or were destroyed and 36% changed character. Such dams significantly affect the timing of flood peaks as they are routed through the channel network; their significance has been demonstrated by preliminary analysis of hydrograph travel times by measurements in a reach at different flow stages, and by measurements before and after dam clearance. There was a difference in travel time of over 100 minutes for the situation with and without dams for a discharge of 0.1 m^3/s but a difference of only 10 minutes for a discharge of 1.0 m^3/s along the same 4028 m channel reach.

273. **Gregory, S.V., G.A. Lamberti, D.C. Erman, K.V. Koski, M.L. Murphy,** and **J.R. Sedell.** 1987. Influence of forest practices on aquatic production. *In* Streamside management: forestry and fishery interactions. E.O. Salo and T.W. Cundy (editors). Univ. Wash., Seattle, WA. Contrib. No. 57, pp. 233-255.

Forestry practices potentially alter solar radiation, water temperature, sediment, nutrient, and litter inputs, woody debris, and channel structure—all of which influence the habitat and nutritional resources of aquatic organisms. Primary producers are generally stimulated by canopy removal and the increases in nutrients and temperature that often accompany timber harvest, but instability of stream sediments may decrease plant abundance. Microbial processes may be enhanced by increases in nutrients, detrital quality, and temperature, but microorganisms may be negatively affected by a decreased quantity of detritus or decreased oxygen concentrations. The ability of streams to retain algae and litter inputs for food resources and retain sediments for habitat is determined by channel complexity, especially accumulations of woody debris. Aquatic insects and other invertebrates respond to changes in habitat and food resources. Sedimentation and decreased substrate stability may decrease the abundance of aquatic insects. Herbivores benefit from stimulation of aquatic plants; detritivores may be negatively affected by the changes in detritus. Frequently, insect community structure shifts toward organisms that are more likely to drift, thereby increasing the availability of food for salmonids. Salmonids also more efficiently capture prey items in open areas where light intensities are greater. These potential benefits may be negated if thermal tolerances are exceeded by temperature increases, if sediments blanket rearing and spawning habitat, or if winter habitat is reduced. Changes in habitat, food, or temperature may also alter fish community structure and potentially increase competition with the species of interest.

Streams in harvested watersheds may therefore be more productive, but the abundance and distribution of organisms in these streams may fluctuate more than in streams in mature forests. Resource objectives must be clearly defined before fishery resources can be effectively managed in forest ecosystems. The landscapes and biotic communities of terrestrial and aquatic ecosystems are intricately linked, and effective management must acknowledge and incorporate such complexity.

274. **Grier,** C.C. 1978. A *Tsuga heterophylla - Picea sitchensis* ecosystem of coastal Oregon: decomposition and nutrient balances of fallen logs. Can. J. For. Res. 8:198-206.

Weight loss and changes in N, P, Ca, Mg, K, and Na content were determined for fallen *Tsuga heterophylla* (Raf.) Sarg. logs in a 121-year-old *Tsuga heterophylla - Picea sitchensis* (Bong.) Carr. stand on the central Oregon coast. Log ages ranged from 2 to 38 years.

Weights of fallen logs decreased in a roughly negative logarithmic pattern; after 38 years the average log had lost 34.5% of its original weight.

Nitrogen, calcium, and magnesium contents of logs increased for about the first 20 years and declined thereafter. Phosphorus and potassium contents decreased steadily with age. Sodium content increased with age. Except for calcium, nutrient input to log surfaces by litterfall and throughfall was greater than any increase in nutrient content.

275. **Grier, C.C., D.W. Cole, C.T. Dyrness,** and **R.L. Fredriksen**. 1974. Nutrient cycling in 37- and 450-year-old Douglas-fir ecosystems. *In* Integrated research in the coniferous forest biome. R.H. Waring and R.L. Edmonds (editors). U.S. International Biolog. Program, Univ. Wash, Seattle, WA. Conif. For. Biome Bull. No. 5, pp. 21-34.

Biomass and nitrogen, phosphorus, potassium, and calcium distribution, and biogeochemical and stand nitrogen, phosphorus, potassium, and calcium budgets were determined for 37- and 450-year-old *Pseudotsuga menziesii* (Mirb.) Franco stands in the U.S. Pacific Northwest. Biomass of the 450-year-old stand is greater, but annual growth is less than that of the 37-year-old stand. About 50% of the annual growth and over 50% of the nutrient uptake and return in the 450-year-old stand occurs in subordinate vegetation compared with less than 15% in the 37-year-old stand. Chemical differences in soil parent material between the two stands are reflected in both the biogeochemical and stand nutrient cycles.

276. **Grier, C.C., K.M. Lee, N.M. Nadkarni, G.O. Klock,** and **P.J. Edgerton**. 1989. Productivity of forests of the United States and its relation to soil and site factors and management practices: review. U.S. Dep. Agric. For. Serv., Pac. NW Res. Stn., Portland, OR. Gen. Tech. Rep. PNW-GTR-222. 51 p.

Data on net primary biological productivity of United States forest are summarized by geographic region. Site factors influencing productivity are reviewed.

This paper is a review of existing literature in the productivity of various forest regions of the United States, the influence of site factors on forest productivity, and the impact of various forest-management practices on site productivity.

277. **Grier, C.C.** and **R.S. Logan**. 1977. Old-growth *Pseudotsuga menziesii* communities of a western Oregon watershed: biomass distribution and production budgets. Ecol. Monogr. 47(4):373-400.

Living biomass, organic matter distribution, and organic matter production budgets were determined for plant communities of a small watershed dominated by 450-yr-old *Pseudotsuga menziesii* (Mirb.) Franco forests. Dominant trees in the communities were large, up to 175 cm diameter and 80 m tall.

Aboveground tree biomass of the various communities ranged from 491.8-975.8 tonnes/hectare, total aboveground living biomass ranged from 500.4-982.5 t/ha, total leaf biomass ranged from 10.4-16.3 t/ha and total organic matter accumulations ranged from 1,008.3-1,513.7 t/ha.

Total tree biomass in the various communities was more related to past mortality than habitat differences. Biomass of standing dead trees and fallen logs was generally inversely related to aboveground tree biomass. Amounts of woody detritus were large, ranging from 59.0-650.6 t/ha or 4.3%-43.0% of total community organic accumulation. Aboveground tree biomass increment was negative in all communities, ranging from -2.9 to -6.2 t/ha. Positive increment by shrubs and trees 15cm dbh, produced overall aboveground biomass increment of -2.5 to -5.0 t/ha. Mortality averaged 1% of standing biomass.

Aboveground net primary production in the various communities ranged from 6.3 to 10.1 t/ha/yr and was roughly proportional to standing biomass. Net primary production consisted entirely of detritus. Total community autotrophic respiration ranged from 102.9-203.7 t/ha/yr of which approximately 70% was by foliage. Gross primary production ranged from 111.2-216.8 t/ha/yr of which only 6.0%-7.9% was net primary production. Net ecosystem production ranged from 0.12-5.6 t/ha/yr, entirely as an accumulation of woody detritus on the soil surface.

Available evidence indicates larger peak biomass in seral *P. menziesii* than in climax *Tsuga heterophylla* forests. These communities may be in the process of declining from seral peak to steady-state climax biomass.

278. **Grier, C.C.** and **S.W. Running**. 1977. Leaf area of mature northwestern coniferous forests: relation to site water balance. Ecology 58:893-899.

Leaf area of mature coniferous forest communities of western Oregon appear to be related primarily to site H_20 balance rather than characteristics of tree species composing the community.

Leaf areas were determined for stands in communities ranked along measured gradients of precipitation and evaporative potential. Nine coniferous and 1 deciduous tree species were found in the various stands along these gradients. Leaf areas of these stands were linearly correlated with a simple site H_2O balance index computed from measurements of growing season precipitation, open pan evaporation, and estimates of soil H_2O storage. Species composition had no apparent influence on the relation between community leaf area and site H_2O balance.

279. **Grumbine, R.E.** 1988. Ecosystem management for native diversity: how to save the national parks and forests. Trumpeter 5(2):47-52.

The author discusses the factors that threaten the integrity of the national parks system. He reports the results of a number of studies that show the inability of the parks to support viable populations of large mammals. The new practice of ecosystem management incorporates a number of the attitude and management practices which the author believes are necessary to maintain current levels of natural diversity. The two main components of ecosystem management are conceptual principles (systems theory) and practical application. If the manager's goal is to maintain natural diversity, a number of policy and regulation changes, as well as changes in interagency cooperation, are required. The author follows with a discussion of some of the types of legislation and agency policies that need changing. **

280. ————————. 1990a. Protecting biological diversity through the greater ecosystem concept. Nat. Areas J. 10(3):114-120.

There is broad consensus today among biologists that an integrated system of large nature reserves is necessary to protect biological diversity at genetic, population, and landscape scales. Current species-oriented strategies do not capture important elements of biodiversity. The greater ecosystem concept is explored as a strategy that protects all elements of biodiversity. The concept provides for (1) habitat for viable populations of all native species, (2) areas large enough to accommodate natural disturbance regimes, (3) protection over a time line of centuries, and (4) integration of human use into protected areas at sustainable levels. Problems of defining and classifying greater ecosystems are discussed.

Implementation of the concept is addressed by focusing on economic, managerial, political, and public participation questions. The greater ecosystem concept challenges fundamental assumptions about nature and human values; the values implications behind protecting biodiversity are briefly explored.

281. ————————. 1990b. Viable populations, reserve size, and federal lands management: a critique. Conserv. Biol. 4(2):127-134.

An examination of current viable population theories and reserve size studies suggest that biological diversity for North American national parks and forests is inadequately protected. This conclusion is further supported by reviews of federal agency management plans and policies. Preservation of biodiversity is thwarted by lack of landscape-level management, insufficient data, competition between federal land management agencies, and bureaucratic inertia, among other factors. To address these problems, an ecosystem management model for reform is outlined. New legislation is also suggested. Ethical and social choices are recognized as the basis for any restructuring of land management to protect biodiversity.

282. **Gurnell, A.M.** and **K.J. Gregory**. 1984. The influence of vegetation on stream channel processes. *In* Catchment experiments in geomorphology. T.P. Burt and D.E. Walling (editors). Geo Books, Norwich, UK, pp. 515-535.

This paper reports the results of a study conducted to determine the influence of vegetation on stream channel process, conducted in the Highland Water basin in the New Forest, Hampshire. The vegetation was divided broadly into heathland and mixed woodland. The significance of vegetation was investigated at three scales: 1) in relation to drainage network dynamics and discharge within the subcatchment; 2) in relation to soil moisture variations and soil permeability on a single hillslope; and 3) in relation to the components of the main drainage network, with emphasis on channel form and change within the Highland Water itself. **

283. **Gutierrez, R.J.** and **A.B. Carey** (technical editors). 1985. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-185. 119 p.

The spotted owl is at the center of the old-growth forest and wildlife habitat management controversy in the Pacific Northwest. There is confusion about USDA Forest Service management activities, the present state of knowledge of spotted owl biology, and what further research is needed to provide managers with the tools to ensure viable populations as mandated by the National Forest Management Act. This proceedings documents current and past management activities, current knowledge, and research needs.

284. **Habeck, J.R.** 1978. A study of climax western redcedar (*Thuja plicata* Donn.) forest communities in the Selway-Bitterroot Wilderness, Idaho. N.W. Sci. 52(1):67-76.

Old-growth *Thuja plicata* forest communities occurring in the Selway-Bitterroot Wilderness in northern Idaho were the subject of investigation. It is within this wilderness that western redcedar reaches its southeastern range limits in Idaho. Mature, climax cedar groves sampled in both lower and upper drainage segments indicate that only the stands at higher elevations are reproducing themselves at this time. Lower cedar groves have well-developed overstories but lack reproduction. The lower cedar groves may be experiencing stress in consequence of lower moisture at its range limits and are incapable of reproducing successfully. A hypothesis is presented that high wildlife populations in the past depleted cedar reproduction, and this depletion effectively inhibited vegetative propagation of the redcedar.

285. ————————. 1985. Impact of fire suppression on forest succession and fuel accumulations in long-fire-interval wilderness habitat types. *In* Proc. Symp. and Workshop on Wilderness Fire, Nov. 15-18, 1983, Missoula, MT. U.S. Dep. Agric. For. Serv., Intermtn. For. Range Exp. Stn., Ogden, UT. Gen. Tech. Rep. INT-182, pp. 110-118.

Succession and fuel characteristics are described and discussed for a series of western redcedar (*Thuja plicata*) forests in the Selway-Bitterroot Wilderness, Idaho. Natural fire cycles in these moist forests are at 100- to 400-year intervals, and modern fire suppression may not have affected the cedar forests in this wilderness. The surrounding upland forests exhibit greater cover and fuel continuity and could threaten the long-fire-interval forest types; an operational wilderness fire plan, however, has led to the burning of thousands of upland acres during the past several years.

286. ————. 1988. Old-growth forests in the Northern Rocky Mountains. Nat. Areas J. 8(3):202-211.

Old-growth forests still remain in significant amounts in the northern Rocky Mountains on federal forest lands; old growth in private ownership has mostly been destroyed. U.S. Forest Service personnel of the Northern Region (a USDA Forest Service subdivision encompassing northern Idaho, Montana, and the western Dakotas) are developing their plans to fulfill the management goals specified by the National Forest Management Act of 1976. Old-growth ecosystems are being preserved on national forests within wildernesses, roadless areas, research natural areas, and other special interest areas. In addition, U.S. Forest Service personnel are designating special management areas to provide habitat for wildlife that requires or prefers old-growth forests. The U.S. Forest Service's efforts in old-growth conservation, from natural area programs to specially designated old-growth management units, are described for the northern Rockies. The perpetuation of viable populations of wildlife species that are dependent on old-growth forests have their own intrinsic ecological value independent of wildlife considerations and deserve conservation in a system of land allocations that represents the range of ecosystems found in the northern Rockies. Such a system would provide for the long-term needs of plants and animals with known dependence on old growth, as well as those organisms whose needs we know little about.

287. ————. 1990. Old-growth Ponderosa pine-Western larch forests in Western Montana: ecology and management. N.W. Environ. J. 6(2):271-292.

Pre-settlement landscape diversity in western Montana included old-growth forest types that were maintained by repeated low-intensity fires. One of these was an old-growth forest type dominated by ponderosa pine and western larch. The author reviews the historical occurrence of these old-growth forests as well as United States Forest Service plans to maintain and manage the fire-dependent pine-larch type in this region. Modern technical knowledge in fire science and in forest fuel management are now at such a stage that foresters could be applying more "innovative" techniques to reduce fire potential, protect natural resources, and improve forest health and aesthetics. These state-of-the-art forest management techniques are needed to assure the maintenance and perpetuation of surviving examples of fire generated old-growth pine-larch in western Montana.

288. **Hagar, D.C.** 1960. The interrelationships of logging, birds, and timber regeneration in the Douglas-fir region of Northwestern California. Ecology 41(1):116-125.

Logging of the forest caused a definite increase in bird population size and a marked change in species composition. There was little change in total number of species at first, but an increase occurred within 3 years after cutting. The junco became predominant on cutovers where an abundance of weed seeds, berries and insects helped the population to flourish. These birds turned largely to Douglas-fir seed when it was available. Other important seed eaters which invaded logged areas to forage on the ground were varied thrush, spotted towhee, mountain quail, golden-crowned sparrow, and fox sparrow. Steller jays and winter wrens also were important in the ecology of logged areas, but the former bird was not a harmful influence in Douglas-fir regeneration. Several species of finches, the redbreasted nuthatch, and the chestnut-backed chickadee attacked the cones of seed producing trees around borders of cutovers. Many other species of birds were affected by logging. (Author's summary)

289. **Hall, F.C., L.W. Brewer, J.F. Franklin, and R.L. Werner**. 1985. Plant communities and stand conditions. *In* Management of wildlife and fish habitats in the forests of Western Oregon and Washington. E.R. Brown (technical editor). U.S. Dep. Agric. For. Serv., Pac. NW Reg. and U.S. Dep. Int. Bur. Land Manage., Portland, OR. Publ. No. R6-F&WL-192-1985, pp. 17-30.

The type of plant community influences structure and length of time for each stand condition discussed, including grass-forb, shrub, open sapling-pole, closed sapling-pole-sawtimber, large sawtimber, and old-growth stand conditions. In contrast to plant communities in grass-forb and shrub conditions, old-growth structure varies widely among the various communities. **

290. **Hanley, D.P., W.C. Schmidt, and G.M. Blake**. 1975. Stand structure and successional status of two spruce-fir forests in Southern Utah. U.S. Dep. Agric. For. Serv., Intermtn. For. Range Exp. Stn., Ogden UT. Res. Pap. INT-176. 17 p.

Knowledge of the age-class distribution in the spruce-fir forests on the plateaus of southern Utah is necessary to prescribe silvicultural systems compatible with the ecological requirements of the species. Engelmann spruce, *Picea engelmanii* (Parry); subalpine fir, *Abies lasiocarpa* (Hook.) Nutt.; and quaking aspen, *Populus tremuloides* (Michx.), constitute the majority of the stands found on these high elevation sites. Random samples of ages and diameters by species were analyzed from two stands on adjacent plateaus. Both stands are uneven-aged. Engelmann spruce, the primary species, is predominantly all-aged; subalpine fir is uneven-aged, but not all-aged; and aspen is even-aged. This age-class structure suggests the need for testing an uneven-aged silvicultural system in the management of these forests.

291. **Hanley, T.A., F.L. Bunnell, E.E. Starkey, S.K. Stevenson,** and **A.S. Harestad**. 1984. Habitat relationships of cervidae (deer) in old-growth forests. *In* New Forests for a Changing World: Proc. 1983 SAF National Conven. K.A. Sabol (editor). Oct. 16-20, 1983, Portland, OR. Soc. Am. For., Bethesda, MD. SAF Publ. 84-03, pp. 361-367.

Most species of North American deer have been considered to be associated with early successional stages of forest vegetation. Black-tailed deer, Roosevelt elk, and woodland caribou, however, sometimes exhibit habitat preferences for old-growth forest over young stands. The most important feature of old-growth forest for all three species is the combination of a productive, nutritious understory with a well-developed overstory capable of providing cover, intercepting snow, and producing arboreal lichens. Whether or not old-growth forest is a habitat requirement depends on many factors: characteristics of old growth and alternative habitats, local climate, potential limiting factors for the population, and desired levels of productivity. Silvicultural research is needed on manipulating second-growth stands to produce the characteristics of habitat naturally provided by old-growth forest.

292. **Happe, P.J., K.J. Jenkins, E.E. Starkey, and S.H. Sharrow**. 1990. Nutritional quality and tannin astringency of browse in clear-cuts and old-growth forests. J. Wildl. Manage. 54(5):557-566.

We compared nutritional quality and morphology of 4 browse forages of black-tailed deer (*Odocoileus hemionus columbianus*) and Roosevelt elk (*Cervus elaphus roosevelti*) in clear-cuts and old-growth forests on the Olympic Peninsula, Washington. Browse in old-growth forests had a greater proportion of leaves, was more succulent, and had higher percent crude protein than browse in clear-cuts. There was no consistent pattern of difference in fiber content and digestibility between forest types. Tannin astringency was greater in clear-cut than in old growth. Because tannins decrease digestible protein (DP), DP was more available in shrubs grown in old growth than in clear-cuts; little DP was available to cervids browsing in clear-cuts. Retention of patches of old growth in the Pacific Northwest will provide optimum year-round habitat for cervid foraging.

293. **Harcombe, A.P.** 1984. Wildlife habitat handbooks for British Columbia: problem analysis. B.C. Min. Environ. and Min. For., Victoria, BC., Wildl. Habitat Res. WHR-8; Fish and Wildl. Rep. No. R-10; Tech. Rep. 8. 236 p.

In British Columbia, wildlife habitat is modified primarily through silvicultural or range management practices. If timber management is to provide good habitat management, the wildlife biologist must be able to provide the forester with an explanation of wildlife-habitat relationships such that the forester can manipulate habitat to achieve wildlife goals. The author suggests that wildlife habitat handbooks will provide a ready source of biological information and a system to predict probable consequences of forest and range management practices on wildlife habitat. With the handbooks as a planning tool, the forester will be better equipped to meet both wildlife and forest management goals. **

294. ——————— (technical editor). 1988. Wildlife habitat handbook of the Southern Interior Ecoprovince. B.C. Min. Environ., Wildl. Br. and Min. For., Res. Br., Victoria, BC. 8 Vols.

This series reports the life histories, distribution information, and habitats of the wildlife species of British Columbia. Four wildlife species groups—mammals, birds, reptiles, and amphibians—are described in two volumes each, one of which includes species notes and the other species-habitat relationship models. **

295. **Harcombe, P.A.** 1986. Stand development in a 130-year-old spruce-hemlock forest based on age structure and 50 years of mortality data. For. Ecol. Manage. 14:41-58.

Influences on forest stand development were assessed using tree and long-term mortality data in ten 0.4 ha permanent plots established in 1935. The stand originated following a major fire in the 1840s with a period of rapid invasion (1851-1870). This was followed by slower filling to full stand closure (1871-1900), recruitment suppression (1901-1930), re-initiation of hemlock recruitment (1931-1950), and continued slow recruitment (1951-present). Recruitment re-initiation was apparently associated with natural stand thinning and not with major disturbance. Large blowdown patches occurred in two plots in the 1960s, but the primary effect was release of hemlock advance regeneration rather than recruitment of new individuals. From 1935 to 1983 annual mortality (calculated from 5-10 years remeasurements) was 0.5-1.2% for both species. At this rate, continued thinning will likely allow a gradual transition to an all-aged forest, as population turnover time is short relative to frequency of intermediate or major disturbances.

296. ———————. 1987. Tree life tables. BioScience 37(8):557-568.

A principal value of tree life tables and stage-projection analysis lies in their potential as tools for investigating ecological and evolutionary questions. With regard to population and community dynamics, stage-projection models can generate quantitative predictions regarding diameter distributions, population growth rates, and stand development and replacement trends. These predictions can be tested using static measures of population structure or short-term measurements of population processes.

Stage projections and life tables promise to crystallize tree life histories and comparative demography in new ways. They help us to view trees as multidimensional and their life histories as integrated wholes. More data on life-table components will help us to clarify the dimensions of the problems and to focus more closely on important site effects and on regional behavior. (From author's conclusions)

297. **Harestad, A.S.** 1984. Seasonal movements of black-tailed deer. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 403-409.

Columbian black-tailed deer were radio-tagged in a deep-snowfall region on northern Vancouver Island and monitored to determine seasonal movements and habitat use. A model of habitat selection is proposed in which seasonal movements occur by deer moving to more favorable habitats. Habitat selection, and thus seasonal movements, result from tradeoffs between energy obtained from available forage and energy expended for locomotion. Deer exhibited either resident or migratory movement patterns. Each seasonal movement pattern, although spatially different, resulted from habitat selection driven by the same causal factors, availability and expenditure of energy.

298. **Harestad, A.S.** and **F.L. Bunnell.** 1981. Prediction of snow-water equivalents in coniferous forests. Can. J. For. Res. 11:854-857.

Less snow accumulates under forest canopies than in small openings. Analysis of relationships between canopy cover and snow-water equivalents (SWE) for coniferous forests indicate substantial differences between areas and years. Many of these differences result from differences in the total amount of snowfall. The difference between SWE values in open and forested areas increases with increasing SWE in the open. However, the relative influence of canopy cover on maximum SWE decreases with increasing SWE in open areas. By incorporating this latter relationship, canopy cover can be used to predict snow-water equivalents in coniferous forests.

299. **Harestad, A.S.** and **D.G. Keisker**. 1989. Nest tree use by primary cavity-nesting birds in south central British Columbia. Can. J. Zool. 67:1067-1073.

Hardwood decay was the most important factor in nest tree selection by primary cavity-nesting birds in the Interior Douglas-fir Biogeoclimatic Zone of British Columbia. Of 243 active nests, most were in trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*). Douglas-fir (*Pseudotsuga menziesii*) and hybrid spruce (*Picea engelmannii* x *glauca*) were not used for nesting. Strong excavators (Yellow-bellied Sapsucker (*Sphyrapicus varius*), Pileated Woodpecker (*Dryocopus pileatus*), and Hairy Woodpecker (*Picoides villosus*)) preferred to nest in live trembling aspen with heartwood decay. Weak excavators (Red-breasted Nuthatch (*Sitta canadensis*), Northern Flicker (*Colaptes auratus*), and Downy Woodpecker (*Picoides pubescens*)) preferred to nest in dead trees or dead tops of live trees. Yellow-bellied Sapsucker preferred to nest in trees larger than 30 cm diameter at breast height, and Pileated Woodpecker preferred trees larger than 40 cm diameter at breast height. No significant preference for nest tree diameter was detected for other species.

300. **Harestad, A.S., J.A. Rochelle,** and **F.L. Bunnell.** 1982. Old-growth forests and black-tailed deer on Vancouver Island. Trans. N. Am. Wildl. and Nat. Resour. Conf. 47:343-352.

From the results of a study of black-tailed deer in the Nimpkish Valley on Vancouver Island, the authors derived a simple model of habitat selection based on energy tradeoffs—energy derived from forage and energy expended for locomotion. It was found that differences in habitat selection in winter were due to snow depth. Although cutover areas have higher energy resources than forested areas, benefits are negated by inaccessibility in the cutover areas from increased snow depths. Thus, the two functions of the model are the relationship between snow depth and energy availability, and the relationship between snow depth and energy expenditure. This relationship holds true regardless of the type of seasonal migration patterns exhibited by the deer population.

During periods of greater snow depth, litterfall from old-growth forests becomes increasingly important to deer as a food source. Management options suggested include preservation of old-growth forest in areas of important winter range, and the use of silvicultural techniques to create old-growth characteristics in a second-growth stand. Appropriate management of second-growth forests could provide reduced snow depth and the forage necessary for survival of deer in severe winter conditions. **

301. **Harmon, M.E.** 1987. The influence of litter and humus accumulations and canopy openness on *Picea sitchensis* (Bong.) and *Tsuga heterophylla* (Raf.) Sarg. seedlings growing on logs. Can. J. For. Res. 17:1475-1479.

The influence of litter and humus accumulations on the surface of logs and canopy openness upon growth and survival of *Picea sitchensis* (Bong.) Carr. and *Tsuga heterophylla* (Raf.) Sarg. seedlings was tested experimentally at Cascade Head Experimental Forest, near Otis, Oregon. This was done by adding litter and humus to the surface of freshly fallen logs. Survival rates of both species increased asymptotically as litter accumulations on logs increased. Mean maximum survival was 58% for *Picea* and 34% for *Tsuga*. *Picea* seedling survival peaked when tree canopy cover ranged from 70 to 80% with lower survival at either higher or lower values. *Tsuga* survival was highest under closed canopies. Seedling growth increased as litter-humus accumulation and canopy openness increased.

302. **Harmon, M.E., G.A. Baker, G. Spycher,** and **S.E. Greene**. 1990. Leaf-litter decomposition in the *Picea/Tsuga* forest of Olympic National Park, Washington, U.S.A. For. Ecol. Manage. 31:55-66.

The factors controlling litter decomposition of eleven species of leaf litter were examined in the Hoh Rain Forest, Olympic National Park, Washington, using the litter-bag method. Leaching of litter decreased the decay rate-constant as compared to unleached litter. This decrease was in proportion to the readily leachable fraction (RLF) in the litter. Decay of both leached and unleached litter was highly correlated ($P<0.001$) with lignin:nitrogen ratio, although the regressions differed significantly between leached and unleached litter. Of the unleached litters used, *Cornus nutallii* decayed fastest ($k = 2.35$-2.46/year), and *Pinus monticola* decayed slowest ($k = 0.38$/year). A double-exponential regression was used to fit decay time-series from four species. This analysis indicated that species differed markedly in the proportion of fast and slow components and that the fast component was correlated with RLF for three of four species tested. Fast components decayed an order of magnitude faster than slow components. The rate at which these components decayed varied between species, indicating that both the amount and decay rate-constant of fast and slow components must be estimated to use the double-exponential equation.

303. **Harmon, M.E., W.K. Ferrell,** and **J.F. Franklin**. 1990. Effects on carbon storage of conversion of old-growth forests to young forests. Science 247:699-702.

Simulations of carbon storage suggest that conversion of old-growth forests to young fast-growing forests will not decrease atmospheric carbon dioxide (CO_2) in general, as has been suggested recently. During simulated timber harvest, on-site carbon storage is reduced considerably and does not approach old-growth storage capacity for at least 200 years. Even when sequestration of carbon in wooden buildings is included in the models, timber harvest results in a net flux of CO_2 to the atmosphere. To offset this effect, the production of lumber and other long-term wood products, as well as the lifespan of buildings, would have to increase markedly. Mass balance calculations indicate that the conversion of 5×10^6 hectares of old-growth forests to younger plantations in western Oregon and Washington in the last 100 years has added 1.5×10^9 to 1.8×10^9 megagrams of carbon to the atmosphere.

304. **Harmon, M.E.** and **J.F. Franklin**. 1989. Tree seedlings on logs in *Picea-Tsuga* forests of Oregon and Washington. Ecology 70(1):48-59.

Logs are the major seedbed for trees in coastal *Picea sitchensis - Tsuga heterophylla* forests. Field experiments were conducted at Cascade Head, Oregon, and Hoh River, Washington, to examine pathogens, predation, competition, and standing water as causes for this close seedling-log association.

More seedlings survived on log blocks than on soil blocks, regardless of whether the blocks were raised or placed flush with the soil surface. Standing water was therefore an unlikely cause of the seedling-log association. Comparisons of plots protected from and exposed to predation revealed that predation was minor and of equal intensity on soils and logs.

Sterilizing soils did not consistently increase seedling survival above controls. Clearing ground-layer vegetation from soil plots significantly increased the survival of conifer seedlings compared with that on uncleared soils. The seed penetration rates through moss mats indicated that 1% of the seedlings germinated within moss mats.

Competition with herbs and mosses on the forest floor therefore appears to be responsible for the disproportionate number of tree seedlings found on logs. Recently fallen logs represent sites where competition is low enough for tree seedling recruitment within many *Picea-Tsuga* forests.

305. **Harmon, M.E., J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.W. Lienkaemper, K. Cromack, Jr.,** and **K.W. Cummins**. 1986. Ecology of coarse woody debris in temperate ecosystems. Adv. Ecol. Res. 15:133-303.

Coarse woody debris (CWD) is an important component of temperate stream and forest ecosystems. This paper is a comprehensive review of known roles and functions of CWD, summarizing over 500 separate works on the topic. The authors reviewed the rates at which CWD is added and removed from ecosystems, the biomass found in streams and forests, its role in nutrient cycling, and its value as a habitat for plants and animals. **

306. **Harr, R.D.** 1976. Hydrology of small forest streams in western Oregon. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-55. 15 p.

The hydrology of small forest streams in western Oregon varies by time and space in terms of both streamflow and channel hydraulics. Overland flow rarely occurs on undisturbed soils. Instead, water is transmitted rapidly through soils to stream channels by displacement of stored soil water. Drainage networks expand and contract according to the interaction between precipitation characteristics and soil's capability to store and transmit water. Drainage networks are more extensive in winter than in summer. Streamflow may be 1,000 to 5,000 times greater during winter storms than during summer low flow. A stream's kinetic energy varies along with streamflow. Channel width and depth, heterogeneity of bed materials, and the accumulation of large, organic debris affects the dissipation of kinetic energy. Clearcutting can increase relatively small peak flows, but forest roads and extensive areas of soil compacted by other means may increase larger peak flows. Both roadbuilding and clearcutting can cause soil mass movements which can drastically alter a stream's channel hydraulics by adding debris or scouring the channel to bedrock. Removal of naturally occurring organic debris that has become part of a stable channel can accelerate bed and bank erosion.

307. ————. 1980. Streamflow after patch logging in small drainages within the Bull Run Municipal Watershed, Oregon. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Res. Pap. PNW-268. 16 p.

Three experimental watersheds in the city of Portland's Bull Run Municipal watershed were used to determine effects of patch logging on timing and quantity of stream-flow. Annual water yields and size of instantaneous peak flows were not significantly changed, but low flow decreased significantly after logging of two small watersheds in small, clearcut patches totaling 25 percent of each watershed's area.

308. ————. 1982. Fog drip in the Bull Run Municipal Watershed, Oregon. Water Resour. Bull. 18(5):785-789.

Net precipitation under old growth Douglas fir forest in the Bull Run Municipal Watershed (Portland, Oregon) totaled 1739 mm during a 40-week period, 387 mm more than in adjacent clearcut areas. Expressing data on a full water year basis and adjusting gross precipitation for losses due to rainfall interception suggest fog drip could have added 882 mm (35 in) of water to total precipitation during a year when precipitation measured 2160

mm in a rain gage in a nearby clearing. Standard rain gages installed in open areas where fog is common may be collecting up to 30 percent less precipitation than would be collected in the forest. Long term forest management (i.e., timber harvest) in the watershed could reduce annual water yield and, more importantly, summer stream flow by reducing fog drip.

309. ———————. 1983. Potential for augmenting water yield through forest practices in western Washington and western Oregon. Water Resour. Bull. 19(3):383-393.

Western Washington and western Oregon comprise a water-rich region that has a very uneven annual distribution of both precipitation and streamflow. Highest demand for water coincides with lowest streamflow levels between July 1 and September 30 when less than 5 percent of annual water yield occurs. Increases in annual water yield in small, experimental watersheds in the region have ranged up to 600 mm after entire watersheds were logged and up to 300 mm in watersheds that were 25 to 30 percent logged. Most of the increase has occurred during the fall-winter rainy season, and yield increases have been largest during the wettest years. Estimated sustained increases in water yield from most large watersheds subject to sustained yield forest management are at best only 3-6 percent of unaugmented flows. Realistically, watersheds in this region will not be managed to produce more water. Water yield augmentation will continue to be only a small and variable by-product of logging. The utility of water yield augmentation is limited by its size and by its occurrence relative to the time of water demand. In some local areas, reduction of fog interception and drip or establishment of riparian phreatophytic hardwoods may reduce summer flows.

310. **Harris, A.S.** 1989. Wind in the forests of southeast Alaska and guides for reducing damage. U.S. Dep. Agric. For. Serv., Pac. NW Res. Stn., Portland, OR. Gen. Tech. Rep. PNW-GTR-244. 63 p.

This paper is a review of wind conditions and blowdown in the forests of southeast Alaska based on the literature and the author's experience. Storm winds resulting in damage to forest stands are described, and some ecological and management considerations of wind that are of concern to forest managers are reviewed.

The author made a general reconnaissance of forest conditions on Prince of Wales Island and adjacent islands based on forest-type maps, aerial photographs, and ground and air checks. Forest conditions associated with blowdown are described and discussed.

311. **Harris, L.D.** 1984. The fragmented forest. Island biogeography theory and the preservation of biotic diversity. Univ. Chicago Press, Chicago, IL. 229 p.

A book showing how the principles of island biogeography can be used to provide guidelines for planning parks and nature reserves. Patches of old-growth forest are treated as islands in a sea of forest plantations or human-dominated landscape. A scheme is described for surrounding each patch with a low-intensity forest management buffer zone (long-rotation management), and the functioning of these long-rotation islands as an archipelago system is considered. Movement of wildlife between patches is to be planned for and the whole system is to be fitted into the landscape. The fieldwork and data for the study are from the Pacific Northwest region of the USA.

The book is organized in four sections: 1) problem setting; 2) current state of knowledge, including description of the forest community, its role as animal habitat, and its use as a resource; 3) analysis of alternatives, applicability of insular biogeography, genetic resources and biotic diversity and evaluation of alternative approaches; and 4) a strategy for management planning which incorporates a system of long-rotation islands, fitting the system to the landscape. It ends with characteristics of the island archipelago approach. There are also five appendices providing data from the study area, as well as author, species and subject indices. **

312. ——————. 1984. An island archipelago model for maintaining biotic diversity in old-growth forests. *In* New Forests for a Changing World: Proc. 1983 SAF National Conven. K.A. Sabol (editor). Oct. 16-20, 1983, Portland, OR. SAF Publ. 84-03, Soc. Am. For., Bethesda, MD, SAF Publ. 84-03, pp. 378-382.

Three aspects of changing forest conditions throughout the world are 1) reduction in overall forest acreage; 2) conversion of old-growth forests to more intensively managed plantations; and 3) fragmentation of formerly expansive forests. All three have significant negative consequences. This paper develops a forest planning strategy whereby remaining old-growth forest fragments are conceived as an archipelago of forest habitat islands and integrated into a more intensively managed forest plantation landscape. The energetic basis of landscape formation and energy transformation is invoked to help guide planning decisions.

313. **Harris, L.D.** and **P. Kangas.** 1988. Reconsideration of the habitat concept. Trans. N. Am. Wildl. Nat. Resour. Conf. 53:137-144.

The concept of habitat has long been of central importance in ecology, and especially in wildlife management. Many attempts have been made to articulate a definition but the authors find there is still confusion surrounding the term and the concept, as well as a tendency to oversimplify the subtleties and complexities of habitat assessment. As a result of this, the wildlife resource is being unduly affected. The authors review various aspects of the habitat concept, and present recommendations for future improvement of habitat-evaluation models. **

314. **Harris, L.D., C. Maser,** and **A. Mckee.** 1982. Patterns of old growth harvest and implications for Cascades wildlife. Trans. N. Am. Wildl. Nat. Resour. Conf. 47:374-392.

This paper describes the harvesting patterns of Douglas-fir in Oregon and Washington, west of the Cascades, and presents basic ecological information for assessing how this harvest affects wildlife. Habitat conservation strategies derived from island biogeography principles are suggested.

Vertebrate species diversity is high in very early and very late stages of the Douglas-fir succession sequence, suggesting that an interdependent system of clearcuts and old growth should be interspersed throughout the managed forest. Island size should be treated as a variable rather than a constant. Recommended size is inverse to the degree the stand is exposed to clearcuts and young stands. Long rotation management islands that buffer the old-growth stands will minimize the old-growth acreage required to be set aside. **

315. **Harris, R.B.** and **F.W. Allendorf.** 1989. Genetically effective population size of large mammals: an assessment of estimators. Conserv. Biol. 3(2):181-191.

We calculated effective population sizes (N_e) for simulated grizzly bear (*Ursus arctos*) populations by tracing the loss of heterozygosity through time, and compared them with estimates of N_e produced by applying published formulas to demographic results from the simulation. Estimates of N_e using different formulas on identical data varied widely. Equations published by Hill (1972), and modifications of those used by Ryman *et al.* (1981) and Reed *et al.* (1986), provided the most accurate estimates. Minor population fluctuations had little effect on N_e, but variation in lifetime reproductive success among males (V_{km}) greatly reduced N_e from its expectation under random mating success. All methods to estimate N_e for populations with complex demographics require extensive data, but estimates for V_{km} in polygynous species are especially difficult to obtain. We suggest that simulation modeling may provide alternative methods to estimate V_{km} and N_e.

316. **Hartman, G., J.C. Scrivener, L.B. Holtby, and L. Powell.** 1987. Some effects of different streamside treatments on physical conditions and fish population processes in Carnation Creek, a coastal rain forest stream in British Columbia. *In* Streamside Management: Forestry and Fishery Interactions. E.O. Salo and T.W. Cundy (editors). Univ. Wash., Seattle, WA. Contrib. No. 57, pp. 330-372.

Carnation Creek is a small (10 km^2) drainage in a high rainfall, coastal western hemlock (CWH) biogeoclimatic zone on the west coast of Vancouver Island, British Columbia. The stream and its fish populations have been studied continuously since 1971, including a period in which 41% of the watershed was logged (1976-81). Three different kinds of streamside treatments, set largely in an alluvial floodplain portion of the stream valley, were evaluated: (1) an intensive treatment involved clearcutting to the streambank, felling of streambank alder, and some yarding of felled trees and merchantable blow down from the stream, (2) a careful treatment involved clearcutting to the margin of the stream and the felling of streambank alder, with virtually no in-channel activity, and (3) a leave strip treatment in which a variable width strip of vegetation was left along the stream.

Stream thermal regimes increased as a result of logging. The decrease in volume and stability of large debris was accompanied by erosion of the streambanks. Population changes among young salmonids were positive to some components of forest harvest and were negative to others.

The Carnation Creek work indicates that the existing P.1 Clauses and the Coast Forest Planning Guidelines, where they are involved with streamside management, should be applied in a fashion that ensures not only the maintenance of the physical integrity of the stream but also that there will be a future source of large woody debris at the stream channel margin. This study has also indicated that different kinds of tributaries and different sections of the main stem respond differently to logging impacts. The work supports the desire on the part of the management agencies to establish a stream classification system and apply protection clauses and planning guidelines with specific reference to stream classes and to upper watershed areas. (From authors' abstract)

317. **Harvey, A.E., M.F. Jurgensen,** and **M.J. Larsen**. 1978. Seasonal distribution of ectomycorrhizae in mature Douglas-fir/larch forest soil in western Montana. For. Sci. 24(2):203-208.

Counts of individual ectomycorrhizal root tips from random soil core samples showed that the greatest number occurred during May and June in the organic soil fractions. Soil humus provided the major substrate for ectomycorrhizae throughout the year except during July and August. During this drier period, more active ectomycorrhizal tips occurred in the decayed soil wood. Moisture levels were higher in the decayed wood than the humus at that time. Decayed wood may serve a critical role in supporting ectomycorrihzae in the soils of mature Douglas-fir/larch forests, particularly during periods of limited moisture availability.

318. ——————. 1981. Organic reserves: importance to ectomycorrhizae in forest soils of western Montana. For. Sci. 27(3):442-445.

The important attributes contributed to forest soils by organic matter make it imperative to determine the quantity and type required to sustain good forest tree growth. Quantitative measurement of soil humus, decayed wood, and charcoal as related to numbers of active ectomycorrhizal root tips (in random soil cores from old-growth sites in western Montana) showed both positive and negative relationships with organic matter. Increased quantities of organic material, to 45 percent by volume of the top 30 cm of soil, were associated with increased numbers of ectomycorrhizae. At 45 percent organic matter or above, numbers of ectomycorrhizae decreased. Study results also showed association with soil organic matter had a relatively greater positive effect on ectomycorrhizae of the dry site than the moist sites.

319. **Harvey, A.E., M.F. Jurgensen, M.J. Larsen,** and **R.T. Graham**. 1987a. Decaying organic materials and soil quality in the Inland Northwest: a management opportunity. U.S. Dep. Agric. For. Serv., Intermtn. Res. Stn., Ogden, UT. Gen. Tech. Rep. INT-225.

Organic debris, including wood residues, provides parent materials for development and function of organic mantles on forest soils. Along with providing a storehouse of nutrients and moisture, organic materials provide either the environment or the energy source for microorganisms critical to both the nutritional quality of forest soils and the ability of conifers to extract nutrients and moisture from the soil. The role and relative importance of specific organic components can vary substantially with site and conifer species. Age of the trees appears to have less of an effect on importance of organic matter than site or species. Of the many organic materials incorporated in a forest soil, the woody component is in many ways the most important. To protect productive potential of forest soils, a continuous supply of organic materials must be provided, particularly in harsh environments. In case of excess losses of the organic mantle, complete recovery of the site may require several hundred years, even with proper management.

320. ————————. 1987b. Relationships among soil microsite, ectomycorrhizae, and natural conifer regeneration of old-growth forests in western Montana. Can. J. For. Res. 17:58-62.

Successful establishment, root distribution, growth, and ectomycorrhizal development of conifer regeneration in three old-growth forests in western Montana showed site-specific associations with soil microsites containing organic matter. A positive association between decayed wood in the soil and establishment of seedlings occurred on the two drier sites. In general, organic soil components supported most of the root system and ectomycorrhizae on all three sites. Associations between soil organic components and occurrence (establishment) and between organic components and performance (growth) were site specific. No observable evidence of feeder root mortality attributable to soil-inhabiting pathogens was present in any soil component. Roots of competing understory species were notably absent in decayed soil wood.

321. **Harvey, A.E., M.F. Jurgensen, M.J. Larsen,** and **J.A. Schlieter**. 1986. Distribution of active ectomycorrhizal short roots in forest soils of the inland northwest: effects of site and disturbance. U.S. Dep. Agric. For. Serv., Intermtn. Res. Stn., Ogden, UT. Res. Pap. 8 p.

Research Summary: An examination of the distribution of active ectomycorrhizal short roots among soil components of eight old-growth stands representative of the important timber growing lands of the Inland Northwest revealed a disproportionate concentration in surface organic materials. A similar concentration in the forest floor was present in six second-growth stands of various ages from the subalpine fir and Douglas-fir habitat series of western Montana. Exceptions to this trend were noted only in an extremely dry, old-growth, ponderosa pine stand and a highly disturbed site regenerating to a pure stand of young western larch. Even in these exceptional cases, ectomycorrhizal activities were concentrated in shallow mineral horizons relatively rich in organic materials. There was considerable variation in the quantity of soil organic materials on the 14 sites. In general, harsh and disturbed sites tended to have the least. The relative proportions of soil organic components (litter, humus, decayed wood) changed signifantly both within and between sites. Distribution of active ectomycorrhizal short roots among those components during the early summer months was also significantly different, both within and between sites. Approximately 75 percent of active ectomycorrhizal short roots occurred in organic materials that represented only the first 4 cm of the soil depth. This disproportionate role of surface organic materials in supporting critical symbiotic processes emphasizes the need to carefully manage this important soil resource in forested ecosystems throughout the Inland West.

322. **Harvey, A.E., M.J. Larsen,** and **M.F. Jurgensen**. 1976. Distribution of ectomycorrhizae in a mature Douglas-fir/larch forest soil in western Montana. For. Sci. 22(4):393-398.

The top 38 cm (15 inches) of a western Montana forest soil was 60 percent mineral, 23 percent humus, 15 percent decayed wood, and 2 percent charcoal. Most (to 95 percent) of the active ectomycorrhizae were associated with the organic fractions. Five percent of all active ectomycorrhizae occurred in the mineral soil fraction, 66 percent in the humus, 21

percent in the decayed wood, and 8 percent in the charcoal. Thus, the organic reserves in this forest soil were the most important substrates for ectomycorrhizal formation. Therefore, the parent materials (leaves, litter, and woody residues) for soil organic reserves may require management during timber harvesting and prescribed burning to prevent a subsequent loss in the capacity of soils of this type (limestone base) to support ectomycorrhizal associations in mature Douglas-fir/larch forests.

323. ——————. 1979. Comparative distribution of ectomycorrhizae in soils of three western Montana forest habitat types. For. Sci. 25(2):350-358.

Soil core samples from three western Montana forest sites representing a range of moisture, productivity, and dominant tree species (Douglas-fir, subalpine fir, and hemlock) were analyzed for differences in quantities and types of soil organic matter and the distribution of active (physiologically functioning) ectomycorrhizae in the soil profiles. The lowest levels of soil organic matter and ectomycorrhizal activity occurred in the Douglas-fir and subalpine fir sites. Most of the ectomycorrhizae occurred in the soil organic matter at all three sites, primarily in humus (02 layer) or in brown cubical decayed wood distributed throughout the soil profiles. In the Douglas-fir site, decayed soil wood was the most frequent substrate for active ectomycorrhizae. In soils of the subalpine fir and hemlock sites, humus was the most frequent substrate for ectomycorrhizae. Consistently high moisture levels in the organic materials, particularly decayed wood, were associated with this phenomenon.

324. **Hatler, D.F.** 1987. History and importance of wildlife in northern British Columbia. *In* The Wildlife of Northern British Columbia: Past, Present and Future. R.J. Fox (editor). Nov. 27-29, 1987, Smithers, BC. Spatsizi Assoc. Biolog. Res., Smithers, BC, pp. 3-17.

This article discusses the history and importance of wildlife in British Columbia. The author devotes his discussion to a particular selection of mammals: caribou, mountain goats, moose, and mule deer. In considering the distant past of British Columbia, the author focuses on aspects of zoogeography, climate history, and human history. He concludes by emphasizing the need for more funds and research to supplement current wildlife management and conservation efforts. **

325. **Haupt, H.F.** 1979. Local climatic and hydrologic consequences of creating openings in climax timber of north Idaho. U.S. Dep. Agric. For. Serv., Intermtn. For. Range Exp. Stn., Ogden, UT. Res. Paper INT-223. 43 p.

Climatic and hydrologic responses of small and large clearcuts on north and south aspects in northern Idaho were studied. The parameters—surface wind, maximum snow deposition, seasonal precipitation, and seasonal percolation—were related to the distance downwind from the west edge of the forest by sets of linear models. On the north aspect an exponential increase in each parameter generally occurred as the distance increased. On the south aspect, the same response was observed with surface wind. However, maximum snow deposition, seasonal precipitation, and seasonal percolation increased for a short distance of 1.0 to 2.0 tree heights and then diminished rapidly. Other attributes such as drip, snow interception, snowmelt, and rates of disappearance were evaluated with supportive data.

326. **Hawk, G.M., J.N. Long,** and **J.F. Franklin.** 1982. Relations between vegetation and environment. *In* Analysis of coniferous forest ecosystems in the western United States. R.L. Edmonds (editor). Hutchinson Ross Publ. Co., Stroudsburg, PA. U.S./I.B.P. Synthesis Ser. No. 14, pp. 28-44.

A biome study of vegetation and community environmental interactions with particular focus on testing hypotheses of relationships between floristic gradients and climatic gradients in moisture, snow depth and duration, and temperature. Studies were carried out in the H.J. Andrews Experimental Forest of Oregon and in the Cedar River watershed in Washington. This research had four objectives: 1) to identify and describe key structural and compositional features of forest ecosystems so that they could be related to ecosystem

function; 2) to ordinate vegetation plots using only vegetation characteristics; 3) to use the resulting data from the two previous objectives to formulate hypotheses to explain vegetation-environmental interactions; and 4) to test these hypotheses.

Both Washington and Oregon sites showed strong correlations between floristic gradients and environmental factors associated with elevation. In Washington, the floristic gradient was found to be associated with a gradient in duration and depth of winter snowpack. In Oregon, however, this gradient was associated with growing season temperature growth index (TGI), an index that reflects a measure of growth conditions regulated by temperature. The second floristic gradient in both sites was found to be associated with a gradient in summer plant moisture deficit (PMD). Site differences between vegetation zones at the Oregon site are reflected in a temperature index; within-community differences were distinguished by moisture deficits and, to a lesser extent, temperature. Several studies have given evidence of the gradient effects on producer, consumers, and decomposers, providing further support for the classification scheme in Oregon. The author concludes that "these studies increase the utility of predictive models of terrestrial primary producer systems and the diversity of the studies makes an interfacing with other major sections of the ecosystem studies more meaningful." **

327. **Hawkins, C.P., M.L. Murphy,** and **N.H. Anderson**. 1982. Effects of canopy, substrate composition, and gradient on the structure of macroinvertebrate communities in Cascade Range streams of Oregon. Ecology 63(6):1840-1856.

The relative importance of surrounding riparian vegetation and substrate composition on invertebrate community structure was investigated in six streams in Oregon, U.S.A. We found that canopy type was more important than substrate character in influencing total abundance and guild structure. Streams without shading had higher abundances of invertebrates than did shaded streams. Most guilds were influenced by qualitative differences in food availability rather than quantity of food or substrate composition. Open streams had higher abundances in the collector-gatherer, filter feeder, herbivore shredder and piercer, and predator guilds. Contrary to expectations, shredders were no more abundant in shaded streams than in streams lacking a riparian canopy. Scraper density was inversely related to standing crop of aufwuch, but biomass was positively correlated with quantity of aufwuchs. Examination of dominance-diversity curves showed that both canopy and substrate influenced ranked abundances of taxa, but neither canopy nor substrate strongly influenced number of taxa. Differences in community structure were not always revealed by analysis of community-level properties, although differences in both the absolute and relative abundances of individual taxa were observed.

328. **Hawkins, C.P., M.L. Murphy, N.H. Anderson,** and **M.A. Wilzbach**. 1983. Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the Northwestern United States. Can. J. Fish. Aquat. Sci. 40(8):1173-1185.

Relationships between density of fish and salamanders, riparian canopy, and physical habitat were investigated by studying 10 pairs of streams. Among vertebrate taxa, salmonids and sculpins were more abundant in streams without riparian shading than in shaded streams. Abundance of salamanders was not affected by canopy type. Densities of both salamanders and sculpins were correlated with substrate composition, whereas salmonid abundance was not or only weakly so. Salamanders were found only at high-gradient sites with coarse substrates, and sculpins were most abundant at lower-gradient sites with finer-sized sediments. An interaction was observed between the influence of canopy and that of physical setting on density of both invertebrate prey and total vertebrates. Among shaded sites, densities decreased as percent fine sediment increased, but a similar relationship did not exist among open sites. Removal of the riparian vegetation surrounding a stream may therefore mask detrimental effects of fine sediment. These data provide one reason why it has been difficult in the past to generalize about the effects of fine sediment on stream biota.

329. **Haynes, R.W.** 1986. Inventory and value of old-growth in the Douglas-Fir region. U.S. Dep. Agric. For. Serv., Pac. NW Res. Stn., Portland, OR. Res. Note PNW-437. 19 p.

Timber inventory data for all owners in western Washington and western Oregon were summarized by age classes to provide an estimate of the remaining amount of old growth timber. The data suggest that roughly 30 percent of the timberlands in the Douglas-fir region contain essentially mature timber (stands whose age is in excess of culmination of mean annual increment). Available information on value of old growth is scanty but does suggest that old-growth Douglas-fir is some 56 percent more valuable than second-growth Douglas-fir.

330. **Heath, B., P. Sollins, D.A. Perry,** and **K. Cromack, Jr.** 1988. Asymbiotic nitrogen fixation in litter from Pacific Northwest forests. Can. J. For. Res. 18:68-74.

Asymbiotic nitrogen fixation in litter was assayed by acetylene reduction across a range of 25 forested sites in the Willamette Valley and Oregon Cascade and Coast ranges and periodically over a year at two Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) plantations in the Willamette Valley. Laboratory experiments showed that optimal conditions for N fixation by Douglas-fir litter were 200% moisture content and 22°C. Annual fixation was 1.08 ± 0.13 kg/ha at one Willamette Valley plantation, 0.39 ± 0.06 kg/ha at the other. Fixation rates at the other 23 sites, which were sampled less frequently, ranged from 0 to 5 g N/ha/day and exceeded trace levels at only six sites, indicating annual totals much less than those at the Willamette Valley plantations. At four coastal and valley sites sampled by litter layer, older L layer Douglas-fir litter fixed the most N per gram dry weight. Percent N, percent C, and the C:N ratio of that litter layer did not differ significantly among sites or correlate with N-fixation rates. Forest floor litter in most Northwest forests fixes no more than trace amounts of N, at most = 1 kg N ha/year. These amounts are smaller than N input from precipitation.

331. **Hebda, R.J.** 1983. Late-glacial and postglacial vegetation history at Bear Cove Bog, northeast Vancouver Island, British Columbia. Can. J. Bot. 61:3172-3192.

At 13 630 ± 310 BP (WAT-721) Port Hardy is the earliest area known to have been deglaciated at the end of the Fraser Glaciation on Vancouver Island. Pollen and macrofossil analyses of two cores from a basin-blanket bog show that about 14 000 years ago *Pinus contorta, Alnus,* and *Pteridium aquilinum* formed pioneering vegetation typical of post-ice environments on the Pacific Northwest coast. Climate is interpreted to have been relatively cool and dry. *Picea sitchensis - Tsuga mertensiana* forest succeeded at about 11 500 BP and persisted until about 10 000 BP. Climate was cool, moist, and maritime. Warming at about 10 000 BP permitted *Tsuga heterophylla* gradually to replace *T. mertensiana.* At 8800 BP *Pseudotsuga menziesii* migrated into the area and together with *P. sitchensis* dominated the forest. Abundant *Pteridium aquilinum* spores suggest forests were open. During the interval 8800 to 7000 BP the climate was warmer and drier than at present because today forests with *Pseudotsuga* do not extend as far north as Port Hardy. During this warm time, shallow ponds dried out. By 7000 BP *Pseudotsuga* declined and *T. heterophylla* and *P. sitchensis* dominated forests. Climate became wetter and cooler than in the preceding period but not as cool as today. About 3000 BP Cupressaceae, presumably both *Thuja plicata* and *Chamaecyparis nootkatensis,* shared the forest canopy with *T. heterophylla.* Sphagnum growth and bog development occurred after 7000 BP as climate became moister. The vegetation sequence described is a "maritime" type similar to sequences on the west coast of Washington State but unlike those from the Fraser Lowland. The xerothermic interval was of short duration between 8800 and 7000 BP but was expressed clearly in this area of moist maritime climate and therefore must have been of considerable amplitude. Vegetation differences between coastal and inland southwestern British Columbia were established by 11 500 BP.

332. **Heede, B.H.** 1972. Influences of a forest on the hydraulic geometry of two mountain streams. Water Resour. Bull. 8(3):523-530.

The influence of a forest on the formation of steps in two small streams of the Colorado Rocky Mountains was studied. Steps provided by logs, fallen across the channel added to flow energy reduction. The streams required additional gravel bars to adjust to slope. Average step length between logs and gravel bars was strongly related to channel gradient and median bed material size. Based on the average number of log steps per 50 feet of channel, an average of 116 percent of gravel bars were added at Fool Creek and 60 percent at Deadhorse Creek. The latter had 52 percent more logs in the channel and therefore required less bed material movement than the former. Although these are "rushing mountain streams," most flow velocities ranged between 0.5 and 2.5 f.p.s. Exponents of a function relating rate of change of depth or velocity to discharge indicated that dynamic stream equilibrium was attained. Implications for forest management are that sanitation cuts (removal of dead and dying trees) would not be permissible where a stream is in dynamic equilibrium and bed material movement should be minimized.

333. **Heilman, P.E., H.W. Anderson,** and **D.M. Baumgartner**. 1981. Forest soils of the Douglas-fir region. Wash. State Univ., Pullman, WA. 298 p.

An update of "An Introduction to the Forest Soils of the Douglas-fir Region" of the Pacific Northwest, published in 1957. This comprehensive book on forest soils of the Douglas-fir region, deals with many aspects of soils, including soil biology and chemistry, physical properties of soils, climate and watershed management related to soils, and forest fertilization practices. Soils of many specific geographical areas (e.g., Willamette Valley and the Olympic Mountains province) are described. **

334. **Heinrichs, J.** 1983. Old growth comes of age. J. For. (Dec):776-779.

The report released by the SAF Task Force on Scheduling the Harvest of Old-Growth Timber is reviewed. Discussed are the recommendations and conclusions made by the SAF directed towards: 1) refining the ecological definition of old growth; 2) improving current inventory of old growth; 3) developing a rational old growth preservation policy; and 4) adopting a more flexible policy for scheduling timber harvest. Four common old-growth myths are discussed and a brief description of old-growth ecosystems is presented. **

335. **Helmers, A.E.** 1966. Some effects of log jams and flooding in salmon spawning streams. U.S. Dep. Agric. For. Serv., Inst. North. For., North. For. Exp. Stn., Juneau, AK. Res. Note NOR-14.

Streambed scouring and deposition occurred in the areas of two constructed log-debris jams. Gravel shifting associated with jams and flood flows reduced the fine material content of the streambed gravel and may have been responsible for the increased dissolved oxygen concentration.

Log-debris jams intensify streambed instability, especially during floods. They may reduce salmon production in otherwise favorable areas. Gravel movement presumably reduces egg and larvae survival. On the other hand, loss of fine material because of gravel movement should benefit the salmon development environment by improving intergravel waterflow, thus increasing dissolved oxygen availability and making possible more effective removal of metabolic wastes. The effect of log-debris jams on salmon production remains undetermined. From a conservative viewpoint, however, temporary or unstable jams are judged to be detrimental. **

336. **Helvey, J.D., W.B. Fowler, G.O. Klock,** and **A.R. Tiedeman**. 1976. Climate and hydrology of the Entiat Experimental Forest watersheds under virgin forest cover. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. 42. 18 p.

Climatic and hydrologic measurements were made on three watersheds, each containing approximately 2 square miles (5.18 km^2) of drainage area, for 9 years under natural forested conditions. This paper describes the watersheds with respect to soils and geology, morphology, vegetation, precipitation and other climatic parameters; and flow, sediment, temperature, and chemistry of streams during this period.

337. **Hemstrom, M.** and **V.D. Adams.** 1980. Modelling long-term forest succession in the Pacific Northwest. *In* Proc. Symp. on Forest Succession and Stand Development Research in the Northwest. J.E. Means (editor). March 26, 1981, Corvallis, OR. Oreg. State Univ., For. Res. Lab., Corvallis, OR, pp. 14-23.

A computer model has been developed to simulate forest succession in western Oregon and Washington based on models for other geographic locations. The model tracks the birth, growth and death of individual trees in a forest gap. Birth is random for species able to grow in the existing shade condition. Species-specific diameter increment is dependent on tree diameter, existing foliage biomass, temperature and moisture effects upon growth, competition and shade tolerance. Slow-growth related mortality is conditioned by the size of the tree and the successional status of the species. The results of simulations for xeric and mesic sites in Oregon compare well to species composition and tree size measured in representative forests of each moisture type. Model development suggested parameters which are likely to have major effects on forest succession but which have not been measured in forests as the species composition changes over time. The model is particularly useful for long-term analysis of the effects of disturbances.

338. **Henderson, G.S., W.T. Swank, J.B. Waide,** and **C.C. Grier.** 1978. Nutrient budgets of Appalachian and Cascade region watersheds: a comparison. For. Sci. 24(3):385-397.

Precipitation inputs and streamflow outputs of nitrogen, calcium, potassium, magnesium, and sodium were compared for two deciduous forest watersheds and a coniferous forest watershed. While nitrogen inputs varied by nearly tenfold among the watersheds, ammonium and nitrate discharge in streamflow was uniformly small resulting in net accumulation within all three ecosystems. In contrast, cation discharge was more variable among the watersheds than cation input and was strongly related to the bedrock of each watershed. The internal distribution and cycling of nitrogen, potassium, and calcium within each of the three watershed ecosystems were also compared. There were interpretable differences between nutrient cycling patterns in the coniferous and deciduous forests. Overall, however, all three ecosystems were effectively retaining and recycling these nutrients.

339. **Hendrickson, O.Q.** 1990. How does forestry influence atmospheric carbon? For. Chron. 66:469-472.

Several approaches to studying the effects of forestry practices on the flux of carbon between forest ecosystems and the atmosphere are examined. If the average live forest biomass carbon pool in mature uncut forests is greater than that in second-growth forests, harvesting causes a long-term loss of carbon to the atmosphere. However, in the short term, increased productivity of cut-over stands relative to comparable uncut stands implies a net carbon flux from the atmosphere to the biomass. Management also affects the return flux of carbon to the atmosphere from non-living pools; values for wood and paper products will differ from those for naturally decomposing materials. The greater the proportion of harvested biomass carbon retained in long-lived forest products, the smaller the increase in atmospheric carbon due to harvesting. Under sustainable management, carbon releases to the atmosphere can also be reduced by use of wood biomass fuels, which displace non-renewable fossil fuels. Models combining growth and decay rates with estimates of major carbon pools will provide the best analyses of forest management impacts on the carbon balance.

340. **Hendrickson, O.Q., L. Chatarpaul, and J.B. Robinson.** 1985. Effects of two methods of timber harvesting on microbial processes in forest soil. Soil Sci. Soc. Am. J. 49(3):739-746.

Microbial populations and activities in a mature, mixed conifer and hardwood stand were compared with those in similar adjacent stands harvested by conventional (CH) and whole-tree (WTH) methods. Samples of forest soil (sandy, mixed, frigid Typic Haplorthods) were collected monthly during the first season after harvesting. The NH_4 - N production, measured over the course of 21-d laboratory incubations, declined in the forest floor of the WTH plot, but increased significantly in mineral soil in both harvested areas. Less than 10% of the NH_4 - N produced was nitrified. Nitrifier and denitrifier populations did not increase during the first year following harvesting, and no significant changes in nitrification activity were noted. Forest floor respiration (measured as CO_2 evolved in laboratory incubations) was significantly reduced on both harvested plots relative to the intact stand. Litter bag experiments indicated a reduction in nutrients (N, P, K, MG) available for decomposer organisms on the WTH plot, and a corresponding reduction in litter decay rates. These effects correspond to reductions in forest floor moisture, water-holding capacity, and organic matter content after harvesting. In the 0 to 5-cm mineral soil depth, total bacteria increased on the CH plot but not on the WTH plot. Despite reduced forest floor moisture and nutrient availability, sprouting of trembling aspen (*Populus tremuloides* Michx.) on the whole tree-harvested area was vigorous.

341. **Henein, K. and G. Merriam.** 1990. The elements of connectivity where corridor quality is variable. Landscape Ecol. 4(2/3):157-170.

Small mammals in heterogeneous environments have been found to disperse along corridors connecting habitat patches. Corridors may have different survivability values depending on their size and the degree of cover they provide.

This deterministic model tests the effects of varying corridor quality on the demographics of a metapopulation of *Peromyscus leucopus*. Two types of corridors are defined based on the probability of survival during a dispersal event.

Results indicate that mortality during movement through corridors influences metapopulation demographics. We found that: 1. Any connection between two isolated patches is better than no connection at all in terms of persistence and population size at equilibrium. 2. Metapopulations with exclusively high quality corridors between patches have a larger population size at equilibrium than do those with one or more low quality corridors. 3. Increasing the number of high quality corridors between patches has a positive effect on the size of the metapopulation while increasing the number of low quality corridors has a negative effect. 4. The addition to a metapopulation of a patch connected by low quality corridors has a negative effect on the metapopulation size. This suggests the need for caution in planning corridors in a managed landscape. 5. There is no relationship between the number of corridors and the metapopulation size at equilibrium when the number of connected patches is held constant. 6. Geometrically isolated patches connected by low quality corridors are most vulnerable to local extinctions.

We conclude that corridor quality is an important element of connectivity. It contributes substantially to the effects of fragmentation and should be carefully considered by landscape planners.

342. **Hetherington, E.D.** 1987. Carnation Creek, Canada: review of a west coast fish/forestry watershed impact project. *In* Forest Hydrology and Watershed Management: Proc. of an International Symp. held during the XIXth General Assembly of the International Union of Geodesy and Geophysics. R.H. Swanson, P.Y. Bernier, and P.D. Woodard (editors). Aug. 2-22, 1987, Vancouver, BC. Internat. Assoc. Hydrol. Sci., Wallingford, Oxfordshire. IAHS Publ. No. 167, pp. 531-538.

The purpose of this paper was to describe the Carnation Creek Experimental Watershed Project, initiated in 1970, which was designed to acquire information needed to help minimize conflict in the management of the fish and forest resources in British Columbia. Carnation Creek is a small salmon stream in the rainforest of western Vancouver Island. The results of this project are reviewed, and the application of research findings by resource managers is discussed. The significance of this project to the fishery and forestry management in coastal British Columbia is also addressed. Logging in the experimental Carnation Creek watershed resulted in increased peak water flows, increased ground water levels, and changes in water quality. Major changes in stream morphology, organic debris structure, and deterioration of fish habitat and spawning gravel quality were observed. **

343. **Hinckley, T.M., J.P. Lassoie,** and **S.W. Running**. 1978. Temporal and spatial variations in the water status of forest trees. For. Sci. (suppl.) 24(3):1-72.

This review focuses on the development of naturally occurring spatial and temporal variations in tree water relations and illustrates how the various components of a tree's hydraulic system interrelate. In developing this review, emphasis is given to mature forest-grown trees. Specifically, three points are developed: (1) the spatial variation of total water potential within a tree, (2) the state of the soil-plant-atmosphere continuum which causes these potentials, and (3) the tree properties which lead to the internal adjustment of total water potential. While examining tree water status as it is related to the soil-plant-atmosphere continuum, several deficiencies in current knowledge are revealed. For example, tissue capacitance has generally been ignored in describing waterflow even though it is known that internally stored water can supply as much as 15 percent of the total amount of water transpired during the summer. Over a 3-month, summer period a mature conifer may transpire 4,000 liters of water. Furthermore, there are various unanswered questions concerning physiological activities at the root-soil and leaf-air interfaces. This review also provides an appreciation of the similarities and differences in internal waterflow, water deficit formation, and stomatal activity between seedlings, saplings, and large trees and between deciduous and coniferous species. This review consolidates and synthesizes information valuable to those researchers currently involved in developing directions and methodologies for new physiological studies of tree water relations and should be useful to those presently evaluating experimental results as well as those interested in model simulations.

344. **Hogan, D.L.** 1986. Channel morphology of unlogged, logged and debris torrented streams in the Queen Charlotte Islands. B.C. Min. For., Victoria, BC. Land Manage. Rep. No. 49. 94 p.

This study examined the characteristics of in-stream large organic debris (LOD) in logged and unlogged watersheds in the Queen Charlotte Islands, British Columbia. The objectives of this study were to: 1) compare the input, storage and output components of LOD budgets in logged, unlogged, and torrented watershed streams; 2) to assess how these changes influenced stream channel morphology; and 3) to infer how such changes would influence the recovery of disturbed stream channels to an undisturbed state. All aspects of LOD budgets were affected after logging and debris torrenting in small and medium watersheds. Initially, size and abundance of debris entering the stream was reduced. A shift in orientation of debris within the stream resulted from decreased debris size, and therefore trapping and scouring functions of debris are altered. Stream morphology becomes less complex, stream depth is reduced, width and sediment texture variability decreases and pool area diminishes. Tendency for major debris jams to occur increased as debris became smaller; these debris jams, storing large amounts of clastic sediment upstream, lead to decreased channel stability. Since the effects of logging and debris torrenting may affect streambank vegetation over a long period of time, it is possible that the resulting disturbances in channel process will not be reversed over forest management time scales. **

345. ————————. 1987. The influence of large organic debris on channel recovery in the Queen Charlotte Islands, British Columbia, Canada. *In* Erosion and sedimentation in the Pacific Rim. Proc. Symp. Internat. Assoc. Hydrol. Sci. R.L. Beschta *et al.* (editors). Aug. 1987, Corvallis, OR. Internat. Assoc. Hydrol. Sci., Wallingford, Oxfordshire. IAHS Publ. No. 165, pp. 343-353.

In-stream LOD characteristics are evaluated in unlogged and logged coastal watersheds. The study examines the input, storage and output components of LOD budgets, how these are altered in logged and torrented channels and how these changes influence the recovery of disturbed channels. In small and medium sized watersheds, all components of the LOD budget are altered after logging and debris torrenting. Initially, the size and abundance of debris staged to enter the stream system are reduced. Reduction in material size leads to a shift in the orientation of debris stored within the channel zone. Consequently, the scouring and trapping functions of debris pieces are altered. A less complex morphology results, including reduced depth, width and sediment texture variability and diminished pool area. The smaller debris is less stable causing an increased tendency for the material to cluster into major debris jams; this stores large volumes of clastic sediment upstream and leads to reduced channel stability. Because logging and debris torrenting can affect streambank vegetation for long periods of time, it is possible that the resultant channel disturbances will not be reversed over forest management time scales.

346. ————————. 1989. Channel response to mass wasting in the Queen Charlotte Islands, British Columbia: temporal and spatial changes in stream morphology. *In* Proc. of Watershed '89, Conf. on the Stewardship of Soil, Air, and Water Resources. E.B. Alexander (editor). March 21-23, 1989, Juneau, AK. U.S. Dep. Agric. For. Serv., Alaska Reg., Juneau, AK. R10-MB-77, pp. 125-142.

A paired watershed study is being used to compare stream channels with various ages of mass wasting disturbance with similar channel types in undisturbed basins. In year 1 of a 4 year program (1988), approximately 27 km of stream channel were inventoried, including a wide range of stream sizes and debris torrent ages from 1 to 150 years. Morphological parameters of relevance to fish habitats were the focus of the field surveys. A case study is presented here.

A fundamental consequence of debris torrent inputs to stream channels is the establishment of sediment wedges associated with debris jams. Specific sedimentological, morphological and hydraulic changes occur upstream and downstream of the jams. The sediment wedges are of two basic types, vertical and lateral. The location, size and function of each type of jam controls morphology and their distribution along the water course influences the spatial adjustment of the channel. The integrity and longevity of the debris jams control the temporal response of the channel. Initial results indicate that severe morphological alterations persist during the first decade following debris torrenting, but the channel begins to develop more normal characteristics during the second and third decades. The morphological nature of stream channels 30 years after disturbance begins to resemble undisturbed channels.

347. **Hogan, D.L.** and **D.J. Wilford**. 1989. A sediment transfer hazard classification system: linking erosion to fish habitat. *In* Proc. of Watershed '89, Conf. on the Stewardship of Soil, Air, and Water Resources. E.B. Alexander (editor). March 21-23, 1989, Juneau, AK. U.S. Dep. Agric. For. Serv., Alaska Reg., Juneau, AK. R10-MB-77, pp. 143-155.

A problem in watershed management is linking upslope erosion associated with forestry practices to downstream sedimentation of fish habitats. To overcome this problem, a sediment transfer hazard classification system was developed and applied to a northwestern British Columbia watershed. The system is based on geomorphic factors that influence sediment production, transport, and deposition. Data to describe these factors are obtained from air photographs, topographic maps, fish habitat inventories and interpretive terrain maps. The final product of the system is a sediment transfer hazard map that indicates

where in a watershed sediment production and movement is a potential problem. This is an important tool for watershed and integrated resource managers because not all unstable or erodable sites pose a sedimentation hazard to fish. Knowing the hazards, managers can decide in an informed way where to restrict forest harvesting or focus limited dollars on special road construction and harvesting techniques. This paper describes the Sediment Transfer Hazard Classification System.

348. **Holland, D.G.** 1986. The role of forest insects and diseases in the Yellowstone ecosystem. West. Wildlands 12(3):19-23.

Exclusion of fire that created mosaics of forest vegetation with a wide distribution of age, species diversity, and size has resulted in "old-growth" forest and extensive pest infestations (insects, fungal diseases, and mistletoe). It is argued that management of the forests in the Greater Yellowstone Ecosystem must be structured and designed to allow realistic integration of pest occurrence, its effects and treatment, with the dynamics of forest stand growth and management objectives. **

349. **Holmes, R.T., R.E. Bonney, Jr.** and **S.W. Pacala**. 1979. Guild structure of the Hubbard Brook bird community: a multivariate approach. Ecology 60(3):512-520.

We examined the similarities and differences in the foraging patterns of 22 insectivorous bird species during their breeding season in the Hubbard Brook Experimental Forest, New Hampshire, U.S.A. Using multivariate techniques (clustering of hyperdimensional Euclidean distances, principal components analysis, and Varimax rotated factor analysis), we distinguish 4 groups of species or guilds, each of which exploits food resources in a distinctly different way. Partitioning occurs primarily by (1) foraging height and height-related characters, (2) foraging locations within the forest canopy, and (3) differential use of tree species, foraging substrates and foraging maneuvers. The results indicate that the importance of vegetation height to bird species diversity is related (1) to foraging opportunities which differ along a gradient from ground level to the upper canopy and which are roughly indexed by measures of foliage height diversity (FHD), and (2) to the presence of the supporting branch and bole framework which provides a major distinct foraging region. We suggest that foraging opportunities vary with height in a forest and are influenced by the physical and chemical characteristics of the plant species, which in turn affect the kinds and distributions of foraging substrates, the ways in which birds search for and find food, and the abundances of food resources. The implications of these findings for understanding the structure of forest bird communities are discussed.

350. **Hoover, M.D.** and **C.F. Leaf**. 1967. Process and significance of interception in Colorado subalpine forest. *In* Forest hydrology. W.E. Sopper and H.W. Lull (editors). Pergamon Press, New York, NY, pp. 213-224.

The process by which snow particles are accumulated by foliage during a storm is discussed. At the outset, most snow ricochets off the needles or slides down them. Snow is first accumulated at the base of the needles, facilitated by upward-inclined needles. Once the initial snow is deposited, more snow is retained by cohesion and the accumulation rate accelerates. Snow held solely within the needle space is quickly lost. Large snow masses build where branches and twigs form a close framework, allowing bridging to adjacent snow masses. Low air temperature favors maximal accumulation. Riming may be the cause of greater interceptions at temperatures near freezing. Snowfalls of 1.2-1.5 inches load crown surfaces to the maximal extent. Time-sequence photos were taken of a forest and showed that trees retained no snow in their crowns 45% of the winter. It is suggested that intercepted snow is not vaporized but simply redistributed. Snow courses revealed that no more snow was held in the entire area and that increased depths in the open were equalled by decreased depths in the forest. Increased stream-flow after cutting is probably due to other evaporation-transpiration factors. **

351. **Horn, H.S.** 1974. The ecology of secondary succession. Ann. Rev. Ecol. Syst. 5:25-37.

In this paper the author discusses recent developments in population biology which have implications for theories and patterns of secondary succession. Factors that influence secondary succession, such as productivity, diversity, and stability, are also discussed. The author follows with an analysis of patterns of stability in succession and reviews new insights into the relation between diversity and stability. He concludes: 1) many patterns of succession are the result of stochastic replacements of one plant by another; 2) both early and late succesional species develop a number of adaptational features for survival and propagation; 3) a number of factors promote diversity in the climax stage; 4) there is no relation between diversity and productivity in plants; and 5) despite some argument, diverse and complex communities are generally less stable than comparable communities with fewer interdependant species, and for this reason, diverse and climax communities inherently fragile to human disturbance should be preserved. **

352. **Huff, M.H., J.K. Agee,** and **D.A. Manuwal**. 1985. Postfire succession of avifauna in the Olympic Mountains, Washington. *In* Proc. Symp. on Fire's Effects on Wildlife Habitat. J.E. Lotan, and J.K. Brown (compilers). U.S. Dep. Agric. For. Serv., Intermtn. Res. Stn., Ogden, UT. Gen. Tech. Rep. INT-186., 8 p.

The lower montane zone in the Olympic Mountains (Olympic National Park) was selected to study fire effects in west-slope western hemlock (*Tsuga heterophylla*)/Douglas-fir (*Pseudotsuga menziesii*) forests. Birds were examined along a postfire chronosequence: years 1 to 3, 19, 110, 181, and 515. The objectives of this research were to document the successional patterns of a moist temperate coniferous forest following large lightning fires and to determine the broad ecological effects of fire in these forests. Avifauna that commonly breed in disturbance or mature-type forests were present in postfire years 1 to 3. In year 1, the breeding density and diversity were similar to the nearby old-growth (preburn) forest. Breeding density and diversity decreased in years 2 and 3. The 19-year-old site maintained the highest number of species and second highest density throughout the study areas. Diversity and density were lower at the closed canopy forest, except in the old-growth forest (year 515), where the highest avian density was recorded.

353. **Hunter, A.F.** and **L.W. Aarssen**. 1988. Plants helping plants: new evidence indicates that beneficence is important in vegetation. BioScience 38(1):34-40.

The study of competition in predation has dominated the study of ecology, especially in studying communities. The interaction between competition and beneficence has remained largely unexplored. This paper summarizes a number of ways in which plants may benefit from interactions with other species, and considers the theoretical implications of beneficence in vegetation, particularly as it may interact with competition in affecting community structure. The positive effects of plants on neighbouring species are distinguished according to whether the environmental improvement is physical or biotic. The author then follows with a discussion of beneficence and its potential impacts on community structure. **

354. **Hunter, M.L., Jr.** 1987. Managing forests for spatial heterogeneity to maintain biological diversity. Trans. N. Am. Wildl. Nat. Resour. Conf. 52:60-69.

Forest managers who wish to maintain species diversity of forests must consider the incredible variation of home range sizes of animals. Management of forests for spatial heterogeneity to maintain biological diversity requires, ideally, harvesting techniques that range from fine scale selection cutting to clearcutting a given area. This will involve making silviculture decisions at a landscape level rather than stand by stand. **

355. ——————. 1989. What constitutes an old-growth stand? J. For. 87(8):33-35.

This article discusses the development of a conceptual definition of old-growth forests. The author begins by first proposing a broad conceptual definition of old-growth forests, from which specific definitions for each forest type can be derived. Age and disturbance criteria that are likely to have ecological significance should then be considered to form locally appropriate old-growth definitions. Several age and disturbance criteria are listed. After the selection of appropriate age and disturbance criteria, old-growth definitions for each forest type should be developed, taking into account forest structure, forest development, and historical and current patterns of human disturbance. Such precise definitions could include information about species composition, vegetative structure (i.e., size and density of live, dead standing, and dead and down trees) and minimum area. Development of a conceptual definition of oldgrowth will have obvious advantages in the management of these forests. **

356. **Hunter, M.L., Jr., G.J. Jacobson, Jr.**, and **T.I. Webb**. 1988. Paleoecology and the coarse-filter approach to maintaining biological diversity. Conserv. Biol. 2(4):375-385.

The difficulties of saving millions of species from extinction often cause conservationists to focus on a higher level of biological organization, the community. They do so for two reasons: (1) communities are considered important biological entities in their own right, and (2) conserving representative samples of communities is seen as an efficient way to maintain high levels of species diversity. This approach will work if the chosen communities contain almost all species. Because it potentially saves most but not all species, community conservation is a "coarse-filter" approach to the maintenance of biological diversity, and contrasts with the "fine-filter" approach of saving individual species. Paleoecological information on the distribution of plant taxa in North America, however, indicates that most modern plant communities are less than 8,000 years old and therefore are not highly organized units reflecting long-term coevolution among species. Rather, they are only transitory assemblages or co-occurrences among plant taxa that have changed in abundance, distribution, and association in response to the large climate changes in the past 20,000 years. During periods when climate changes are large, communities are too ephemeral to be considered important biological entities in their own right. Large climatic changes are also likely to occur during the next century because of increased concentrations of CO_2, and we therefore propose that the coarse-filter approach to selecting nature reserves should be more strongly influenced by the distribution of physical environments than by the distribution of modern communities. Ideally, nature reserves should also encompass a broad enough range of environments to allow organisms to adjust their local distribution in response to long-term environmental change, and should be connected by regional corridors that would allow species to change their geographic distributions.

357. **Hyde, W.F.** and **D.C. le Master**. 1979. The marginal lands provision. J. For. 77(1):19-21.

Identifying national forestlands unsuited for timber production is a yet-to-be-completed task of implementing the National Forest Management Act. As a general criterion for decision-making, the authors propose maximization of net public benefits. These are direct benefits from timber production net of direct costs and equal to or greater than the opportunity costs incurred in creating the benefits. This criterion can be extended to take into account contending multiple-use values, lands that have commercially valuable timber on them but are marginal in terms of site capabilities for growing new crops, and situations where marginal and productive lands are intermingled.

358. **Isaac, L.A.** 1946. Fog drip and rain interception in coastal forests. U.S. Dep. Agric. For. Serv., Pac. NW For. Exp. Stn., Portland, OR. For. Res. Notes No. 34. 2 p.

Rain gauges installed on the Cascade Head Experimental Forest from 1938 to 1941 revealed the role of tree canopies in rain interception and the creation of fog drip. Notable differences in annual precipitation were shown by gauges in the open where there was no influence from a forest canopy. The station at the ocean front had the least rainfall and the ridge 5

miles from the ocean had the most. Tree crowns had a significant effect on the amount of water reaching the gauges. Light rains merely wetted the foliage and evaporated. In foggy weather, fog condensed and dripped to the ground in considerable quantities (particularly on the cloud-ridden ridge near the ocean) when there was no moisture caught by gauges in the open. There was an increase in precipitation on timbered regions close to the coast compared to stations further inland. Fog drip plays a significant role in these forests, lessening the flamability of timber. **

359. **Isaacs, F.B.** and **R.G. Anthony**. 1987. Abundance, foraging, and roosting of bald eagles wintering in the Harney Basin, Oregon. N.W. Sci. 61(2):114-121.

Bald eagles (*Haliaeetus leucocephalus*) were observed in the Harney Basin, Oregon, during the winters of 1982-83 and 1984. The number of bald eagles peaked at ≅ 170 during 28 February-6 March 1983 and ≅ 180 during 19-25 March 1984. Both peaks coincided with large numbers of migrating waterfowl in the basin. Eagles foraged primarily on waterfowl from November to December, on mammal carrion from December to February, and again on waterfowl from February to April. Fifteen communal roosts were located; eight were in ponderosa pine (*Pinus ponderosa*) stands in the forested foothills of the Blue Mountains, and seven were in deciduous trees on the basin floor. Coniferous roost trees were the largest, dominant or codominant trees in roost stands. Most (98%) roost trees were larger than the USDA Forest Service minimum old-growth specifications for the ponderosa pine forest type. Management of bald eagle habitat in the Harney Basin should include maintenance of old-age trees, planting of deciduous trees close to feeding sites, avoidance of activity that drastically changes normal seasonal flooding patterns, and encouragement of ranchers to leave cow carcasses available for eagles.

360. **Jablanczy, A.** 1989. Sustainable silviculture: redefining fundamental issues. Trumpeter 6(2):61-62.

The author discusses the need for an environmentally based forest management system to replace the current simplified mechanized plantation approach. He also suggests a gradual process (legal and scientific) to achieve this goal. **

361. **Janzen, D.H.** 1983. No park is an island: increase in interference from outside as park size decreases. Oikos 41:402-410.

As areas of conserved pristine forest are reduced in size they are increasingly susceptible to significant immigration of animals and plants from nearby anthropogenic secondary successional habitats, and the animals of the pristine forest are also likely to forage outside of the pristine forest in the food-rich secondary succession. This phenomenon should be of particular importance to the interactions that occur in natural disturbance sites with pristine forest (e.g., succession in tree falls). However, since much large tree regeneration begins in tree fall gaps in the canopy, even the composition of the canopy may be influenced by large bodies of non-pristine vegetation surrounding the preserved area. From a conservation standpoint, this emphasizes that in some cases a patch of pristine forest may remain ecologically intact longer if surrounded by croplands and closely grazed pastures than if surrounded by extensive areas of secondary succession rich in plants and animals that will invade the pristine forest. Colonization of a tree fall by *Cecropia peltata* trees in pristine forest in Santa Rosa National Park, northwestern Costa Rica is used as an example. The phenomenon emphasizes some of the ways that small islands of vegetation may be only poorly analogous to more conventional islands surrounded by water.

362. **Jarvis, P.G.** and **J.W. Leverenz**. 1983. Productivity of temperate, deciduous and evergreen forests. *In* Physiological plant ecology. Vol. 4. Ecosystem processes. D.L. Longe *et al.* (editors). Springer-Verlag, New York, NY, pp. 233-280.

The productivity of forest ecosystems depends primarily on the productivity of the overstory species. This analysis deals particularly with the environmental and physiological variables responsible for determining the productivity of major tree species, as authors were not able

to take into account the whole field of ecosystem dynamics. Information concerning managed and unmanaged forests, including plantations, is referenced. The major sections of this work deal with: 1) a conceptual growth model; 2) radiation interception; 3) leaf area index and photsynthetic efficiency; 4) respiratory losses; and 5) mortality losses. Six forest properties, all of which have substantial effects on growth, are identified. **

363. **Jenkins, K.J.** and **E.E. Starkey.** 1982. Social organization of Roosevelt elk in an old-growth forest. J. Mamm. 63(2):331-334.

This study was conducted to determine home range and habitat behavior in non-migratory Roosevelt elk in Olympic National Park, Washington. The grouping behavior of adult cow elk was evaluated from an examination of home ranges, elk association within social groups, and mean monthly sizes of elk groups. Social organizations of elk in stable old-growth forests of Olympic National Park, in stable meadow habitats in north-coastal California, and in silviculturally managed forests were compared. These organizations were found to be similar in old-growth and meadow habitats but not in silviculturally managed forests. The authors conclude that these results support the previous hypothesis that cohesiveness of elk groups is related to development and maintenance of strong social bonds in predictable and stable habitats. Large group sizes observed in both closed forest and open meadow were attributed to the same process of social maturation which could influence cohesiveness of elk social units. Populations with traditionally strong bonding were expected to have larger group sizes than those lacking these attributes. The authors believed that the uncharacteristically large home ranges of elk found in this study may be attributed to the nature of the forage source and the large group sizes of elk. Small groups that inhabited diverse environments with concentrated forage had the opportunity to obtain seasonal and daily requirements in a smaller area than large groups observed in the relatively homogeneous old-growth forest. **

364. **Jennings, M.D.** and **J.P. Reganold.** 1989. Local government policies toward environmentally sensitive areas in British Columbia, Canada; Washington and Oregon, USA. Environ. Manage. 13(4):443-453.

While there has been sustained debate on the issue of provincial and state versus local government environmental planning, maintaining privately owned natural resources in the public interest is increasingly viewed as beyond the scope of local governments alone. This paper describes and compares province- and state-level mandates and options for local governments (i.e., city, county, or district) to regulate land uses of environmentally sensitive areas (ESAs) in British Columbia in Canada and in Washington and Oregon in the United States. We define ESAs as landscape elements or places that are vital to the long-term maintenance of biological diversity, soil, water, and other natural resources, especially as they relate to human health, safety, and welfare, both on-site and in a regional context. Underlying similarities are that all three jurisdictions legally express the need for land-use planning by local governments in managing ESAs. Although all three jurisdictions exhibit similar problems in their attempt to accomplish this, ESA planning by local governments is an optional process in British Columbia and Washington but mandatory in Oregon. Furthermore, actual processes prescribed by each of the three jurisdictions are quite different. The information base upon which local regulation of privately held ESAs depends is variable, both within and between the province- and state-level jurisdictions. Other than for some specific water-related resources, standard definitions and inventory methods for ESAs are lacking, as is coordination among local governments or among the province- and state-level governments. This study concludes that there is a need for a regional environmental information system in the Pacific Northwest based upon an integrated and scientific approach toward ESA structures and functions.

365. **Johnson, E.A., G.I. Fryer, and M.J. Heathcott.** 1990. The influence of man and climate on frequency of fire in the interior wet belt forest, British Columbia. J. Ecol. 78:403-412.

(1) The effects of man and climate on fire frequency have been studied using historical data and a fire-history model in Glacier National Park in British Columbia, Canada.

(2) Glacier National Park experienced a change in fire cycle in the 1760s, which could be related to the occurrence of the Little Ice Age. Before 1760, the fire cycle was 80 years and after 1760 it was 110 years. The longer fire cycle after 1760 was clearly related to the cooler, moister climate which also resulted in the advance of glaciers at that time in the Park.

(3) The construction of the Canadian Pacific Railroad through the Park corresponded to a period in which the area burnt by man increased (1883, 1885 and 1886) and many lightning fires occurred. There has not been a decrease in the fire frequency since the establishment of Glacier National Park in 1888, despite a fire-suppression policy.

(4) Large, high-intensity, rapidly spreading fires caused by lightning are associated with a characteristic synoptic weather pattern which consists of two parts: (i) intense fuel drying associated with a stationary high-pressure system blocking access of moist Pacific air, and (ii) one or more periods of breakdown of the high-pressure system into low-pressure systems, which create lightning and high winds.

(5) To have supplanted climate as a major determinant of fire frequency, man must either have used regular management burning or suppressed fires during critical weather periods. Because this has not ocurred in Glacier National Park, the present fire regime is largely natural.

366. **Johnson, W.M.** 1942. The interceptions of rain and snow by a forest of young ponderosa pine. Trans. Am. Geophys. Union 23:566-570.

A study of rain and snow interception in ponderosa pine forests. There was an initial storage of precipitation in the canopy of 0.03 - 0.05 inches. After the crowns had been saturated, almost all precipitation reached the ground. There were no seasonal differences in interception loss; snow was intercepted in the same magnitude as was rain.

367. **Jones, G.W.** and **F.L. Bunnell.** 1984. Response of black-tailed deer to winters of different severity on northern Vancouver Island, a case study. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 385-390.

In the mountainous interior of Vancouver Island, British Columbia, snow was the greatest single factor influencing habitat selection by black-tailed deer in winter. The tree canopy of old-growth forests intercepted falling snow, and consequently snow was much shallower than in adjacent logged habitats. The deep, soft snow in cut-over areas prevented deer movement and restricted deer to old-growth winter ranges during a severe winter. Deer were more widely distributed in a mild winter having less snow. The severe winter restricted diets, worsened the condition of the deer, caused mortality, reduced juvenile recruitment, and reduced production of fawns the following summer. Identification of the necessity of old growth as winter habitat resulted in efforts to protect important winter ranges from logging in watersheds having periodic severe winters.

368. **Joyce, L.A., M.A. Fosberg,** and **J.M. Comanor.** 1990. Climate change and America's forests. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-187. 12 p.

This report summarizes the current research on the effects of climate change on America's forests. Unfortunately, the work to date has not been systematic, coverage is not uniform for the country, and different methods of assessments have been used in different areas.

Gap-phase models, interpretations of historical change, and fossil pollen records are some of the methods used. In the west, attention has focused on individual species, not on ecosystem responses. Douglas-fir can be expected to move to higher elevations, decreasing in southern limit of range; ponderosa pine to move upslope, expanding to California and Oregon and decreasing in the southern Rocky Mountains; western hemlock be restricted to wetter sites, while it and western larch would disappear from the Idaho panhandle and east side of Oregon and Washington. Lodgepole pine will likely be minimally affected. Ecological uncertainties of these projections are discussed. **

369. **Juday, G.P.** 1978. Old growth forests: a necessary element of multiple use and sustained yield national forest management. Environ. Law 8:497-522.

This paper outlines the important ecological characteristics of old growth and the management techniques for promoting them. The author provides an analysis of the national forest land allocation decision-making process and suggests improvements for this process. He notes the four major recognized vegetation zones in western Washington and Oregon are: the Sitka Spruce zone, the Valley Margin zone, the Pacific Silver Fir zone, and the Western Hemlock zone. Various characteristics of old growth are described, including age groupings, size of trees, stand attributes, structure, mortality, habitat, and ecological processes. A number of management techniques to promote old growth are suggested: establishing a network of old-growth enclaves; allowing for long rotations; providing stream buffers; retaining groves of old-growth trees in clearcuts; retaining snags and logs; importing logs; and creating snags in managed areas. The author has suggestions for improving the national forest land-allocation process so as to better manage and perpetuate old growth. **

370. ————. 1988. Old-growth forests and natural areas: an introduction. Nat. Areas J. 8(1):3-6.

This is an introduction to a series of special issue articles on old-growth forests, published by the Natural Areas Journal. It discusses old-growth concepts and definitions, and emphasizes the need for greater public awareness of the value of old-growth forests. Characteristic features of old-growth forests are described—"the old-growth forest syndrome". The author then follows with brief discussions of several problems concerning future management, protection, sustainability, and creation of old-growth forests. **

371. **Jurgensen, M.F., M.J. Larsen, R.T. Graham,** and **A.E. Harvey.** 1987. Nitrogen fixation in woody residue of northern Rocky Mountain conifer forests. Can. J. For. Res. 17:1283-1288.

Nitrogen fixation rates, as estimated by the acetylene reduction technique, were determined for four decay stages of down Douglas-fir logs on two old-growth sites in northwestern Montana. Acetylene reduction rates increased as wood decay progressed, but were not affected by site location. Wood carbohydrate, soluble sugar, total and soluble nitrogen, and moisture content also varied among decay stages. Acetylene reduction rates were positively correlated with wood moisture content and nitrogen concentration, and negatively correlated with carbohydrate level. The annual nitrogen additions to the sites from nitrogen fixation in decaying Douglas-fir logs were small, 0.72 kg/ha/yr on the moister site and 0.26 kg/ha/yr on the drier site. These differences in nitrogen inputs were related to differences in residue loading between sites. Although small, such nitrogen gains may be significant over the rotation life of a stand.

372. **Jurgensen, M.F., M.J. Larsen, S.D. Spano, A.E. Harvey,** and **M.R. Gale.** 1984. Nitrogen fixation associated with increased wood decay in Douglas-fir residue. For. Sci. 30(4):1038-1044.

N fixation rates were estimated using the acetylene reduction technique for 4 decay stages of fallen logs with *Fomitopsis pinicola* fruiting bodies on 2 old growth sites in NW Montana. Acetylene reduction rate increased as wood decay progressed but was not affected by site location. Wood carbohydrate, soluble sugar, total and soluble N and moisture content

also varied among decay stages. Acetylene reduction rates were positively correlated with wood m.c. and N concn. and negatively correlated with carbohydrate content. Additions of nitrogen to sites resulting from N fixation in decaying logs were small: 0.72 kg/ha p.a. on the moister site and 0.26 kg/ha p.a. on the drier site; these differences were related to differences in residue loading (7.6 cm diam.), which were 114 and 49 t/ha respectively.

373. **Kaiser, F., D. Schweitzer,** and **P. Brown.** 1984. Economic value analysis of multiple-use forestry: research today for tomorrow's forests. Proc. IUFRO. Dep. Resour. and Recreation Manage., Oreg. State Univ., Corvallis, OR. 187 p.

The papers presented at this conference illustrate world research on economic value analysis of multiple use forestry. Social benefits of forests are strongly emphasized in many papers. **

374. **Kaufmann, M.R.** and **C.A. Troendle.** 1981. The relationship of leaf area and foliage biomass to sapwood conducting area in four subalpine forest tree species. For. Sci. 27(3):477-482.

Leaf dry weight and area were strongly correlated with sapwood area measured at 1.37 m, but leaf area per unit sapwood area varied widely among species: 1.88 $m^2.cm^{-2}$ for subalpine fir, 0.72 for Engelmann spruce, 0.44 for lodgepole pine, and 0.19 for aspen. The leaf area: sapwood area relationship was nearly constant for different portions of the crown, although the relationship was erratic in subalpine fir. Thus the upper portion of a larger tree has the same leaf area:sapwood area ratio as the entire crown of a smaller tree. This supports the hypothesis that a physiological balance exists between conducting tissue and the water requirements of the shoot.

375. **Keisker, D.G.** 1987. Nest tree selection by primary cavity-nesting birds in south-central British Columbia. B.C. Min. Environ. Parks, Wildl. Br., Victoria, BC. Wildl. Rep. No. R-13. 66 p.

I examined use and selection of nest trees by six species of cavity-nesting birds in the Interior Douglas-fir Biogeoclimatic Zone (IDF) near Kamloops, British Columbia. Analyses were based on 243 active nests located during 1984 and 1985.

Presence of heartwood decay was the most important tree characteristic influencing selection of nest trees; all bird species strongly preferred trees bearing fruiting bodies of heartrot fungi. Most nests occurred in trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*). Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) and hybrid spruce (*Picea engelmannii x glauca*) were not used for nesting, probably because their pattern of decay was unfavourable for cavity-nesting. However, dead conifers appeared to be important foraging substrates. In trembling aspen, infection with heartwood decay occurred in live trees, leaving a sound sapwood shell protecting nest holes excavated in the softened heartwood. Such trees were preferred by the stronger excavators, Yellow-bellied Sapsucker (*Sphyrapicus varius*), Pileated Woodpecker (*Dryocopus pileatus*), and Hairy Woodpecker (*Picoides villosus*), which were able to penetrate the hard sapwood. Weaker excavators, Red-breasted Nuthatch (*Sitta canadensis*), Northern Flicker (*Colaptes auratus*), and Downy Woodpecker (*Picoides pubescens*), preferred dead trees or dead tops of live trees for nesting. Yellow-bellied Sapsucker preferred to nest in trees larger than 30 cm dbh, and Pileated Woodpecker preferred trees larger than 40 cm dbh. No significant preference for nest tree diameter was detected for the other species. Results were very similar when analyses were based on old, unoccupied cavities instead of active nests.

Stands containing deciduous trees were strongly preferred to coniferous forest for nesting. Structural variation of the vegetation within the deciduous or mixed stands had very little influence on nest tree selection.

Trees with attributes preferred for nesting occur as part of the deciduous, maturing and overmature seral vegetation, which is replaced by coniferous climax forest as succession proceeds. Uneven-aged forest management and fire suppression create adverse conditions

for establishment of deciduous stands. To ensure continuous availability of nesting habitat for primary cavity-nesters over time, a mosaic of successional stages should be maintained by periodically creating openings in sites suitable for regeneration of deciduous trees.

Tree species differ in their decay characteristics, their ecology, and in the role they play in forest management. Nest tree preferences and management guidelines outlined in my study may, therefore, not be relevant to areas where species other than trembling aspen and paper birch are important for nesting.

376. **Keller, E.A., A. MacDonald,** and **T. Tally.** 1981. Streams in the coastal redwood environment: the role of large organic debris. *In* Proc. Symp. on Watershed Rehabilitation in Redwood National Park and Other Coastal Areas. R.N. Coats (editor). Kendal/Hunt Publ. Co., Binghampton, NY, pp. 161-176.

The authors offer several lines of evidence supporting the conclusion that large organic debris (LOD) plays a major role in stream channel form and process, and thus in anadromous fish habitat in coastal redwood environments. The evidence is as follows: 1) LOD may reside in streams for lengthy periods of time—for centuries—and is therefore a permenant part of this fluvial system; 2) LOD has a significant role in determining channel morphology, particularly in the development of pools; 3) LOD is responsible for the production of sediment storage sites, supporting a sediment buffer system that controls the routing of sediment through fluvial systems; and 4) LOD in streams has a significant effect on the way potential energy is expended by concentrating energy expenditure over short reaches where accumulations of LOD exist. The implications of these findings to stream management for the maintenance of anadromous fish habitat are discussed. **

377. **Keller, E.A., W.N. Melhorn,** and **M.C. Gardner.** 1976. Effects of autodiversion (logjams) on stream channel morphology. Geol. Soc. Am. 8(6):950.

Formation of logjams in meandering streams is associated with: (1) erosional processes that locally increase channel width by more than 50 percent as water is diverted around an obstruction; (2) depositional processes that initiate the development of mid-channel bars as islands immediately downstream from a logjam; and (3) a backwater effect upstream and localized scour adjacent to the logjam.

Investigation of logjams in the midwestern and southeastern United States suggests that they may be intimately associated with the development of short, braided stream reaches and meander cutoffs that resemble but are distinctly different from chute cutoffs. Mapping of recent logjams in a stream establishes morphologic criteria (bank erosion and associated island development) used to recognize sites of former logjams. Dendrochronology is used where possible to date islands that developed in response to logjams no longer present in the channel.

Autodiversion of a stream channel by a logjam which ponds water and locally increases overbank flow may facilitate the development of a meander cutoff provided: (1) the jam is in a favorable location on the bend; and (2) a favorable flood plain drainage system exists to concentrate the diverted water across the meander bend. Furthermore, the chance of a cutoff is dependent upon the size of the stream. Large rivers rarely have logjams and in very small streams trees tend to bridge rather than block the channel. Therefore, the most favorable conditions for a cutoff to develop in association with a logjam occur with an intermediate size stream. The time during which a cutoff develops in a few tens of years may be in response to the formation of several logjams in the same vicinity over that period of years.

378. **Keller, E.A.** and **F.J. Swanson.** 1979. Effects of large organic debris on channel form and fluvial processes. Earth Surface Processes 4:361-380.

Stream channel development in forested areas is profoundly influenced by large organic debris (logs, limbs and rootwads greater than 10 cm in diameter) in the channels.

In low gradient meandering streams large organic debris enters the channel through bank erosion, mass wasting, blowdown, and collapse of trees due to ice loading. In small streams large organic debris may locally influence channel morphology and sediment transport processes because the stream may not have the competency to redistribute the debris. In larger streams flowing water may move large organic debris, concentrating it into distinct accumulations (debris jams). Organic debris may greatly affect channel form and process by: increasing or decreasing stability of stream banks; influencing development of midchannel bars and short braided reaches; and facilitating, with other favourable circumstances, development of meander cutoffs.

In steep gradient mountain streams organic debris may enter the channel by all the processes mentioned for low gradient streams. In addition, considerable debris may also enter the channel by way of debris avalanches or debris torrents. In small to intermediate size mountain streams with steep valley walls and little or no floodplain or flat valley floor, the effects of large organic debris on the fluvial processes and channel form may be very significant. Debris jams may locally accelerate or retard channel bed and bank erosion and/or deposition; create sites for significant sediment storage; and produce a stepped channel profile, herein referred to as "organic stepping", which provides for variable channel morphology and flow conditions.

The effect of live or dead trees anchored by rootwads into the stream bank may not only greatly retard bank erosion but also influence channel width and the development of small scour holes along the channel beneath tree roots. Once trees fall into the stream, their influence on the channel form and process may be quite different than when they were defending the banks, and, depending on the size of the debris, size of the stream, and many other factors, their effects range from insignificant to very important.

379. **Keller, E.A.** and **T. Tally.** 1979. Effects of large organic debris on channel form and fluvial processes in the coastal redwood environment. *In* Adjustments of the fluvial system. D.D. Rhodes and G.P. Williams (editors). Kendal-Hunt, Dubuque, IA, pp. 169-197.

This paper discusses the role of large organic debris in channel form, fluvial processes, and development and maintenance of anadromous fish habitat in streams flowing within redwood old-growth forests. The author places emphasis on the effects of large organic debris on stream slope, width and depth, fish habitat diversity (i.e., pools, bars and riffles), the time of residence of large organic debris in the streams, areal sorting of bedload material, and erosion and deposition patterns. Recommendations for management of anadromous fish habitat in coastal redwood forests are offered.

380. **Kellman, M.C.** 1970. The viable seed content of some forest soil in coastal British Columbia. Can. J. Bot. 48:1383-1385.

The upper 10 cm of surface soil and litter beneath a coniferous forest in coastal British Columbia was found to contain over 1000 viable seeds per square meter. (*Alnus rubra*) Bong. made up 68.9% of all viable seed, although 18 other species, mainly weedy and secondary types, were recorded.

381. ————————. 1974. Preliminary seed budgets for two plant communities in coastal British Columbia. J. Biogeog. 1:123-133.

Production, movement and storage of seed in an old growth coniferous forest and adjacent secondary community in British Columbia, Canada, were monitored for 3 years. The old growth forest possessed a small seed budget that included some seed of secondary species, characteristic of disturbed situations. The secondary community possessed a far larger seed budget, dominated by locally-growing secondary species. Small quantities of seed of secondary species were able to infiltrate appreciable distances into the old growth forest. However, the store of seed of these species within the forest was insufficient to account for the large populations that soon appear at logged sites, unless initial populations deriving from this source had undergone very rapid expansion thereafter. The development of

rotational tree harvesting in the area is likely to promote an expanding seed budget for secondary species, and a diminishing one for the primary species, characteristic of old growth forests.

382. **Kelly, D.** and **G. Braasch.** 1986. The decadent forest. Audubon 88(2):46-73.

This article discusses aspects of ancient forests that make them complex communities. Fire disturbance and succession, dead and down woody debris, old-growth canopies (their habitat values), and the importance of N contribution to the forest ecosystem by various epiphytes are just a few of the factors mentioned which play a role in maintaining biotic diversity within old-growth forests. This article also addresses one of the most troubling environmental issues facing ecologists and conservationists today: the disappearance of our old-growth forest and, along with it, biological diversity. Much of this paper is devoted to the contributions of several scientists concerned with the conservation of old growth. Their primary intent has been to alter our understanding of these forests by using a relatively new approach of ecosystems research. The connection of the northern spotted owl (as well as other wildlife) with the old-growth issue is examined. Finally, the authors discuss the human role as predators of old-growth forests. **

383. **Kerfoot, O.** 1968. Mist precipitation on vegetation. For. Abst. 29(1):8-20.

This paper reviews experiments conducted over the past 80 years to determine the relationship between fog and mist precipitation and vegetation. The historical review includes: 1) early qualitative observations; 2) relationships between coastal redwoods and fog in California; 3) quantitative approaches to measurement of rainfall interception; 4) fog drip and symbiotic relationships; 5) fog drip and ecological relationships; and 6) physiological implications of fog. The author summarizes the shortcomings of these early experiments and concludes that these inadequacies have restricted our appreciation of the role of fog and mist in the ecosystem. **

384. **Kerrick, M.A., K. Johnson,** and **R.J. Pedersen.** 1984. What information is necessary for planning the management of old-growth forests for wildlife? *In* New Forests for a Changing World: Proc. 1983 SAF National Conven. K.A. Sabol (editor). Oct. 16-20, 1983, Portland, OR. Soc. Am. For., Bethesda, MA. SAF Publ. 84-03. pp. 383-386.

The challenge of managing old-growth forests for wildlife is being faced by managers and decisionmakers in the Forest Service through the current land management planning cycle. To find credible solutions and make informed land management decisions, certain questions need to be answered. Foremost of these information needs is a precise and defensible definition of old growth in terms of the habitat characteristics that support dependent wildlife. Description of these characteristics and dependent wildlife habitat requirements must be comprehensive enough for the land manager to quantify the amount and distribution of these suitable old-growth habitats throughout the forest. Information facilitating long-term silvicultural maintenance of biological conditions necessary to maintain viable populations of old-growth associated wildlife species is also needed. Until additional research data regarding habitat characteristics for old-growth wildlife species is available, we must be innovative. We will meet the management challenge by using our current technology and by monitoring our practices.

385. **Kessler, W.B.** and **T.E. Kogut.** 1985. Habitat orientations of forest birds in southeastern Alaska. N.W. Sci. 59(1):58-65.

Spring/summer bird surveys were conducted in coastal forest stands in southeast Alaska in 1978 and 1979. The 10 habitat categories surveyed included riparian and nonriparian situations and a successional sequence from new clearcuts to old growth. For 35 species recorded, over half of total observations were contributed by the Winter Wren (*Troglodytes troglodytes*), Dark-eyed Junco (*Junco hyemalis*), and Golden-crowned Kinglet (*Regulus satrapa*), Chestnut-backed Chickadee (*Parus rufescens*), Golden-crowned Warbler

(*Vermivora celata*). Lowest species richness occurred in new clearcuts and in young second-growth sawtimber. Riparian situations supported greater avian abundance and species richness than did riparian stands of the same successional stage. Trends in avian occurrence are related to stand structural changes that occur through the successional sequence. Silvicultural practices such as thinning may have potential to enhance habitat structure and avian diversity in managed second-growth stands.

386. **Kimmins, J. P.** 1987. Forest ecology. Macmillan Publ. Co., New York, NY. 531 p.

A thorough review of forest ecology is presented in three major parts: Part I. Man and the forest or why the science of forest ecology developed; Part II. Forest ecology: the biological basis for management of forest resources, including sections on ecosystem ecology—the forest as a functional system, genetic and evolutionary aspects of ecosystems, the physical environment, the biotic environment, and temporal changes in ecosystem structure and function; and Part III. Application of ecological information in the management of forest ecosystems. **

387. **Kirchhoff, M.D.** and **J.W. Schoen.** 1987. Forest cover and snow: implications for deer habitat in southeast Alaska. J. Wildl. Manage. 51(1):28-33.

Relationships between snow depth and overstory characteristics were studied on 19 0.4-ha old-growth plots and 1 60-year-old 0.4-ha 2nd-growth plot near Juneau during winter, 1983-84. Mean tree diameter at breast height (DBH), number of stems/ha, percent Sitka spruce (*Picea sitchensis*), mean tree height, percent timber defect, basal area, and net timber volume were measured using variable plot and point-centered quarter techniques. Canopy cover was measured from photographs of the overstory taken at each snow measurement point. Snow depth in a high-volume plot (>100,000 board feet/ha) averaged 29% of that in an adjacent forest opening. Snow depth was correlated with net timber volume (r_s = -0.90), tree height (r_s = -0.85), basal area (r_s = -0.79), percent canopy cover (r_s = -0.76, percent spruce (r_s = -0.66), and mean tree diameter (r_s = -0.65). Old-growth plots with high net timber volume had the lowest snow depths. The low snow depths observed in high-volume, old-growth stands are attributed to the large-diameter limbs and deep crowns of older, dominant trees.

388. **Kittredge, J.** 1948. Forest influences. McGraw Hill Book Co. Inc., New York, NY.

Chapter XIV is an excellent and influential review of forest effects on snow cover. Topics dealt with are measuring snow, snow density, evaporation of snow, snow accumulation, and snowmelt.

Density of snow decreases with increasing canopy cover. In California, this effect is more noticeable above 7,000 ft. In general, tree crowns reduce snow accumulation. If openings between crowns are small, excess accumulation in these openings will be small or negative. The greatest excess in snow accumulation occurs in openings at least 1 TH in diameter. The degree to which snow disappearance is retarded is related to forest density. **

389. ————. 1953. Influences of forests on snow in the Ponderosa-subalpine-fir zone of the central Sierra Nevada. Hilgardia 22:1-96.

A classic report of 7 years' work on the effects of forest cover on snow. A total of 100 stations sampled 10 forest types of various age, density, species, and cover. New snow had an average density of 10% and was 1-5% higher under tree crowns. From 13-27% of seasonal snowfall was intercepted by forest canopies. The largest percentages were in the denser types and under crowns. Open screen cutting resulted in greater accumulations than in the open. Maximum snow depths were greater in open areas or in stands with large openings. Dates of maximum snow depths were earlier than dates of maximum SWE. The date when snow reached a density of 40%, the percentage at which percolation begins, was earlier in more open areas. Maximum SWE were smallest in the densest stands. Snow was

maintained longer on the south side of clearings. Snow evaporation was less under tree crowns. The date of snow disappearance varied inversely with crown coverage within a 20-ft radius. **

390. **Kline, J.R., K.L. Reed, R.H. Waring,** and **M.L. Stewart.** 1976. Field measurement of transpiration in Douglas-fir. J. Appl. Ecol. 13(1):273-283.

(1) Transpiration rates of Douglas-fir trees (*Pseudotsuga menziesii*) were measured in the field, using tritiated water (HTO) as a tracer for water. Sites were located in the Cedar River Watershed near Seattle, Washington, and in the Andrews Experimental Forest near Eugene, Oregon.

(2) Transpiration rates ranged from 8.41/day in a small tree to 530 1/day in a large old-growth tree on the Oregon site.

(3) A relationship between transpiration rate and sapwood cross-sectional area of trees was found which would permit extension of individual tree measurements to forest populations.

(4) The HTO measurements, linked to current physical theories of evapotranspiration, permit the computation of actual daily transpiration rates for individual trees or areas of forest.

(5) The method allows direct measurements of water loss from forests in situations where lysimeter installation would be impractical.

(Authors' summary)

391. **Klinka, K., R.E. Carter,** and **M.C. Feller.** 1990. Cutting old-growth forests in British Columbia: ecological considerations for forest regeneration. N.W. Environ. J. 6:221-242.

Two closely related, critical decisions in forest management are: 1. setting the best tree species to regenerate on a given site, and 2. devising the most appropriate method of cutting an old-growth stand with its regeneration in mind. Both decisions presume knowledge of a management objective, the ecological characteristics of ecosystems, stand characteristics, and the climatic conditions conducive to successful regeneration. This knowledge is, in part, provided from the development of an ecological site classification. This ecological site classification can then be used to devise biologically viable, site specific reproduction methods to meet a given regeneration objective. Selected species for regeneration may be the same as or different than the trees being replaced. Regeneration success will depend on protection/exposure requirements and tolerance of the selected species, and may require the use of different reproduction methods on different sites. Reproduction methods providing little or no light interception are suitable for regeneration of exposure-requiring and exposure-tolerant species, whereas methods providing partial light interception and shelter are suitable for exposure-tolerant and protection-requiring species. Old-growth values may be maintained by using selection methods or renewed by using methods such as clearcutting, seed-tree, and shelterwood with reserves and extended rotations. This is illustrated for the Coastal Douglas-fir zone of British Columbia.

392. **Knight, D.H., T.J. Fahey,** and **S.W. Running.** 1985. Water and nutrient outflow from contrasting lodgepole pine forests in Wyoming. Ecol. Monogr. 55(1):29-48.

Factors affecting water and nutrient outflow beyond the rooting zone were studied during a 3-yr period, using data from eight contrasting stands of lodgepole pine (*Pinus contorta* ssp. *latifolia*) forest in southeastern Wyoming and the output of a hydrologic simulation model (H20TRANS) based on tree physiology. Nutrient outflow during a specific time period was estimated by multiplying simulated water outflow times element concentrations in the soil solution, the latter determined from samples collected periodically near the bottom of the rooting zone.

Estimates of actual evapotranspiration (ET) for the period from early spring to late fall ranged from 21 to 53 cm, which was 33-95% (x = 73%) of total annual precipitation. For all stands and years, transpiration accounted for 50-661% of ET, and 9-44% of the transpiration occurred during the spring drainage period (vernal transpiration, VT). Estimated VT and outflow varied considerably among the stands, with VT accounting for 4-20% of the snow water. Outflow occurred only during the snow melt period and accounted for 0-80% of the snow water. Snow water equivalent varied annually by 300% or more. Nutrient outflow from the different stands also varied greatly. Ratios between simulated annual outflow and atmospheric inputs (bulk precipitation) were consistently >1.0 for Ca, Na, and Mg; were consistently <1.0 for N; and ranged from 0.3 to 2.0 for P and from 0.2 to 3.3 for K. Much of the variability in water and nutrient outflow can be attributed to the degree of biotic control, with water outflow affected by a different combination of factors than nutrient outflow. H20TRANS was used to simulate the effects on outflow of different snow water equivalents and different total leaf areas. One result of the simulations was that nitrogen appears to be retained even at the highest levels of water outflow. Another was that increases in water outflow following reduction in leaf area were proportional to the leaf area removed.

The results indicate that stands differing in site or habitat type experience different rates of water and element losses at different times during the snow melt season, and contribute differentially to streamwater quality and hydrograph shape. Factors affecting outflow are discussed in the context of successional trends, common perturbations including timber harvest, and hypotheses pertaining to nutrient conservation in terrestrial ecosystems. Nutrient retention in the snow-dominated lodgepole pine ecosystem appears to be primarily dependent on evergreen leaf area, duration of the VT period, and high carbon/nutrient ratios of the forest floor. Net losses of limiting nutrients probably occur primarily in pulses after abiotic perturbations such as fire.

393. **Knight, R.L.** 1988. Relationships of birds of prey and riparian habitat in the Pacific Northwest: an overview. *In* Streamside management: riparian wildlife and forestry interactions. K.J. Raedeke (editor). Univ. Wash., Seattle, WA. Contrib. No. 59, pp. 79-91.

In this paper the author reviews information dealing with raptor communities, including nesting, foraging, nocturnal roosting, seasonal use, and the effects of human disturbances. Management practices used to mitigate the effects of human disturbances on raptors in riparian zones are also discussed. The author also points out information and research gaps in this topic. Most information provided comes from studies of the bald eagle (*Haliaeetus leucocephalus*) in the Pacific Northwest. Raptors show a strong affinity for riparian zone in terms of nesting, foraging and roosting. They also show strong seasonal variations in the use of riparian zones. Human disturbance of riparian and adjacent areas strongly disrupts raptor use of riparian habitat. The author concludes that managers and researchers must make a concerted effort to preserve remaining riparian habitats. **

394. **Koehler, G.M.** and **J.D. Brittell.** 1990. Managing spruce-fir habitat for lynx and snowshoe hares. J. For. 88(10).

Providing habitat for lynx is compatible with other forest resource uses and can be integrated into a forest management program. Prescribed fires, logging, and timber thinning can create the young-aged forests needed as habitat for the principal prey. However, mature forest stands must also be maintained as habitat for denning. The key to managing forests for lynx is to provide a temporal and spatial mosaic of forest age classes. Managing high-elevation forests in the West for both timber and lynx may result in increased management costs initially, but these could be offset by greater economic and ecological diversity. (From authors' conclusion)

395. **Koehler, G.M.** and **M.G. Hornocker.** 1977. Fire effects on marten habitat in the Selway-Bitterroot Wilderness. J. Wildl. Manage. 41(3):500-505.

An investigation in the Selway-Bitterroot Wilderness of north-central Idaho helped evaluate the effects of fire on marten (*Martes americana*) habitat and food sources. Voles (*Microtinae*) were the most abundant item in the marten diet, occurring in 79 percent of 129 marten scats. These were most abundant in mesic habitats. A total of 2,896 trap days during November 1973 through March 1974 and November and December 1974 resulted in 80 captures of 13 marten and 255 track observations. Marten used a variety of forest types. The highest activity when snow depths were normal was in stands having an Engelmann spruce/subalpine fir (*Picea engelmannii/Abies lasiocarpa*) overstory, canopy cover greater than 30 percent, mesic habitat type, and an overstory age greater than 100 years. The effects of fire on marten habitat and foods are discussed.

396. **Koehler, G.M., W.R. Moore,** and **A.R. Taylor.** 1975. Preserving the pine marten management guidelines for western forests. West.Wildlands 2:31-36.

This paper discusses results of a study on pine marten conducted during 1973-1974 in Idaho's Selway Bitterroot Wilderness, integrates these results with other studies, and offers management guidelines for pine marten preservation. The study of 1973-1974 showed that red-backed voles and meadow voles were the most important food items in the marten's diet, and that mature coniferous forests have the greatest amount of marten activity. Also discussed are effects of habitat disturbance on marten populations. Study of the pine marten may shed light on the effects of forest management on other major predators and climax species. **

397. **Kotter, M.M.** and **R.C. Farentinos.** 1984. Formation of ponderosa pine ectomycorrhizae after inoculation with feces of tassel-eared squirrels. Mycologia 76(4):758-760.

Hypogeous mycorrhizal fungi appear to depend on small animals for spore dispersal. Tassel-eared squirrels (*Sciurus aberti*), which inhabit ponderosa pine forests of the southern Rocky Mountains, depend on hypogeous fungi for food during the summer months. This study showed that after inoculation of ponderosa pine seedlings with feces containing fungal spores, ponderosa pine ectomycorrhizae formed. These results indicated that spores remained viable after passage through the digestive tracts of these squirrels, and that tassel-eared squirrels may serve as vectors of spore dissemination for hypogeous ectomycorrhizal fungi in ponderosa pine forests. The author concludes that these squirrels appear to be the link in perpetuating the symbiotic relationship between the host, ponderosa pine, and mycorrhizal fungi. **

398. **Krajina, V.J.** 1969. Ecology of forest trees in British Columbia. Ecol. West. N. Am. 2(1):1-146.

The autecology of forest trees in British Columbia is abstracted here mainly on the basis of many synecological studies, carried out in the field since 1950. Some ideas, formed during the field studies were tested experimentally in the greenhouses. Conclusions were drawn mainly on the basis of the following integration levels: (1) biogeoclimatic zonal units; (2) biogeocoenoses; (3) higher systematic units; (4) specific and subspecific populations (species, subspecies, varieties), and their floristic and vegetation elements. Out of these integration levels biogeocoenoses and biogeoclimatic zones are of special importance. In different edatopes of different biogeocoenoses, occurring in different biogeoclimatic units, the response of forest trees is indicated by their growth classes (or site indices). In the same biogeocoenosis the site indices of the same tree species may vary according to its edatopes. However, the same growth classes (site indices) coordinate the edatopes as well as their biogeocoenoses even without definite evidence of a continuum pattern in their floristic structure.

If all four previously mentioned integration levels are investigated, analyzed and computed, and if they are coupled with some experimental tests, the results will provide a well substantiated autecological framework for the ecological function of every species. With this approach, an attempt was made to present information on the ecological function of every native tree species in British Columbia.

399. **Krajina, V.J., K. Klinka,** and **J. Worrall.** 1982. Distribution and ecological characteristics of trees and shrubs of British Columbia. Univ. B.C., Fac. For., Vancouver, BC. 131 p.

This report describes the ecology and distribution of 35 tree species and 11 shrub species native to British Columbia. A species-by-species description is provided detailing the following characteristics of each species: nutritional type, edatopic requirements, geographic distribution, climatic requirements, orographic position, physiognomic type, frost tolerance, shade tolerance, and flooding tolerance. The biogeoclimatic units in which each species is found are listed. The ecological requirements and the silvicultural importance of each species is discussed. A map of species diversity on the basis of similar ecolgical affinities, derived by cluster analysis, is also provided. **

400. **Krumlik, G.J.** and **J.P. Kimmins.** 1976. Biomass and nutrient distribution in two undisturbed forest ecosystems. *In* Ecosystems, Biological Productivity. Congress Group 1. Proc., Div. I (Forest Environment and Silviculture), XVIth IUFRO World Congress. June 20-July 2, 1976, Oslo, Norway. Norwegian IUFRO Congress Committee, Norway, pp. 92-103.

The distribution of the above-ground biomass and macronutrient content of the trees were studied on two undisturbed old growth forest ecosystems in south coastal British Columbia, near Vancouver. The stands differed in elevation (1,500 and 700 m), volume of standing timber (993 and 148 m^3/ha), landform and soil. Both stands were overmature (mean age 420 and 250 years), with tree age ranging from 150 to 530 years. The tree cover on the high elevation stand consisted of *Tsuga mertensiana* (Bong.) Carr. (mountain hemlock) and *Abies amabilis* (Dougl.) Forbes (Pacific silver fir) while the lower elevation stand was occupied by *Tsuga heterophylla* (Raf.) Sarg. (western hemlock), *Thuja plicata* D. Don (western red-cedar) and *Chamaecyparis nootkatensis* (D. Don) Spach (yellow-cedar). Twenty-four trees were sampled to determine the biomass and nutrient content of wood, bark, branches, twigs, foliage and cones and another nine trees were sampled for the biomass and nutrient content of wood and bark only.

Regression analysis was used to establish the relationship between d.b.h., tree length, crown length and biomass of the various tree components. The regression equations obtained were used to estimate the total biomass of the sample stands. These data were combined with data on chemical concentrations and used to estimate the distribution of macronutrient elements in different above-ground biomass components of the stands. The results are discussed in terms of different levels of tree utilization.

401. **Lambert, R.L., G.E. Lang,** and **W.A. Reiners.** 1980. Loss of mass and chemical change in decaying boles of a subalpine balsam fir forest. Ecology 61(6):1460-1473.

Decay of balsam fir (*Abies balsamea*) boles was examined in an upper subalpine forest of the White Mountains, New Hampshire, U.S.A. Fifty percent of the initial mass was lost in 23 yr: 90% was lost in 77 yr. High decay rates were attributed to the small diameters of the boles, ample moisture, and a nitrogen-rich environment. Average dead wood mass in this forest was 4.9 kg/m, representing 25% of the sum of dead wood, live plant biomass, and forest floor organic matter.

Changes in density and moisture and in the concentrations and content of various chemical components of the boles were traced over the decay sequence. Changes in the content of cellulose, lignin, carbon and sodium followed loss of mass during decay. Contents of calcium, magnesium, potassium and phosphorus decreased faster than loss of mass in the early stages of decay. Much of this initial loss was ascribed to sloughing of nutrient-rich bark which in these small boles comprised 13% of dry mass. Later in decay, the loss rates

of calcium, magnesium and potassium were about the same or slightly less than the loss rate of mass. After a steep initial drop, phosphorus content of the boles remained approximately constant between years 12 and 33. Thereafter the loss rate paralleled loss of mass. Nitrogen content was approximately constant in the first 33 yr after which it declined in parallel with loss of mass.

402. **Lande, R.** 1988. Genetics and demography in biological conservation. Science 241:1455-1460.

Predicting the extinction of single populations or species requires ecological and evolutionary information. Primary demographic factors affecting population dynamics include social structure, life history variation caused by environmental fluctuation, dispersal in spatially heterogeneous environments, and local extinction and colonization. In small populations, inbreeding can greatly reduce the average individual fitness, and loss of genetic variability from random genetic drift can diminish future adaptability to a changing environment. Theory and empirical examples suggest that demography is usually of more immediate importance than population genetics in determining the minimum viable sizes of wild populations. The practical need in biological conservation for understanding the interaction of demographic and genetic factors in extinction may provide a focus for fundamental advances at the interface of ecology and evolution.

403. **Landres, P.B., J. Verner, and J.W. Thomas.** 1988. Ecological uses of vertebrate indicator species: a critique. Conserv. Biol. 2(4):316-328.

Plant and animal species have been used for decades as indicators of air and water quality and agricultural and range conditions. Increasingly, vertebrates are used to assess population trends and habitat quality for other species. In this paper we review the conceptual bases, assumptions, and published guidelines for selection and use of vertebrates as ecological indicators. We conclude that an absence of precise definitions and procedures, confounded criteria used to select species, and discordance with ecological literature severely weaken the effectiveness and credibility of using vertebrates as ecological indicators. In many cases the use of ecological indicator species is inappropriate, but when necessary, the following recommendations will make their use more rigorous: (1) clearly state assessment goals, (2) use indicators only when other assessment options are unavailable, (3) choose indicator species by explicitly defined criteria that are in accord with assessment goals, (4) include all species that fulfill stated selection criteria, (5) know the biology of the indicator in detail, and treat the indicator as a formal estimator in conceptual and statistical models, (6) identify and define sources of subjectivity when selecting, monitoring, and interpreting indicator species, (7) submit assessment design, methods of data collection and statistical analysis, interpretations, and recommendations to peer review; and (8) direct research at developing an overall strategy for monitoring wildlife that accounts for natural variability in population attributes and incorporates concepts from landscape ecology.

404. **Lang, G.E.** 1985. Forest turnover and the dynamics of bole wood litter in subalpine balsam fir forest. Can. J. For. Res. 15(1):262-268.

A chronosequence of three stands of balsam fir was sampled in 1974 and 1982; during these 8 years, recruitment was absent so mortality alone accounted for an 18-30% decrease in live tree density. In a mature 78-year-old stand, the mass of bole wood on the forest floor was 1.4 kg/m^2 compared with an estimated aboveground live and dead bole biomass of 17.2 kg/m^2. During 5 years of repetitive sampling, annual bole input to the forest floor was episodic and variable in time and space, ranging from 3 to 365 g/m^2/year. A mass balance model was used to characterize the changes in wood litter on the forest floor. If most of the live trees die within a short period of time, bole input would occur in a pulse event and cause a peak in wood litter mass, which would then decline over time (and with stand maturation) as decomposition prevails. The assumption of steady-state conditions for wood litter is not valid; rather the mass of wood litter will wax and wane through time. Over a landscape, spatial patterns in the abundance of wood litter reflect a stand's history; old

mature stands would have little wood litter while young regenerating stands would have large amounts. A maximum value for wood litter would be found in a stand located immediately behind a fir wave. Natural disturbances from wind and avalanches lead to contrasting patterns with high and low wood litter values, respectively. About 41% of forest turnover in the balsam fir zone is initiated from natural disturbance and fir waves.

405. **Lassoie, J.P.** 1982. Physiological activity in Douglas-fir. *In* Analysis of coniferous forest ecosystems in the western United States. R.L. Edmonds (editor). Hutchinson Ross Publ. Co., Stroudsburg, PA., U.S./IPB Synthesis Ser. No. 14, pp. 126-185.

This chapter elucidates the abiotic and biotic control of those physiological processes felt to be of major importance to the functioning of the western coniferous biome. Specifically, emphasis is on temporal and spatial variations in, and interrelations between, net photosynthesis, tree water relations meristematic activities, and biomass accumulations. Futhermore, owing to their ecologic and economic dominance throughout the biome, large, field-grown Douglas-fir (*Pseudotsuga menziesii*) are considered primarily in the following discussion. Presented here is an integrated view of whole-tree physiological processes in Douglas-fir. The approach is based on a wide variety of interrelated physiological data and is viewed in reference to the functioning of the entire coniferous biome. Also presented is physiological support for other chapters in this volume and physiological reasoning behind the distribution and abundance of Douglas-fir throughout the coniferous forest biome is illustrated. Voids in the understanding of Douglas-fir tree physiology and future research needs and directions are suggested. (From author's introduction)

406. **Leaf, C.F.** 1975. Watershed management in the Rocky Mountain Subalpine Zone: the status of our knowledge. U.S. Dep. Agric. For. Serv., Intermtn. For. Res. Stn., Fort Collins, CO. Res. Pap. RM-137.

Watershed management in the subalpine zone of Wyoming, Colorado, and New Mexico is described. Forest hydrology is briefly discussed, followed by an in-depth discussion and review of (1) field studies of the effects of watershed management practices on snow accumulation, melt, and subsequent runoff; and (2) simulation models designed to predict the hydrologic impacts of timber harvesting and weather modification. Pertinent literature is included, along with unpublished research, observations, and experience. Research needs are highlighted, and guidelines for implementing watershed management principles in land use planning are summarized.

407. **Ledec, G.** and **R. Goodland.** 1988. Wildlands: their protection and management in economic development. The World Bank, Washington, DC. 278 p.

This book addresses the protection and management of wildlands in light of economic and demographic pressures to develop these lands for human use. Eight chapters are devoted to this topic, including: 1) Wildlands and economic development; 2) The need for systematic attention to wildlands; 3) The World Bank and wildland management; 4) Incorporating wildland management components in development programs; 5) Other development activities that benefit wildland management; 6) Wildland management in economic and sector planning; 7) The economic analysis of wildland management; and 8) Accommodating the needs and interests of local people in wildland management. Several appendices discuss aspects of international wildland management. **

408. **Ledig, F.T.** 1988. The conservation of diversity in forest trees. BioScience 38(7):471-479.

This paper points out the threat human population growth imposes on the loss of biological diversity on our planet—not only the loss of species diversity, but the loss of genetic diversity within populations on which long-term survival and evolution are dependent. The author's objective in this paper is to outline and discuss the scope of gene conservation relative to wild plants, particularly forest trees. Important questions considered are why conserve, what should be conserved, and how should it be conserved. Most of this article is

devoted to a discussion of genetic vulnerability—a genetic uniformity which leaves plants vulnerable to new environmental or biotic changes. Conservation efforts to preserve genetic diversity, particularly *ex situ* and *in situ* preservation are discussed. Global issues concerning genetic conservation are briefly addressed. **

409. **Lennartz, M.R.** 1988. The Red-Cockaded Woodpecker: old-growth species in a second-growth landscape. Nat. Areas J. 8(3):160-165.

The conservation of old-growth forests has become a major conservation issue. The maintenance of wildlife diversity is an important value associated with old-growth conservation. Lately, policies related to managing old-growth wildlife have emphasized just one management strategy, habitat preservation. The ecology of the red-cockaded woodpecker (*Piciodes borealis*), a species dependent on old-growth pine forests in the South, suggests that additional management strategies are appropriate for some old-growth species. Professional conservationists—wildlife biologists, foresters, and ecologists—can work together to develop scientifically sound management alternatives that would lessen the controversies surrounding old-growth management and increase the prospects for preserving faunal diversity.

410. **Lertzman, K.** 1990. What's new about New Forestry: replacing arbocentrism in forest management. For. Plan. Can. 6(3):5-6.

The author examines the approach of "New Forestry" and discusses its relevance to British Columbia. New Forestry is different from traditional forestry in three key ways: New Forestry is ecosystem-focused whereas traditional management is tree-focused; New Forestry explicitly looks at the stand and landscape level; and New Forestry involves long rotations. The author notes that while New Forestry has been developed in the Pacific Northwest of the U.S., the scientific principles which underlie it are valid in British Columbia. Other key ideas on which New Forestry is based are described. These include a focus on conserving biological diversity and "ecosystem health," retaining important ecosystem components (e.g., snags, woody debris), maintaining structural diversity, understanding the role of old-growth forests as carbon sinks, and considering landscape level effects such as fragmentation. **

411. **Lestelle, L.C.** and **C.J. Cederholm.** 1984. Short-term effects of organic debris removal on resident cutthroat trout. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1983, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 131-140.

Excessive cleanup of logging residues along small streams can deplete the stream environment of large, stabilized organic debris. An experiment was conducted to determine the effects on a resident salmonid population of overcleaning a stream course of organic debris. The study was conducted in two headwater streams of the Clearwater River in Washington during 1972 and 1973. Clearing of the stream had little or no effect on numbers and biomass of cutthroat (*Salmo clarki clarki*) immediately after alteration and prior to winter. Subsequently, population reductions occurred in the treated stream over winter 1972-1973, but these losses were short-term. The decline in number of overwintering trout was apparently associated with habitat instability brought on by the removal of large organic debris from the stream channel. Within 1 year of debris removal, the cutthroat trout population had returned to pretreatment levels. Also, the physical habitat characteristics of the altered stream were largely restored to pretreatment conditions within 1 year of debris removal. If there had not been a source of debris to replace that which was removed, habitat and fish recovery may have been slower.

412. **Lienkaemper, G.W.** and **F.J. Swanson.** 1987. Dynamics of large woody debris in old-growth Douglas-fir forests. Can. J. For. Res. 17:150-156.

Transfer of large woody debris (10 cm diameter) from old-growth Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco) forests into five first- to fifth-order stream reaches (drainage area of 0.1 to 60.5 km2) has ranged from 2.0 to 8.8 Mg/ha/year in 7- to 9-year study periods. Amounts of large woody debris in these streams range from 230 to 750 Mg/ha, with generally lower values in larger channels. The addition of woody debris is widely scattered in time and space and comes mainly from single trees rooted away from the stream bank. We infer that wind is a major agent for entry of wood into these streams. Downstream movement of debris is strongly related to length of individual pieces; most pieces that moved were shorter than bankfull width.

413. **Lightfoot, D.C.** 1986. Invertebrates of the H.J. Andrews Experimental Forest, Western Cascades, Oregon: III. The Orthoptera (Grasshoppers and Crickets). U.S. Dep. Agric. For. Serv., Pac. NW Res. Stn., Portland OR. Res. Note PNW-443. 23 p.

An inventory of Orthoptera (grasshoppers and crickets) at the H.J. Andrews Experimental Forest, near Blue River, Oregon, was conducted to determine the species present and ecological relationships. A key for identification and an annotated list are presented. From qualitative assessments of successional habitat relationships, generalized species associations of forest Orthoptera are proposed, and their responses to forest succession are predicted.

414. **Likens, G.E.** and **R.E. Bilby.** 1982. Development, maintenance and role of organic-debris dams in New England streams. *In* Sediment Budgets and Routing in Forested Drainage Basins. F.J. Swanson, R.J. Janda, T. Dunne, and D.N. Swanston. (technical editors). U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-141, pp. 122-245.

We propose that the formation of organic-debris dams on streams depends primarily on the size of tree (log) available. After disturbance, organic-debris dams are at first diminished and then form on larger and larger stream channels as the terrestrial ecosystem develops, and as a result, the regulation of erosion and transport of dissolved and particulate material from the landscape is enhanced. The species composition and phase of development of hardwood forests also may affect the occurrence and longevity of organic-debris dams. Steady-state amounts of organic matter in stream channels may reflect the stream order, as well as the developmental phase of the terrestrial ecosystem.

415. **Lisle, T.E.** 1986. Effects of woody debris on anadromous salmonid habitat, Prince of Wales Island, Southeast Alaska. N. Am. J. Fish. Manage. 6:538-550.

The effects of woody debris on anadromous salmonid habitat in eight streams on Prince of Wales Island, southeast Alaska, were investigated by comparing low-gradient (2-9%) first- or second-order streams flowing through either spruce hemlock forests or 6- to 10-year-old clearcuts, and by observing changes after debris was selectively removed from clear-cut reaches. Woody debris decreased the rate of shallowing as discharge decreased, thus helping to preserve living space for fish during critical low-flow periods. Debris dams were more frequent in clear-cut streams (14.9/100 m), which contained more debris, than in forested streams (4.2/100 m). As a result, total residual pool length (length when pools are filled with water but there is no flow) and length of channel with residual depth greater than 14 cm the depth range occupied by 84% of coho salmon (*Oncorhynchus kisutch*) were greater in clear-cut streams than in forested streams. Greater volumes of woody debris in clear-cut streams produced greater storage of fine sediment (<4mm diameter) unless the stream gradient was sufficiently high to flush sediment from storage. One-half of the debris dams broke up or were newly formed over a 3-year period, which suggests that they usually released sediment and woody debris before the pools they formed were filled with sediment. Woody debris removal decreased debris-covered area, debris dam frequency, and hydraulic friction in some cases but, in others, these variables were unaffected or recovered within 2

years after erosion and adjustment of the streambed. No consistent differences in pool dimensions were found between treated and untreated clear-cut reaches. Comparisons of habitat in forested and clear-cut streams suggested that removing debris from clear-cut streams reduced salmonid carrying capacity. Retention and natural reformation of debris dams in cleared reaches prevented the expected deterioration of habitat. However, the removal and destabilization of existing woody debris may cause depletion of debris before riparian trees can regrow and furnish new material to the clear-cut streams.

416. **Loomis, J.B., D.M. Donnelly, C.F. Sorg,** and **L. Oldenburg.** 1985. Net economic value of hunting unique species in Idaho: bighorn sheep, mountain goat, moose, and antelope. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO, Resour. Bull. RM-10. 16 p.

The net economic value of hunting unique species in Idaho was estimated using the Travel Cost Method. The net willingness to pay per hunting permit was $239 for bighorn sheep, $360 for mountain goat, $113 for moose, and $78 for antelope.

417. **Lorimer, C.G.** 1989. Relative effects of small and large disturbances on temperate hardwood forest structure. Ecology 70(3):565-567.

In ecosystems where large catastrophic disturbances occur at intervals shorter than the potential lifespan of the trees, the role of small gaps in tree regeneration and ecosystem function may be somewhat limited. Large scale disturbances also appear to reduce the subsequent frequency of small gaps. Evidence suggests that old forests may have higher rates of gap formation, larger average gap sizes, and gaps that are less likely to be completely closed over by border trees. **

418. **Lovett, G.M., W.A. Reiners,** and **R.K. Olson.** 1982. Cloud droplet deposition in subalpine balsam fir forests: hydrological and chemical inputs. Science 218:1303-1304.

Subalpine forests of the northern Appalachians are subject to significant deposition of water and chemicals via cloud droplet impaction. This deposition has been estimated by a method linking micrometeorological measures of turbulent transfer, a detailed representation of canopy structure, and experimentally derived capture efficiences. Water inputs from clouds are about 46 percent, and chemical inputs range from 150 to 430 percent of the bulk precipitation.

419. **Luckman, B.H., L.A. Jozsa,** and **P.J. Murphy.** 1984. Living seven-hundred-year-old *Picea engelmannii* and *Pinus albicaulis* in the Canadian Rockies. Arct. Alp. Res. 16(4):419-422.

Living specimens of *Picea engelmannii* and *Pinus albicaulis* with ring series of 680 and 713 yr and estimated germination dates of 700 yr are reported from two sites in the Canadian Rockies. These are the oldest individuals of these species reported in the literature and indicate that isolated subalpine stands of these trees offer good potential for tree-ring records of over 500 yr in the Canadian Rockies.

420. **Luman, I.D.** and **W.A. Neitro.** 1980. Preservation of mature forest seral stages to provide wildlife habitat diversity. Trans. N. Am. Wildl. Nat. Resour. Conf. 45:271-277.

This paper addresses the concern of the loss of biotic diversity, as remaining stands of old-growth forests are being rapidly converted to even-aged second growth. Projected timber shortages have put increasing pressure on companies to harvest old growth despite the consequences to wildlife. The authors emphasize the need for older seral stages as wildlife habitat for many species of mammals, birds, reptiles and amphibians depends on the understory diversity and multilayered canopy provided by old growth. Also discussed is the importance of old growth to wildlife in riparian zones, the problem of past efforts to provide suitable habitat for old-growth dependent species through single species management, and the problem of fragmented old-growth stands. The authors follow with a proposal to

structure the timber management program to provide for naturally self-sustaining populations of all native wildlife species. The key to achieving this goal lies in vegetative diversification. The proposal, discussed in greater detail, is to manage forest lands so that all vegetative successional stages are adequately represented over time. **

421. **Lunan, J.S.** and **J.R. Habeck.** 1973. The effects of fire exclusion on ponderosa pine communities in Glacier National Park, Montana. Can. J. For. Res. 3:574-579.

Ponderosa pine (*Pinus ponderosa*) forest communities in Glacier National Park, Montana, were investigated to determine the effects of fire exclusion. Analysis of age data in these fire-dependent communities indicates that ponderosa pine is not reproducing itself as well as other mesophytic conifers invading these stands. In addition to these compositional changes, it was determined that fuel accumulations are greater in these park communities compared with similar wilderness area pine communities subject to more recent burning.

422. **Lynds, A.** 1989. Nova Scotia's old-growth forests. Conservation 13(2):4-6.

Old-growth forest in Nova Scotia is estimated to be less than 1% of the total productive forest land. Three stands, representing three different forest types are briefly described: 1) eastern hemlock-white pine; 2) multilayered red spruce; and 3) hardwood forest ,with beech and sugar maple dominating the canopy. Criteria for the "old-growth" designation are described for individual trees as well as for individual stands. The role of old-growth forest in maintaining biological diversity, particularly the genetic options, is explored. Preservation of old-growth areas for long-term research is also discussed. **

423. **McClelland, B.R.** 1979. The pileated woodpecker in forests of the northern Rocky Mountains. *In* The role of insectivorous birds in forest ecosystems. J.G. Dickson, R.N. Conner, R.R. Fleet, J.C. Kroll, and J.A. Jackson (editors). Academic Press, New York, NY, pp. 283-299.

This paper describes a study of the nesting and roosting habitat of the pileated woodpecker (*Dryocopus pileatus*), conducted in northwestern Montana from 1974 to 1978. From auditory and visual clues, 54 active nest trees and active roost trees were identified. Over 50% of both nest and roost holes were found in large western larch (*Larix occidentalis*) snags. Ponderosa pine (*Pinus ponderosa*) and black cottonwood (*Populus trichocarpa*) were also important in providing nesting and roosting habitat. Forests with numerous old-growth trees of the above-mentioned species seem to be essential for the long-term maintenance of pileated woodpecker populations in the northern rocky mountains. Measurements taken at nest trees provided the following mean data: dbh= 75 cm, tree height = 28 m, nest hole height = 15.2 m, and surrounding forest basal area = 25 m^2/ha. The function of pileated woodpeckers in acting as pathfinders for non-excavating hole nesters, in acting as an indicator species, and in being a key species in consideration of forest management plans is discussed. **

424. **MacClintock, L., R.F. Whitcomb,** and **B.L. Whitcomb.** 1977. Evidence for the value of corridors and minimization of isolation in preservation of biotic diversity. Am. Birds 31(1):6-16.

This paper describes a study of a 35-acre "island" which was found to have an avifaunal composition that closely approximated that of much larger woodlands. The area was connected by a disturbed corridor to a 400-acre woodland which was further connected to a 10,000-acre forest system. The study offers evidence that biotic diversity can be maintained in small tracts of land if isolation is minimized through the use of corridors. **

425. **McCorison, M., G. Johnejack,** and **E. Kissinger.** 1989. A method to analyze watershed sensitivity. *In* Proc. of Watershed '89, Conf. on the Stewardship of Soil, Air and Water Resources. E.B. Alexander (editor). March 21-23, 1989, Juneau, AK. U.S. Dep. Agric. For. Serv., Alaska Reg., Juneau, AK. R10-MB-77, pp. 157-164.

This paper is intended to describe the method that was used for determining Watershed Sensitivity in the Supplemental Environmental Impact Statement (SEIS) for North Kuiu Island. We are currently using this method as an analysis tool for several other environmental documents. It uses data available in the GIS for the Tongass National Forest and develops an empirical rating of the relative sensitivity of a watershed to potential management related impacts. Prescriptions for the proportions (percent) of watersheds to harvest in any 20 year period are developed that reflect both the Value of the watershed as well as its Sensitivity. The method is simple and easy to use, requires only limited amounts of data, and provides a reasonable basis for weighing watershed resource values.

426. **McCune, B.** and **T.F.H. Allen.** 1985. Will similar forests develop on similar sites? Can. J. Bot. 63:367-376.

Abies grandis, Taxus brevifolia, Thuja plicata or any combination of these may dominate old-growth mesic forests of the Bitterroot Canyons, western Montana. Similar sites need not develop similar, relatively stable forests. This is shown by (i) anomalous distributional patterns of tree species; (ii) broad overlap of tree species abundance in environmental space (shown by ordination and discriminant analysis of stands in environmental space, and (iii) weak or undetectable correspondence of species x stand and site factor x stand matrices (multiple regressions of compositional dissimilarity against environmental differences; also, canonical correlation and Mantel tests). Since a one-to-one mapping from site factors to species composition in old-growth vegetation is a fundamental tenet for applications of the climax concept, caution is warranted where the concept is to be applied within a narrow range of site factors or to insular communities.

427. **MacDonald, A.** and **E.A. Keller.** 1987. Stream channel response to the removal of large woody debris, Larry Dam Creek, northwestern California. *In* Erosion and Sedimentation in the Pacific Rim. Proc. of a Symp., Internat. Assoc. Hydrolog. Sci., Aug., 1987, Corvallis, OR. R.L. Beschta *et al.* (editors). Wallingford, Oxfordshire, IAHS Publ. No. 165, pp. 405-406.

The author studied the effects of the removal of large woody debris (LWD) from Larry Dam Creek, a third-order tributary in the Redwood Creek watershed of northern California. Seventy cubic meters of LWD, most of which had been in the stream for a minimum of 68 years, was removed. Travel time through the stream section was measured before and after the removal. Changes in channel cross section, long profile and substrate size was also noted. The net result of the removal was a tendency of the stream to evolve towards a more "alluvial" state, with the stream being stabilized by bends at rock outcrops and by woody debris-dependent banks. Observed effects included: up to 25% increase in water velocity through the debris jams; approximately 100 m^3 of sediment entrained in the first year from affected areas; and creation or deepening of pools at bends above and below the debris jams at the expense of scour pools within the jams. **

428. **McKenzie, D.S.** and **R.M. Storm.** 1970. Patterns of habitat selection in the clouded salamander (*Aneides ferreus*) (Cope). Herpetologica 26:450-454.

Simulated field conditions were used to study habitat selection of the clouded salamander, *Aneides ferreus*. Adult, subadult and young display somewhat different preferences at different temperatures. Young selected bark litter; subadults selected bark litter at higher temperatures, but displayed no preference between rock and bark at a lower temperature. Adults exhibited no marked preference between bark litter and rock litter.

429. **McLaughlin, S.P.** 1978. Overstory attributes, light, throughfall, and the interpretation of overstory-understory relationships. For. Sci. 24(4):550-553.

This study examines basal area and three measures of canopy cover as predictors of both throughfall and light in an Arizona ponderosa pine forest. Overhead canopy cover, as measured with canopy photographs, accounted for the largest proportion of the variance in throughfall. The amount of open canopy in the east, south, and west directions (ESW

canopy open), as measured with the spherical densiometer, accounted for the largest proportion of the variance in light penetration. Basal area was the poorest predictor of both throughfall and light penetration. Statistical fitting of each of these overstory attributes with understory cover or production should be an important aid in determining whether moisture, light, or root competition are limiting growth.

430. **McLean, A.** 1976. Protection of vegetation in ecological reserves in Canada. Can. Field Nat. 90(2):144-148.

Security of the land is necessary for the preservation of vegetation growing on it; governmental legislation is required to achieve this in Canada. The concept of ecological reserves offers the best protection for native plants if appropriate management plans are made. Most of the publicly owned lands in Canada are under the control of provincial governments so that legislation has to be prepared at this level. At present, only British Columbia, Quebec, and New Brunswick have passed special legislation that deals specifically with ecological reserves. Ontario and some of the other provinces use existing legislation to protect natural areas that are equivalent to ecological reserves. For adequate control and management, an ecological reserve system should have a director-in-charge with a technical advisory committee; British Columbia, Quebec, and New Brunswick have such a structure. Management plans for each reserve are necessary, based on the objectives of the reserve. In the plan, a mechanism should be outlined for the reporting of activities, resolving of conflicts between users, and the reviewing of plans by participants. Research which forms the ecological basis for management, including that which is designed to lead to improved management of the area, must be encouraged.

431. **McLean, J.A.** and **S.M. Salom.** 1989. Relative abundance of ambrosia beetles in an old-growth western hemlock/Pacific silver fir forest and adjacent harvesting areas. West. J. Appl. For. 4(4):132-136.

Semiochemical-baited multiple-funnel traps were set out in two new logging areas and in mature forest on northeastern Vancouver Island near Kelsey Bay, British Columbia. The large numbers of ambrosia beetles captured indicated that *Trypodendron lineatum* and *Gnathotrichus sulcatus* are distributed along logging rights-of-way as well as in the surrounding forest. Results suggest that logs must be removed as soon as possible after felling in order to minimize degrade of the logs and to prevent the transport of ambrosia beetles from the harvest areas to dryland sorting areas, booming grounds, and sawmills.

432. **McLellan, B.N.** 1990. Relationships between human industrial activity and grizzly bears. Int. Conf. Bear Res. and Manage. 8:57-64.

Most grizzly bears (*Ursos arctos*) live outside parks and reserves and often have to contend with, among other things, resource extraction industries. These activities can affect individual bears and therefore populations by: 1) causing strong, energetically expensive reactions by bears that disrupt their normal behaviour, 2) displacing bears from areas of human use, 3) altering habitats in which bears live, 4) disrupting the bears' social system, and 5) industrial personnel killing bears or increasing mortality rates indirectly by improving access for hunters, poachers, other resource users, and settlers. Grizzly bears are able to adapt to many habitat changes and a temporary increase of human presence. In most cases, increased motorized access that results in a long term increase of human activity and/or settlement with consequent increase in bears being shot is the most significant aspect of industrial developments. If an industrial activity is conducted with adequate guidelines to maintain important habitats, properly locate camps, incinerate garbage, restrict use of firearms, and close motorized access after the job is complete, the bear population probably will be maintained at a satisfactory level. Although many bears may be alive when an industry has completed its work, if access remains intact, the grizzly population is placed in a precarious position and may decrease in size and eventually be extirpated. Closing access

after job completion is often physically and politically difficult. Industry personnel and government managers must take leading roles in planning advertising, and implementing road closures.

Cumulative effects models have been built to predict the impact of human activities on bear populations. These models are in early stages and require data to support the coefficients used and the relationships between coefficients. Then they should be tested. One significant variable the models lack is the potential for a specific activity to be the seed for blooming additional and perhaps more harmful developments.

433. **McLellan, C.H., A.P. Dobson, D.S. Wilcove,** and **J.F. Lynch.** 1986. Effects of forest fragmentation on new- and old-world bird communities: empirical observations and theoretical implications. *In* Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates. J. Verner, M.L. Morrison, and C.J. Ralph (editors). Oct. 7-11, 1984, Fallen Leaf Lake, CA. Univ. Wisconsin Press, Madison, WI, pp. 305-313.

The effects of forest fragmentation on the bird communities of England and the eastern United States are considered, using complementary sets of empirical data. Monograms for both countries reveal that a series of small reserves will contain more species than a single large reserve of the same total area, but that the large reserves are needed to preserve a number of area-sensitive species. A simulation model is then presented to illustrate the key effects of fragmentation on the species pool of an originally contiguous habitat. The model suggests that extinctions of species are initially low, but increase rapidly once a critical percentage of the original habitat has been destroyed. This percentage depends crucially upon both the territory sizes and dispersal abilities of the species pool under consideration. We then discuss how the optimum conservation strategy for preserving woodland birds will depend upon the number of area-sensitive species, the slope of the species-area curves, and the extent to which the habitat has already been fragmented. We conclude by discussing the work's more general implications for conservation policymakers on a variety of different geographic, taxonomic, and administrative scales.

434. **MacMillan, P.C., K. Cromack, Jr.,** and **J.E. Means.** 1978. Nutrient capital and substrate quality of logs in an old-growth Douglas-fir forest. Proc. Indiana Acad. Sci. 88:101-102.

Douglas-fir logs in a 450-yr-old stand in western Oregon were classified into 5 decay classes (1 = most recent; 5 = most decayed) of av. age 7, 16, 36, 82 and 159 yr respectively. Over this time decreases occurred in % cellulose and log density (over 50%), while % of N, P, K, Ca, Mg, Na and lignin all increased.

435. **MacMillan, P.C., J.E. Means,** and **K. Cromack, Jr.** 1978. Log input and decomposition in an old-growth Douglas-fir forest. Proc. Indiana Acad. Sci. 88:168.

A further report from the same stand. Numbers of logs/ha in each decay class were 27, 15, 21, 39 and 128. Log biomass by class ranged from 324 to 15 t/ha (total for all classes 587 t/ha). Estimated annual log input was between 0.76 and 2.32 (mean 1.33) logs/ha. Mean wood density by class ranged from 543 to 151 mg/ml, 50% of original density being reached in 94 yr. The decay rate was positively correlated (r = 0.99) with surface to volume ratio.

436. **McNay, R.S.** 1985. Forest crowns, snow interception and management of black tailed deer winter habitat. B.C. Min. Environ. and Min. For., Victoria, BC. IWIFR-19. 111 p.

The phenomenon of snow interception by forest stands is examined. Interception relationships extracted from literature are evaluated for their applicability to the silvicultural and climatic conditions of south coastal British Columbia. Hypotheses tested address: 1) the prediction of snow interception, 2) comparisons of heterogeneity in snow interception between second-growth and old-growth forests, and 3) how interception and interception efficiency vary depending on forest crown completeness and storm size.

General relationships regarding snow interception under continental conditions were found to hold in coastal conditions, but relationships between crown completeness and interception were weak. Storm size and melt are identified as confounding factors in making predictions about snow interception based on stand crown completeness. Several approaches to modelling snow interception are discussed. Particular reference is made to the effect of interception on energetic costs of locomotion for deer. Management of coastal forests for the interception of snow should focus on maximizing crown completeness and crown surface area. Further research is required concerning the relationships used in the simulation models. Emphasis should be placed on deer response to snowpacks, the influence of melt on snowpack development, and the influence of canopy closure on spatial distribution of snowpacks.

437. **McNay, R.S., L.D. Peterson, and J.B. Nyberg.** 1988. The influence of forest stand characteristics on snow interception in the coastal forests of British Columbia. Can. J. For. Res. 18(5):566-573.

The capability of forest stands to intercept snow is an important factor in determining management prescriptions for such hydrologically related phenomenon as avalanches, floods, and water supply as well as suitability for ungulate winter habitat. This study tested the hypothesis that snow interception can be predicted as a function of various stand characteristics and storm sizes. The dependent variable was fresh snow depth under the forest canopy; the independent variables were crown completeness, crown length, crown width, basal area per hectare, tree height, tree density, and storm size. Ten stands were selected for study from two locations on Vancouver Island. Snow depth was monitored over 24 storms ranging from 1.4 to 38.0 cm. The best simple linear regression models that incorporated forest variables were those for individual storms, with fresh snow expressed as a function of mean crown completeness. The best assessments of a particular stand's capability to intercept snow were made using an equation with both storm size and mean crown completeness as independent variables.

438. **Mader, H.-J.** 1984. Animal habitat isolation by roads and agricultural fields. Biol. Conserv. 29:81-96.

Natural areas are continuously disappearing. Surviving patches resemble islands in terms of limited area, isolation and distance from each other.

Road construction and agricultural activities contribute to habitat isolation. Field studies suggest that roads represent barriers and cut off the gene flow by dividing animal populations into fractions on either side of the road.

Several mobility diagrams show significant isolation effects of roads on populations of forest-dwelling mice (*Apodemus flavicollis*) and carabid beetles.

Small habitat islands tend to hold more animal species than expected according to the island biogeographic theory. The Ns/Ni ratio is highest in small isolates, indicating continuous movement of individual animals from surrounding agricultural areas resulting in unstable species composition.

439. **Mannan, R.W.** and **E.C. Meslow.** 1984. Bird populations and vegetation characteristics in managed and old-growth forests, Northeastern Oregon. J. Wildl. Manage. 48(4):1219-1238.

Populations of breeding birds and structure and composition of vegetation were examined in managed and old-growth mixed-coniferous forests in northeastern Oregon. Forest stands were about 85 and over 200 years of age and were dominated by Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*). Components of vegetation that distinguish old-growth forests from managed forests include the number of large trees (51 + cm dbh) and snags (31 + cm dbh), small understory grand fir (*Abies grandis*) trees (2.5-10 cm dbh), and tree height diversity; mean values of all of these components were greater in old-growth forests. Three of these variables could be associated, either directly or indirectly with major

differences in bird populations between managed and old-growth forests. The abundance of large snags in old-growth forests was probably responsible, in part, for the relatively high numbers of red-breasted nuthatches (*Sitta canadensis*), and most other hole-nesting birds, observed in this habitat. Large trees were indirectly important to hole-nesting birds because they provided a source of large snags. Grand fir trees were used by Townsend's warblers (*Dendroica townsendi*) and golden-crowned kinglets (*Regulus satrapa*) when foraging and nesting, and we attributed the abundance of these two bird species in old-growth forests to the presence of this understory tree component. Species of birds that were more abundant in managed forests than in old-growth forests appeared to be attracted to the open structure of the managed stands. We discuss the effects of replacing old-growth forests with managed forests on bird species in northeastern Oregon. Methods of maintaining habitat for those species that will decline in density following removal of old-growth forests are suggested.

440. **Mannan, R.W., E.C. Meslow,** and **H.M. Wight.** 1980. Use of snags by birds in Douglas-fir *Pseudotsuga menziesii* forests, Western Oregon. J. Wildl. Manage. 44(4):787-797.

Use of standing dead trees, or "snags," by birds was investigated in the Douglas-fir (*Pseudotsuga menziesii*) region of western Oregon in spring and summer, 1975 and 1976. Snags were examined in Douglas-fir forests approximately 10, 35, 75, 110, and 200+ years of age. Use of snags was quantified on the basis of evidence of past and present use by hole-nesting birds. On the average, hole-nesting birds used Douglas-fir snags over 60 cm in dbh and over 15 m tall for foraging and nesting; these snags usually had broken tops, few or no branches, decayed sapwood and heartwood, and less than 100% bark cover. Snags of this size and type occurred primarily in forests over 110 years of age; consequently, use of snags by hole-nesting birds was concentrated in older forests (110 years old). Bird censuses were conducted in 1 representative area from each forest age-class. Density and species diversity of hole-nesting birds increased with forest age. Density of hole-nesting birds was positively correlated ($r = 0.98$, P 0.05) with mean dbh of snags. Intensive management of Douglas-fir forests does not allow for the production or retention of large snags. A reduction in the number of large snags could reduce populations of hole-nesting birds. Possible means for retaining and producing large snags are discussed.

441. **Manuwal, D.A.** and **M.H. Huff.** 1987. Spring and winter bird populations in a Douglas-fir forest sere. J. Wildl. Manage. 51(3):586-595.

Changes in bird species richness, abundance, and guild structure were compared among young (42-75), mature (105-165), and oldgrowth (250-500+ years) and between winter and spring, for 2 years in Douglas-fir (*Pseudotsuga menziesii*) forests of the southern Washington Cascade Mountains. In winter, bird species richness, diversity, and abundance were all greater in old growth than in younger stands. The most abundant species were the chestnut-backed chickadee (*Parus rufescens*), golden-crowned kinglet (*Regulus satrapa*), pine siskin (*Carduelis pinus*), and red crossbill (*Loxia curvirostra*). In spring, there were few differences in diversity and abundance along the stand age gradient. Species richness showed a slight increase from young to old growth. The most abundant spring species were the winter wren (*Troglodytes troglodytes*) western flycatcher (*Empidonax difficilis*), varied thrush (*Ixoreus naevius*), hermit warbler (*Dendroica occidentalis*), and chestnut-backed chickadee. The Vaux's swift (*Chaetura vauxi*) exhibited the strongest association with old growth in the spring. Seasonal changes in abundance were greater in young and mature stands than in old growth. This pattern was most noticeable among permanent resident species. A more favorable microclimate and probably better foraging conditions in old growth in winter may explain the observed seasonal patterns of abundance.

442. **Manuwal, D.A., M.H. Huff, M.R. Bauer, C.B. Chappell,** and **K. Hegstad.** 1987. Summer birds of the upper subalpine zone of Mount Adams, Mount Rainier, and Mount St. Helens, Washington. N.W. Sci. 61(2):82-92.

Fifty-five bird species were observed during the summers of 1982 and 1985 using the upper subalpine habitat on three Cascade volcanoes. The vegetation differed somewhat among the study areas, although subalpine fir (*Abies lasiocarpa*) was the dominant tree at all sites. Bird species richness was highest at Mount Adams and Pine Creek on Mount St. Helens, and lowest at Butte Camp on Mount St. Helens. Bird abundance was highest at Butte Camp where there were large numbers of pine siskins. Several species exhibited wide variation in abundance among study areas. Approximately 18 species nested at each study area, but there was variation in species composition. Differences in abundance and species composition were partly attributable to vegetation features of the study areas. Birds feeding on insects on or near the ground, and conifer seed-eaters were numerically dominant. There appeared to be no longterm impact of the 1980 eruption of Mount St. Helens on the subalpine avifaunas except at Pine Creek where the trees were scorched and subsequently died.

443. **Marcot, B.G.** and **R. Holthausen.** 1987. Analyzing population viability of the spotted owl in the Pacific northwest. Trans. N. Am. Wildl. Resour. Conf. 52:333-342.

In this paper the authors provide a history of the spotted owl (*Strix occidentalis*) controversy and discuss how the viability of spotted owl populations in the Pacific Northwest were analyzed. (The spotted owl controversy revolves around the question of how much old-gowth forest habitat is required to maintain a viable population of the species. In 1981 the Oregon Interagency Wildlife Committee recommended setting aside 1000 acres of old-growth per pair of owls. In 1984 conservationists asked that this be increased to 2200 acres per pair.) The viability analysis involved: assessing empirical information on the ecology and biology of the spotted owl; assessing the probability that many key factors could cause the extinction the species; and, from these results, assessing the probability of continued existence of the species under a number of different management scenarios. The procedure for assessing viability involved the following steps: 1) estimating current and future amount and distribution of spotted owl habitat; 2) estimating capability of this habitat to support spotted owl pairs; 3) investigating the probabilities of extinction caused by key factors (random birth and death rates, inbreeding, environmental catastrophes, and interspecific interactions); and 4) estimating the overall probability that species will continue to exist to specific times in the future. In conclusion, the authors judge the value of their analysis on the basis of biological management and legal criteria. **

444. **Marcot, B.G., R.S. Holthausen, J. Teply,** and **W.D. Carrier.** 1990. Review of old-growth definitions. For. Plan. Can. 6(1):17-19.

This paper presents a review of definitions of old-growth forests in the Pacific Northwest. These definitions are of two kinds: those based on timber production criteria and those based on ecological criteria. The authors also address the question of how much old growth remains in the Pacific Northwest. One estimate is that 17% of the original old growth remains, making up approximately 2.5 million ha on national forests in the area. Several studies indicate that most of the remaining old growth exists as small patches, which may adversely affect persistence of localized old-growth wildlife populations. The authors describe management plans for the region's remaining old growth and discuss possible implications for wildlife. Recommendations for developing a multi-purpose old-growth inventory are offered. The inventory should be attribute-based rather than category-based, map-based to address landscape issues, and be part of a system that describes the distribution and amount of the various forest types. **

445. **Marcot, B.G.** and **V.J. Meretsky.** 1983. Shaping stands to enhance habitat diversity. J. For. 81(8):526-528.

The shape of forest stands or openings is a facet of habitat diversity and can be silviculturally manipulated and related to use by wildlife. One index assesses stand shape by relating perimeter to area. A means to determine useful values of the index

considers distance to the edge from points within the stand. The shape of existing or proposed stands can be assessed for adequacy of meeting particular wildlife management goals.

446. **Marshall, D.B.** 1988a. The marbled murrelet joins the old-growth forest conflict. Am. Birds 42(2):202-212.

There is concern that marbled murrelet populations are at risk from, in part, continued destruction of old-growth forests in the Pacific Northwest. A summary is given of the current state of knowledge of the murrelet including information on distribution and populations, biology, and habitat. The need for additional knowledge of distribution on numerical groupings of nesting areas is emphasized as a requirement for proper management of this species. An overview of current efforts in research by government agencies, scientists, the press, and the general public is presented. **

447. **Marshall, D.B.** 1988b. Status of the marbled murrelet in North America: with special emphasis on populations in California, Oregon, and Washington. U.S. Fish Wildl. Serv., Washington, DC. Biol. Rep. 88(30). 19 p.

Preservation of old-growth forest is needed to maintain populations of the marbled murrelet outside treeless areas in Alaska. A major research effort must be undertaken to identify other conservation needs, especially to locate and characterize forest habitat used by the species. Population monitoring is required to track population trends and to determine if future conservation measures are effective. Reproductive success, mortality rates, and longevity data are needed for determining acceptable mortality rates. (From author's summary)

448. **Marshall, J.D.** and **R.H. Waring.** 1986. Comparison of methods of estimating leaf-area index in old-growth Douglas-fir. Ecology 67(4):975-979.

Leaf-area index (LAI, the projected total surface area of foliage per unit ground area) of an old-growth Douglas-fir stand in western Oregon was estimated from litterfall, light interception, sapwood cross-sectional area, and tree diameter. Estimates made by the first three techniques were similar, but the estimate based on tree diameter was twice as high as the others. For large trees with variable amounts of live crown, estimates of leaf area based on tree diameter appear to be inaccurate; therefore, the exceedingly high leaf-area indices previously reported for Douglas-fir forests are unreliable. Sapwood cross-sectional area varies in correspondence with the canopy area and therefore is a better estimator of leaf area on large trees. Maximum LAI estimates based on sapwood area are similar to those for other temperate coniferous forests.

449. **Marston, R.A.** 1982. The geomorphic significance of log steps in forest streams. Ann. Assoc. Am. Geogr. 72:99-108.

A functional account of log steps in forest streams is provided by field surveys of 163 kilometers of streams in the central Oregon Coast Range. Natural treefall, rather than silvicultural activities, accounts for the majority of log steps. During low-flow conditions, dissipation of potential stream energy by log steps amounts to 6 percent, approximately equal to that by falls. There are no statistically significant differences regarding spatial distribution of log steps between study basins with contrasting silvicultural and natural stream inputs of large woody debris. However, significant spatial differences are revealed between streams of various orders, a finding that points to channel flushing capacity and stream-adjacent topography as dominant controls on log step development. Application of thermodynamic principles to stream systems demonstrates that neither falls nor log steps cause a statistically significant difference in equilibrium conditions of stream networks. The volume of sediment stored behind log steps in third-, fourth-, and fifth-order streams is 123 percent of the mean annual sediment discharge (suspended load and bed-load). Depriving some streams of log steps by stream clean-out or repeated harvest of stream-adjacent trees

may initiate an episode of progressive erosion by not dissipating stream energy in excess of that needed to transport imposed sediment supplies. Addition of log steps to streams with energy already insufficient to balance sediment inputs and outputs may only serve to accentuate progressive deposition. Functions of instream large woody debris not incorporated as log steps must also be addressed in forest management decisions.

450. **Martin, R.** 1989. Island forest. Trumpeter 6(2):49-50.

Emphasizing spiritual and wildlife values of the forest, the author gives his reasons why Hornby Island should remain undeveloped and unmanaged for silviculture. **

451. **Maser, C.** 1988. The redesigned forest. R. & E. Miles, San Pedro, CA, 234 p.

This book discusses: 1) the differences between natural forest ecosystems and managed forests; 2) historical, technological, economic, and philosophical factors that direct forest management practices; 3) impediments to changing forest management practices to an ecologically based approach; and 4) forest management practices for sustainable forests. **

452. ————————. 1989. Life cycles of the ancient forest. For. Watch (Mar):12-23.

The ancient forest is the database for information on how natural ecosystems function. This article provides a look at how large trees (logs) decompose and what this means in terms of the long-term health and productivity of the forests of the Pacific Northwest.

Decomposing logs act as year-round water reservoirs, prevent erosion by holding back upslope soils, and provide habitat for insect species which act as biological controls for forest insect pests. The surrounding forest provides habitat for the small mammals that deposit fungal spores and nitrogen-fixing bacteria vital to a tree seedling's survival. Still other small mammals, which are the food supply of larger predators, require the deadwood fungal decomposers as their own food supply.

Present forest practices, clearcut logging followed by burning, destroy the woody debris so important to a natural productive ecosystem. The author discusses the changes in attitude that are necessary if we wish to have a truly *sustainable* forest industry.**

453. ————————. 1990. The future is today: for ecologically sustainable forestry. Trumpeter 7(2):74-78.

The author takes a look at some of the global problems facing present and future generations, including human poverty, the nuclear arms race, and global deforestation. Much of the article is devoted to global deforestation, particularly of ancient forests. The author emphasizes the need for future generations to respond to decisions on resource management—including those regarding our vanishing ancient forests—as they will inherit the circumstances of these decisions. The author then discusses valid reasons for preservation of the ancient forests and addresses issues surrounding conservation of the northern spotted owl, which has become a symbol of the survival of these forests. The author believes that today's forestry practices counter sustainable forestry. Instead of training foresters to manage the forests, tree-farm managers are being trained to manage the short-rotation, "economic" tree farms that are replacing our native forests. Such management practices are stripping our lands of their natural biological diversity. Finally, the ecological importance and maintenance of our native forests are discussed. **

454. **Maser, C., R.G. Anderson, K. Cromack, Jr., J.T. Williams,** and **R.E. Martin.** 1979. Dead and down woody material. *In* The Blue Mountains of Washington and Oregon. J.W. Thomas. (technical editor). U.S. Dep. Agric. For. Serv., Washington, DC. Agric. Handb. 533, pp. 78-95.

The authors discuss the form and function of dead and down woody debris in forest ecosystems, as well as the effect of timber harvesting on the accumulation of woody debris. A brief account of the use of logs by wildlife and the management of logs as wildlife habitat is given. Land-planning for the management of woody debris for wildlife habitat in forests is discussed and 12 management tips are offered. **

455. **Maser, C., Z. Maser, J.W. Witt,** and **G. Hunt.** 1986. The northern flying squirrel: a mycophagist in southwestern Oregon. Can. J. Zool. 64:2086-2089.

Fecal samples were collected over 27 months from the northern flying squirrel (*Glaucomys sabrinus* [Shaw]), a mycophagist in the Pacific Northwest portion range. Nine genera of hypogeous *Basidiomycetes*, 10 of hypogeous *Ascomycetes*, and 1 of hypogeous *Zygomycetes* were identified from fecal samples (hypogeous fungi fruit underground). The squirrel food habits generally paralleled the seasonal availability of the hypogeous fungi, but with notable exceptions. Our data demonstrate the functional diversity an individual species lends to its habitat when viewed in a functional context.

456. **Maser, C., B.R. Mate, J.F. Franklin,** and **C.T. Dyrness.** 1981. Natural history of Oregon coast mammals. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-133. 496 p.

The book presents detailed information on the biology, habitats, and life histories of the 96 species of mammals of the Oregon coast. Soils, geology, and vegetation are described and related to wildlife habitats for the 65 terrestrial and 31 marine species. The book is not simply an identification guide to the Oregon coast mammals but is a dynamic portrayal of their habits and habitats. Life histories are based on fieldwork and available literature. An extensive bibliography is included. Personal anecdotes of the authors provide entertaining reading. The book should be of use to students, educators, land-use planners, resource managers, wildlife biologists, and naturalists.

457. **Maser, C., R.F. Tarrant, J.M. Trappe,** and **J.F. Franklin** (technical editors). 1988. From the forest to the sea: a story of fallen trees. U.S. Dep. Agric. For. Serv., Portland, OR. Gen. Tech. Rep. PNW-GTR-229. 153 p.

Large, fallen trees in various stages of decay contribute much-needed diversity of ecological processes to terrestrial, aquatic, estuarine, coastal beach, and open ocean habitats in the Pacific Northwest. Intensive utilization and management can deprive these habitats of large, fallen trees. This publication presents sound information for managers making resource management decisions on the impact of this loss on habitat diversity and on ecological processes that have an impact on long-term ecosystem productivity.

458. **Maser, C.** and **J.M. Trappe.** 1984a. The fallen tree: a source of diversity. *In* New Forests for a Changing World, Proc. 1983 SAF National Conven. K.A. Sabol (editor). Oct. 16-20, 1983, Portland, OR. Soc. Am. For., Bethesda, MD. SAF Publ. 84-03, pp. 335-339.

When thinking of and dealing with diversity in a forest, conventional vision focuses on structure and habitat. Diversity, however, has another dimension—one that is only now being perceived: function. The basic components of structural and functional diversity are inseparably interwoven in a forest. A broadened philosophical view of management—a forest versus a commodity—is necessary if certain structurally related functions, such as retention of water and cycling of nutrients in large, fallen trees, are to be options in managed forests of the future. We have used an automobile engine as a metaphor in discussing some of the functions that "drive" the forest system because many of an engine's parts are unseen and little understood by the average person. Yet that person can get a learner's permit and then a license to drive the automobile. The average driver knows little about engines, with the result that many automobiles are barely functional. Future generations cannot afford the consequences of our ignorance while we learn how to manage forests.

459. **Maser, C.** and **J.M. Trappe** (technical editors). 1984b. The seen and unseen world of the fallen tree. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-164. 56 p.

Large fallen trees in various stages of decay contribute much-needed diversity to terrestrial and aquatic habitats in western forests. When most biological activity in soil is limited by low moisture availability in summer, the fallen tree-soil interface offers a relatively cool, moist habitat for animals and a substrate for microbial and root activity. Intensified utilization and management can deprive future forests of large fallen trees. The impact of this loss on habitat diversity and on long-term forest productivity must be determined because managers need sound information on which to base resource management decisions.

460. **Maser, C., J.M. Trappe,** and **C.Y. Li.** 1984. Large woody debris and long-term forest productivity. *In* Proc. Conf. on Pacific Northwest Bioenergy Systems: Policies and Applications. May 10-11, 1984, Corvallis, OR. 6 p.

The presence of woody debris on the forest floor provides habitat diversity that is, in turn, increased by the complexity of the debris. Four functions of large fallen trees are described: 1) provision of moisture (critical to the survival of many organisms); 2) support of microbial activity; 3) diversification of fresh water habitat; and 4) diversification of estuarine habitat. Problems with current resource management and options for the future are discussed. **

461. **Maser, C., J.M. Trappe,** and **R.A. Nussbaum.** 1978. Fungal-small mammal interrelationships with emphasis on Oregon coniferous forests. Ecology 59(4):799-809.

Most higher plants have evolved with an obligatory symbiotic relationship with mycorrhizal fungi. Epigeous mycorrhiza formers have their spores dispersed by air currents, but hypogeous mycorrhizal fungi are dependent upon small mammals as primary vectors of spore dissemination. Mammalian mycophagists defecate within the coniferous forest ecosystem, spreading the viable spores necessary for survival and health of the conifers. As one unravels and begins to understand the interrelationships between small-mammal mycophagists and mycorrhizal fungi, it becomes apparent that the various roles of small mammals in the coniferous forest ecosystem need to be reevaluated. One can no longer accept such simplistic solutions to timber management as poisoning forest rodents to "enhance" tree survival. One must consider the direct as well as the indirect costs and benefits of timber management decisions if one is to maintain balanced, healthy coniferous forests.

462. **Maser, C., J.M. Trappe,** and **D.C. Ure.** 1978. Implications of small mammal mycophagy to the management of western coniferous forests. Trans. N. Am. Wildl. Nat. Resour. Conf. 43:78-88.

The purpose of this paper is to examine some interrelationships between small mammals, hypogeous ectomycorrhiza-forming fungi, and trees; and to study the implication of these relationships to management of western coniferous forests. No data are presented. A description of mycorrhizae and their symbiotic relationships is given, and dispersal of mychorrhiza-forming fungi and co-evolution with trees and mammals is explained. Forest management, in light of small mammal mycophagy, is discussed. The authors conclude that the most obvious spore dispersal method of hypogeous mychorrhiza-forming fungi is mycophagy by small mammals. Although is is apparent that mycophagy results in the parititioning of resources among mammalian species, the implication to the establishment, survival and growth of plant communities and terrestrial ecosystems is presently being discovered. To understand the significance of small mammal mychophagy within the ecosystem and to forest management, additional research is required. Such research may give new insight to forest management and timber production. Finally, the authors conclude that we cannot oversimplify and say that small mammals such as deer mice and chipmunks impede reforestation by eating the trees. We should also consider the fact that these mammals disperse an inoculum of mycorrhiza-forming fungi. **

463. **Maser, Z., C. Maser, and J.M. Trappe.** 1984. Food habits of the northern flying squirrel (*Glaucomys sabrinus*) in Oregon. Can. J. Zool. 63:1084-1088.

Digestive tracts of 91 northern flying squirrels (*Glaucomys sabrinus*) were analyzed for food items; 28 were from northwestern Oregon and 63 from northeastern Oregon. Ninety percent or more of the ingested materials were fungi and lichens, including 20 genera of hypogeous fungi. The northern flying squirrel, in using hypogeous fungi as a major food source, is an important nocturnal disperser of the spores. In Oregon coniferous forests, these fungi are obligatory ectomycorrhizal symbionts with the trees in which the squirrels live.

464. **Massman, W.J.** 1982. Foliage distribution in old-growth coniferous tree canopies. Can. J. For. Res. 12:10-17.

The vertical distribution of foliage for several old-growth trees is discussed and modeled. The data include the foliage distribution of nine Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) crowns, the foliage distribution of a sugar pine (*Pinus lambertiana* Dougl.) crown, and the foliage distribution of a composite of the nine Douglas-fir trees which represents the stand canopy. The data show that the foliage is distributed asymmetrically in the crown with the maximum amount often located at a height approximately equal to 80% of the tree height. The data further show that the crown base is 9-30 m above the ground. Five different mathematical models of the foliage distribution (a normal distribution, a chi-square distribution, a *beta* distribution and the chi-square distribution appear to fit the data slightly better than the others; but the differences in r^2 between all the models are often small. The normal distribution has the advantage that it shows the least variability from one tree to the next; however, it also has the disadvantage that it is significantly different from zero at the top of all the tree crowns modeled here.

465. **Masters, A.M.** 1990. Changes in forest fire frequency in Kootenay National Park, Canadian Rockies. Can. J. Bot. 68:1763-1767.

Time-since-fire distribution analysis is used to estimate forest fire frequency for the 1400 km^2 Kootenay National Park, British Columbia, located on the west slope of the Rocky Mountains. The time-since-fire distribution indicates three periods of different fire frequency: 1988 to 1928, 1928 to 1788, and before 1788. The fire cycle for the park was 2700 years for 1988 to 1928, 130 years between 1928 and 1788, and 60 years between 1778 and 1509. Longer fire cycles after 1788 and 1928 may be due, respectively, to cool climate associated with the Little Ice Age and a recent period of higher precipitation. Contrary to some fire history investigations in the region, neither a fire suppression policy since park establishment in 1919, nor the completion of the Windermere Highway through the park in 1923 appear to have changed the fire frequency from levels during pre-European occupation. Spatial partitioning of the time-since-fire distribution was unsuccessful. No relationship was found between elevation or aspect and fire frequency.

466. **Mathewes, R.W.** 1973. A palynological study of postglacial vegetation changes in the University Research Forest, southwestern British Columbia. Can. J. Bot. 51:2085-2103.

The postglacial vegetation history of the University of British Columbia Research Forest was investigated using percentage and absolute pollen analysis, macrofossil analysis, and radiocarbon dating. A marine silty clay deposit records the oldest (12 690 ≤ 190 years before present (B.P.)) assemblage of terrestrial plant remains so far recovered from the postglacial of south-coastal British Columbia. Lodgepole pine (*Pinus contorta*) dominated this early vegetation, although some *Abies, Picea, Alnus*, and *herbs* were also present. Sediment cores from two lakes were also studied. The older is Marion Lake, where five pollen assemblage zones are recognized, beginning with a previously undescribed assemblage of *Pinus contorta, Salix*, and *Shepherdia* in clay older than 12 350 ± 190 B.P. The pollen diagram from Surprise Lake (11 230 ± 230 B.P.) is divided into three pollen zones which show the same major trends of vegetation change as the Marion Lake diagram.

The first report of the postglacial vegetation history of cedar (*Thuja* and perhaps *Chamaecyparis*) in southwestern British Columbia is presented from pollen and macrofossil analyses.

At about 10 500 B.P. in both lakes, pollen of Douglas fir (*Pseudotsuga menziesii*) began a rapid increase, probably in response to climatic amelioration. The palynological evidence, supported by well-preserved bryophyte subfossils, suggests that humid coastal conditions have prevailed in the study area since about 10 500 B.P., with virtually no evidence for a classical Hypsithermal interval between 8500 B.P. and 3000 B.P.

467. **Matson, P.A.** and **R.D. Boone.** 1984. Natural disturbance and nitrogen mineralization: wave-form dieback of mountain hemlock in the Oregon Cascades. Ecology 65(5):1511-1516.

Wave-form dieback of relatively pure stands of mountain hemlock provided an opportunity to study changes in nutrient availability following natural disturbance. Nitrogen mineralization rates of forest floor and mineral soil were estimated using laboratory and in situ incubations. Nitrogen mineralization rates in both the mineral soil and O_2 horizon were at least doubled following the pathogen-induced disturbance. As the regenerating stands developed, rates declined again to the very low predisturbance levels. These changes in nitrogen availability may in turn influence tree resistance to the pathogen, suggesting that in this system the pattern of nitrogen availability is both a consequence and a cause of natural disturbance.

468. **Medin, D.E.** 1985. Breeding bird responses to diameter-cut logging in west-central Idaho. U.S. Dep. Agric. For. Serv., Intermtn. Res. Stn., Ogden, UT. Res. Pap. INT-355.

Populations of breeding birds responded differently to structural changes in a Douglas-fir forest caused by diameter-cut logging. Little change occurred in total bird density or standing crop biomass of birds either between years or between logged and unlogged plots. But there were pronounced changes in the composition of the breeding bird community. Logging the forest resulted in increases in numbers for species that require more open habitats and decreases in populations for species that require more closed habitats. Several species maintained relatively stable densities on both logged and unlogged plots.

The number of breeding bird species (species richness) was consistently higher on logged plots than on unlogged plots and trended upward each year after logging. Ten species were territorial only in the logged forest. One species that was territorial in the unlogged forest was absent from the logged forest. There were no clear patterns in bird species diversity either between years or between logged and unlogged plots. The evenness (equitability) component of bird species diversity declined each year after logging.

Two categories (guilds) of birds—the foliage foragers and the timber gleaners—were less numerous on logged plots. The timber-gleaning guild, the most severely affected, dropped to only one-third of prelogging densities in the third year after logging. The ground-foraging and flycatching guilds were more numerous on logged plots. Of nine species represented in the ground-foraging guild, each was proportionately more abundant in the logged forest than in the unlogged forest. The timber-drilling guild, at least in total, was a relatively stable component of the breeding bird population.

Patterns observed in this study, and other studies that were compared, suggest consistencies of response among certain breeding bird species to logging in western coniferous forests.

469. **Medin, D.E.** and **G.D. Booth.** 1989. Responses of birds and small mammals to single-tree selection logging in Idaho. U.S. Dep. Agric. For. Serv., Intermtn. Res. Stn., Ogden, UT. Res. Pap. INT-408. 11 p.

Responses of birds and small mammals to logging depend on the cutting methods used and the degree to which forest stands are altered. This study examined short-term changes in the composition and abundance of small mammals and breeding birds following single-tree

selection logging in an Idaho Douglas-fir forest. Populations of birds and small mammals were estimated on a logged plot and on a nearby unlogged plot from 1975 (2 years prelogging) to 1979 (3 years postlogging).

Total numbers of breeding birds were relatively stable between years and between logged and unlogged plots. More pronounced patterns of response occurred in the populations making up the breeding bird communities. Species with positive numerical responses to the selection cut were olive-sided flycatcher, Swainson's thrush, yellow-rumped warbler, and chipping sparrow. Species with negative numerical responses to logging were red-breasted nuthatch and brown creeper. Fourteen other species showed little numerical response to the timber harvest.

Birds that forage by gleaning the surface of the bark (timber gleaners) declined in number after logging. Foliage feeders, aerial-sally feeders, and timber drillers were about equally abundant before and after logging. The ground gleaning guild showed a slightly positive pattern of response. Of six nesting guilds represented, only the secondary cavity tree nesters tended to increase after timber harvest.

Dear mice, yellow pine chipmunks, and boreal redback voles accounted for 93 percent of 815 individual animals trapped during the study. Postlogging estimates of deer mice density were generally similar on both the logged and the unlogged plots. But when results were expressed as the mean number of individual animals trapped each year, significantly fewer deer mice were trapped on the logged plot. Numbers of yellow pine chipmunks increased on logged sites; it was the most commonly trapped small mammal in postlogging environments. No significant difference was found in the number of redbacked voles trapped in the cut and uncut forest. Other species were trapped irregularly and in smaller numbers.

470. **Meehan, W.R., T.R. Merrell, Jr.,** and **T.A. Hanley.** 1984. Fish and wildlife relationships in old-growth forests. Proc. Symp. April 12-15, 1982, Juneau, AK. Am. Inst. of Fish. Res. Biol., Morehead City, NC. 425 p.

This symposium provided a forum for exchange of current research which demonstrated the importance of old-growth forests for both fish and wildlife habitat. The numerous papers were organized and presented as six sessions: 1) old-growth forests/fisheries ecology (topics included stream ecology, morphology, habitat utilization, food source, salmonid distributions); 2) timber management/fish management productivity (salmonid populations of clearcut vs forested watersheds, effects of debris removal, effects of logging on stream temperatures, sediment content of streambeds, and management approaches); 3) community structure and ecology of old-growth forests (structure and development of old-growth forests, effects of disturbance, comparison of old- vs second-growth forest structure, relationship of wildlife populations to stand age and area, effects of introduced wildlife); 4) wildlife ecology of old-growth forests (old growth as habitat for deer, ancient murrelets, Canada geese, and blue grouse); 5) wildlife management in old-growth forests (forest management for habitat of deer, caribou, moose, northern flying squirrels, cavity-nesting birds; general wildlife management objectives related to forest fragmentation); and 6) relationships between deer and old-growth forests on Vancouver Island: a case study (seasonal habitat, effects of severe winters, and food availability for the black-tailed deer). Panel discussions followed the two fishery-related sessions and four wildlife sessions. **

471. **Megahan, W.F.** 1982. Channel sediment storage behind obstructions in forested drainage basins draining the granitic bedrock of the Idaho Batholith. *In* Sediment budgets and routing in forested drainage basins. F.J. Swanson, R.J. Janda, T. Dunne, and D.N. Swanston (technical editors). U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-141, pp. 114-121.

Data on sediment storage behind obstructions were collected on seven forested, mountain drainage basins in the Idaho Batholith for a 6-year period from 1973-78. Four of the drainage basins were undisturbed throughout the study period, one contained an old road,

and two were logged during the course of the study. The total volume of sediment stored behind obstructions varied between drainage basins and years in response to changes in bankfull channel width and annual peak-flow rates, respectively. Logs were the most important type of obstruction because they had the greatest longevity and stored the greatest amount of sediment. An average of 15 times more sediment was stored behind obstructions than was delivered to the mouths of the drainages as annual average sediment yield. Logging reduced total channel-sediment storage behind obstructions because many natural obstructions were destroyed by felling and subsequent component of the overall sediment routing through forested drainage basins. Accordingly, erosion and sedimentation monitoring must be carefully designed to avoid misinterpretation. Also, some guidelines are presented to help minimize the change in channel-sediment storage caused by timber harvest.

472. **Meidinger, D.V.** and **J. Pojar** (compilers/editors). [1991]. Ecosystems of British Columbia. B.C. Min. For., Victoria, BC. Special Rep. Ser. No. 6. In press.

This report describes the ecosystems of British Columbia using the framework of the British Columbia Ministry of Forests' ecosystem classification system. After an introduction to the concepts of Biogeoclimatic Ecosystem Classification, general information is presented on the ecology of the Province and the fourteen biogeoclimatic zones. Each zone is then summarized in terms of location and distribution, general ecological conditions, biogeoclimatic subzones, selected ecosystems and wildlife habitats and species. Additional information on freshwater wetlands is also included.

473. **Melillo, J.M., R.J. Naiman, J.D. Aber,** and **K.N. Eshleman.** 1983. The influence of substrate quality and stream size on wood decomposition dynamics. Oecologia 58:281-285.

Woody materials decayed more rapidly in a first order stream than in larger streams in eastern Quebec, Canada. The rate of annual mass loss (k) was highest (k= 1.20) for alder wood chips in a first order stream and lowest (k= 0.04) for black spruce wood chips in a ninth order stream. Decay rates for woody materials in a first order stream were inversely related to their initial lignin to nitrogen ratios. In larger streams, decay rates of woody materials were inversely related to their initial lignin concentrations. A number of quantifiable relationships were found to exist between the initial lignin and nitrogen contents of woody materials and the nitrogen dynamics of decaying wood.

474. **Meslow, C.E.** 1978. The relationship of birds to habitat structure: plant communities and successional stages. *In* Proc. of Workshop on Non-Game Bird Habitat Management in the Coniferous Forest of the Western United States. R.M. DeGraaf (editor). Feb. 7-9, 1977, Portland, OR. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-69, pp. 12-18.

Measures of bird species diversity are commonly used as indicators of community structure relationships. Diversity of vegetation and structure within a habitat allows diversity in its avian community. Managed succession in the Douglas-fir region attempts to speed regeneration and establish an even-aged monoculture of Douglas-fir for harvest at optimal size. Bird species inhabiting five seral stages of these forests are identified. Four spheres of influence where timber management conflicts with forest birds are discussed: 1) Shortening of the grass-forb and shrub state. 2) Effect of an even-aged Douglas-fir monoculture. 3) Elimination of snags. 4) Elimination of old-growth forest.

475. **Meslow, E.C., C. Maser,** and **J. Verner.** 1981. Old-growth forests as wildlife habitat. Trans. N. Am. Wildl. Nat. Resour. Conf. 46:329-335.

The authors briefly describe the major structural characteristics of old-growth forests: large live trees, large snags and large logs. Some old-growth characteristics of individual trees are irregular, large, coarse branch systems, a deep crown, large size, and, often broken tops. The stands are structurally complex, with great vertical and horizontal variability. This vertical development and horizontal patchiness provides habitat for a relatively high number of

wildlife species and individuals. Of these species, as many as 18 have been identified as being old-growth dependent or as finding optimum habitat in old-growth forest. Old-growth forests are rapidly disappearing from the Pacific Northwest; time estimates of remaining old-growth timber range from 10 to a maximum of 65 years before all old growth will be liquidated from given areas. If the U.S. Forest Service and Bureau of Land Management are to carry out their policy to manage for viable populations of all species of native wildlife using their lands, management strategies and goals must plan for the maintenance or replacement of old-growth stands in future forests. The authors suggest that high priority be given to acquiring the biological information necessary to make these management decisions by 1) obtaining a measure of abundance for wildlife species in both old-growth and younger stands; and 2) identifying the ecological relationships of species that use old growth as habitat. **

476. **Michaels, P.J.** and **B.P. Hayden.** 1987. Modeling the climate dynamics of tree death. BioScience 37(5):603-610.

With the possibility of global climate change looming, or already under way, the question of how much climate change can be tolerated without causing a significant amount of change in forest and other ecosystems arises. In this paper the authors explore the relationship between the mortality and the atmospheric environment over large spatial scales. The authors note that air mass distributions and jet stream patterns strongly influence vegetation, and that changes in these weather systems are likely an early sign of climate change. A research protocol based on a large number of field surveys, simulation models for tree mortality and community death, and climatic data is proposed. Such a protocol will produce results which show how sampled communities actually respond to atmospheric disturbances. This will allow scientists to better predict the ecological impacts of climate change. **

477. **Middleton, J.** and **G. Merriam.** 1985. The rationale for conservation: problems from a virgin forest. Biol. Conserv. 33:133-145.

We compared the distribution of 111 taxa of plants and animals in 18 forests that had received four very different levels of disturbance. A stand of virgin forest undisturbed for over 200 years had the lowest number of taxa of any of the forests examined and contained no rare species not found in the more disturbed forests. The relationship of degree of disturbance to species richness among the forests of this study raises questions about the use of ecological knowledge in rationales for conservation. Ecological knowledge must be used in these arguments but with caution and in conjunction with other argments such as some based on moral philosophy.

478. **Millar, C.I., F.T. Ledig,** and **L.A. Riggs.** 1990. Conservation of diversity in forest ecosystems. For. Ecol. Manage. 35:1-4.

This paper introduces a series of papers which were presented at a symposium aimed at increasing awareness among forest managers of the importance of conserving biological diversity, with special focus on genetic diversity. In this article the author gives a preview of more than 12 of these papers, which can be grouped into three categories: 1) papers that discuss current threats to diversity; 2) papers that discuss approaches to the conservation of forest biological diversity; and 3) papers that provide case studies of forest conservation efforts. **

479. **Miller, D.H.** 1962. Snow in the trees - where does it go? Proc. West. Snow Conf. 30:21-27.

A discussion of the movement of snow intercepted by tree canopies. Wind is less of an agent in snow removal than it might appear. Unless strong winds follow snowstorms directly, snow masses resist mechanical removal. Partial melting may occur which causes snow masses to slide off the foliage. It is likely that 1/4 of the snow mass is melted before it slides off. Meltwater leaving the crowns as stemflow is thought to be small in conifers and possibly moderate in deciduous trees; it is more important in maritime climates. Sublimation

requires much more energy than melting. Sublimation is often considered to be the major source of snow removal from crowns; however, that seems unlikely due to lack of sufficient heat influx. More data are required.

480. ——————. 1964. Interception processes during snowstorms. U.S. Dep. Agric. For. Serv., Pac. SW For. Range Exp. Stn., Berkeley, CA. Res. Paper PSW-18. 24 p.

This is a discussion of how vegetation intercepts snowfall. It is broken down into 4 main topics: a) delivery of snow; b) throughfall of particles to the forest floor; c) impaction and adhesion of particles to the foliage; and d) cohesion of particles into snow loads. Delivery of snow is nearly horizontal (4° from horizontal). Snow falls at less than one m/sec; about 1/8-1/10 the velocity of raindrops. The low angle of incidence has the effect of increasing crown surface. For this reason, crown coverage in two dimensions is a poor predictor of snow penetration. Perhaps selective logging increases snow penetration less by opening the canopy than by removing dominant trees. Deposition of snow depends on the cube of the difference between initial and final air velocities; therefore, even small wind decreases can result in large depositions. Understanding snow delivery requires conceptualizing the canopy as seen from above. Micrometeorological study of the canopy suffers from lack of reproductibility—there are no measures adequate to handle the variability. True throughfall, penetration of canopy without alighting on branches, is analogous to solar penetration. At temperatures near freezing, one degree Celsius of warming can increase interception by 30% due to greater adhesion. High winds drive snow into the canopy but also dislodge it. Dry snow is most easily dislodged. Roughness of the surface of the twigs, branches, and leaves affect adhesion. Flexibility of the foliage determines how much adheres. Volume of foliage plays a role in interception but this is still undefined. From Kittredge's (1948) data, it is calculated that 0.1 cm^3 of water is held on 3 cm^2 of leaf area as snow. Foliage weight is near 0.1 g cm^2 of ground surface whereas 2 mm of snow load is 0.2 g cm^2—a load ratio of 2:1 which is much less than severe ice storms. Bare winter hardwoods may intercept considerable snow although many workers report little interception. This has implications for snow breakage. After the first layer of snow has adhered to the foliage, further accumulation is a function of the cohesion of snow particles. Cohesion may be by friction or sintering. Cohesion must overcome gravity and wind. Wind may increase cohesion. Maximum adhesion and cohesion occur near the freezing point. Research needs are outlined. **

481. ——————. 1966. Transport of intercepted snow from trees during snow storms. U.S. Dep. Agric. For. Serv., Pac. SW For. Range Exp. Stn., Berkeley, CA. Res. Paper PSW-33. 30 p.

It has proven difficult to find simple, universally applicable relations between snowfall in forested and unforested areas. The failure suggests that the process is not a unitary phenomenon but a series of processes each of which must be described and quantified. This paper supplements Miller (1964) in examining five basic processes by which intercepted snow is transported from tree branches. Part I treats wind erosion. Part II deals with snow sliding from the branches as the twigs bend under the snow load. The triggering action for snow drop may be an external disturbance or melting of the ice bonding the snow to the sloping surface. Part III treats stemflow and drip. This process has been reported to be negligible by some and very significant by others. The last two processes treated are vapour transport from melt-water and from the snow itself. Pages 17-21 deal with factors affecting the differences between snow accretions in the forest and nearby open areas; a quantity termed "A". Forest factors influencing "A" do not group well into any classification. An extensive review of forest effects on "A" is provided. **

482. ——————. 1978. The factor of scale: ecosystem, landscape mosaic, and region. *In* Sourcebook on the environment: a guide to the literature. K.A. Hammond, G. Macinko, and W.B. Fairchild (editors). Univ. Chicago Press, Chicago, IL, pp. 63-88.

This chapter discusses how scale affects our analysis and interpretation of ecosystem units and their linkages. Detailed discussion is provided for the following aspects of scales: 1) environmental phenomena, including terrain analysis and economic and urban systems; 2) scales of contrasts among terrestrial systems including nature of contrasts, contrasts within ecosystems, contrasts among ecosystems (albedo, interface form, substrate energy, mass budgets, productivity), contrasts among landscape mosaics, regions, continents, and oceans; 3) scale effects in processes linking terrestrial systems including linkages with and among ecosystems (zones in which linkages operate, resistance to linkage, edges, integration of ecosystems in a landscape mosaic), linkage among landscape mosaics and region, and edge effects; and 4) changes in spatial scale resulting from fragmenting or merging systems. The chapter concludes with a brief discussion of the spatial scale of man's impact on the environment. **

483. **Miller, D.H.** and **L.L. Getz.** 1977. Factors influencing local distribution and species diversity of forest small mammals in New England. Can. J. Zool. 55:806-814.

Napeozapus insignis and *Blarina brevicauda* were more abundant in sites with greater vegetation cover, especially herbaceous vegetation; *Peromyscus leucopus* and *P. maniculatus* were more abundant in sites with lesser herbaceous cover. *Napeozapus insignis* and *Clethrionomys gapperi* were more abundant in moist sites: *B. brevicauda* was only slightly more abundant in moist situations. Differences in water availability in their food appeared to be the primary reason for differences in local distributional patterns of the latter two species, both of which have high water requirements. The food of *B. brevicauda* (invertebrates) has a high water content even in dry sites, while water content of the food of *C. gapperi* (seeds, plant material, and fungi) reflects more directly soil moisture conditions. *Napeozapus insignis, Microtus pinetorum,* and *Sorex cinereus* had the narrowest habitat breadths; habitat breadths of *P. leucopus, P. maniculatus, C. gapperi,* and *B. brevicauda* were widest. Only the total number of species of trees and shrubs in a site displayed a correlation (positive) with species diversity of small mammals. Diversity of available food is presumed to be the proximate factor influencing diversity of forest small mammals in New England.

484. **Miner, C.** 1989. Douglas-fir old growth as habitat. For. Res. West (Oct.):9-12.

A research effort, led over the last several years by the Forest Service, has created a new and comprehensive understanding of late-successional Douglas-fir as habitat for plants, amphibians, small mammals, and diurnal birds in the Pacific Northwest and northern California. Old growth as wildlife habitat is complex, and animal associations vary, particularly by geographical locations. Snags, downed wood, headwaters, and ephemeral ponds are important habitat features. The studies show that more than 20 species of amphibians, diurnal birds, and small mammals and at least several plant species thrive more in old growth than in young or mature natural forests. Most of these species also have significant populations in other age classes of natural forests. A few, such as the Vaux's swift, seem to depend on old growth. (From author's summary)

485. **Minore, D.** 1979. Comparative autecological characteristics of northwestern tree species: a literature review. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-87. 72 p.

This report is a compilation of autecological information previously scattered about in several hundred publications. It includes a comparison of the tolerances, traits, and attributes of native northwestern tree species. The species are ranked with respect to 69 environmental factors, phenotypic characteristics, and physical parameters. These rankings, with the literature references from which they were derived, should be useful aids to species selection, management, and research in the Pacific Northwest.

486. **Minshall, G.W., R.C. Petersen, K.W. Cummins, T.L. Bott, J.R. Sedell, C.E. Cushing,** and **R.L. Vannote.** 1983. Interbiome comparison of stream ecosystem dynamics. Ecol. Monogr. 53(1):1-25.

Studies were conducted in four distinct geographic areas (biomes/sites) in northern United States to examine changes in key ecosystem parameters: benthic organic matter (BOM), transported organic matter (TOM), community production and respiration, leaf pack decomposition, and functional feeding-group composition along gradients of increasing stream size. Four stations ranging from headwaters (1st or 2nd order) to midsized rivers (5th to 7th order) were examined at each site using comparable methods. The results for each parameter are presented and discussed in light of the River Continuum Concept of Vannote *et al.* (1980). The postulated gradual change in a stream ecosystem's structure and function is supported by this study. However, regional and local deviations occur as a result of variations in the influence of: (1) watershed climate and geology, (2) riparian conditions, (3) tributaries, and (4) location-specific lithology and geomorphology. In particular, the continuum framework must be visualized as a sliding scale which is shifted upstream or downstream depending on macroenvironmental forces (1 and 2) or reset following the application of more localized "micro"-environmental influences (3 and 4). Analysis of interactions between BOM and TOM permitted evaluation of stream retentiveness for organic matter. Headwaters generally were most retentive and downstream reaches the least. Estimates of organic matter turnover times ranged between 0.2 and 14 yr, and commonly were 1-4 yr. Both turnover times and distances were determined primarily by the interaction between current velocity and stream retention. Biological processes played a secondary role. However, the streams varied considerably in their spiraling of organic matter due to differences in the interplay between retentiveness and biological activity. Differences in the relative importance of retention mechanisms along the continuum suggest that headwater stream ecosystems may be functionally more stable, at least to physical disturbances, than are their intermediate river counterparts.

487. **Mitchell, R.S., C. Sheviak,** and **D.J. Leopold** (editors). 1990. Ecosystem management: rare species and significant habitats. N.Y. State Museum, Albany, NY. Bull. No. 471. 314 p.

This publication contains 62 papers from presentations made at the 15th Annual Natural Areas Conference, the 10th annual meeting of the Natural Areas Association. These papers, addressing the topic of ecosystem management, are arranged in 10 chapters covering: 1) goals and strategies; 2) habitat assessment; 3) monitoring and inventory; 4) demographics and species biology of rare animals; 5) species and biology of rare plants; 6) endangered bryophytes; 7) management law; 8) management in practice; 9) stewardship; and 10) agency and public involvement. **

488. **Moir, W.H.** and **J.H. Dieterich.** 1988. Old-growth Ponderosa pine from succession in pine-bunchgrass forests in Arizona and New Mexico. Nat. Areas J. 8(1):17-24.

The growing understanding of the importance of landscape diversity has led forest managers to anticipate the need to maintain or create old-growth ponderosa pine stands in the southwest United States. Recurrent low intensity fires were historically part of the process that created and sustained old growth. Succession is described for *Pinus ponderosa/Festuca arizonica, P. ponderosa/Muhlenbergia virescens, P. ponderosa/Muhlenbergia montana*, and *Pseudotsuga menziesii/Festuca arizonica* habitat types. These environments all have similar fire histories, grassy understories, and old-growth *Pinus ponderosa* in late successional and climax stages. Eleven stages of succession are described and the role of fire is enumerated. Stages 8, 9, and 10 are old growth, the features of which begin to develop at about 200 years (age of oldest trees at breast height) but are best expressed after about 300 years.

Fire is important within early stages to direct succession to an old-growth objective. Recurrent fires are needed to maintain quality old growth and to lessen the probability of a stand-replacing catastrophic fire. Fire management within old-growth reserves could be

applied to the Monument Canyon and G.A. Pearson research natural areas as well as wilderness areas, national parks, and forest districts where planned landscape diversity includes an old-growth allocation.

489. **Moldenke, A.R.** and **B.L. Fichter.** 1988. Invertebrates of the H.J. Andrews Experimental Forest, western Cascade Mountains, Oregon: IV. The oribatid mites (*Acari: Cryptostigmata*). U.S. Dep. Agric. For. Serv., Pac. NW Res. Stn., Portland, OR. Gen. Tech. Rep. PNW-GTR-217. 112 p.

A fully illustrated key is presented for identifying genera of oribatid mites known from or suspected of occurring in the Pacific Northwest. The manual includes an introduction detailing sampling methodology; an illustrated glossary of all terminology used; two color plates of all taxa from the H.J. Andrews Experimental Forest; a diagrammatic key to the 16 major groups of adult oribatids; illustrations to aid in quick recognition of the 16 adult groups; keys to all adult genera; and a diagrammatic key to the major types of immature oribatid mites with local species illustrated. The text on adults is broken into 16 sections, each structured around a key to a genera within each major type of oribatid mite; the text associated with the keys describes each species from the Andrews Forest, its microhabitat preference, pattern of abundance, and seasonal phenology. A total of 246 scanning electron micrographs (with pointers indicating characters useful for identification) are provided to help in identifying species.

490. **Moldenke, A.R., B.L. Fichter, W.P. Stephen,** and **C.E. Griswold.** 1987. A key to arboreal spiders of Douglas-fir and true fir forests of the Pacific Northwest. U.S. Dep. Agric. For. Serv., Pac. NW Res. Stn., Portland, OR. Gen. Tech. Rep. PNW-GTR-207. 48 p.

This illustrated key for identifying spiders inhabiting true fir and Douglas-fir is based on extensive collections from throughout the three North American Pacific Coast States. Details of the age classes present at budburst and the season in which to expect adults are presented for all species. This paper is written for people unfamiliar as well as familiar with spider taxonomy; a glossary of all technical terms is included. References to pertinent technical literature are also included.

491. **Moore, K.** 1990. Where is it and how much is left? The state of the temperate rainforest in British Columbia. For. Plan. Can. 6(4):15-19.

This report presents an assessment of the state of British Columbia's temperate rainforest. Noting that temperate rainforest in the province coincides with the Coastal Western Hemlock biogeoclimatic zone, the author assesses the state of this forest type on a watershed basis. Opportunity for conservation of entire temperate rainforest watersheds is discussed.

For the purpose of the study, the British Columbia coast is divided into four areas: Vancouver Island, south coast, north coast, and Queen Charlotte Islands. The number of logged and unlogged watersheds of various sizes (e.g., greater than 5 000 ha, or greater than 20 000 ha) in these areas is presented. Opportunities for conservation of large areas of temperate rainforest do still exist, most notably in Clayoquot Sound, the Kyuquot/Brooks area, and Gardner Canal. **

492. **Moore, P.D.** 1987. What makes a forest rich? Nature 329(24):292.

The author discusses a variety of factors influencing biological diversity. A general decline in species richness occurs from the tropics to the tundra, creating an overall latitudinal gradient of diversity. Isolated locations (from peninsulas to islands) also exhibit declining species richness, and topographically or ecologically variable sites provide greater habitat diversity and thus greater species diversity. The author also cites an experiment conducted to reveal the most influential variable determining species richness of forests in North America.

In it, a relationship between annual evapotranspiration and species richness was discovered. Evapotranspiration is one of the major factors influencing primary productivity, so the results of this experiment imply species richness of a forest is determined by potential productivity. **

493. **Morrison, P.H.** 1988. Old growth in the Pacific Northwest: a status report. The Wilderness Soc., Washington, DC. 46 p.

This report provides a valid, scientific assessment of the amount of ecologically viable old growth remaining on 6 of the 12 westside national forests. It also describes the condition of the resource and, where available, the short-term plans to log it. In view of the results of this study, it is especially important that a similar analysis be conducted on the other six westside national forests. The Forest Service has the necessary information and should undertake such a study. Continued reliance on inaccurate and inflated estimates of the old-growth resource can only lead to decisions spelling a swift and final end to the ancient forest.

494. **Mosley, M.P.** 1981. The influence of organic debris in channel morphology and bedload transport in New Zealand forest streams. Earth Surface Processes and Landforms 6:571-579.

The behaviour and form of, and bedload sediment transport through, a 3.5 m wide forest stream have been monitored for nearly three years. Bedload transport is highly episodic and spatially variable, and is controlled less by water discharge than by sediment availability. Organic debris in the channel creates temporary base levels and sites at which coarse sediment may remain stored for long periods; collapse or disruption of log and debris jams makes sediment available for transport in only a small proportion of the runoff events that are actually competent to move the material. Even then, sediment travels only a short distance before being redeposited, frequently behind debris accumulations further downstream. Rates of sediment transport during a given runoff event can vary markedly over short distances along the stream, again depending on whether sediment was made available for transport by log jam collapse upstream. Organic debris is therefore a major constraint on the application of physical laws and theories to explaining sediment movement in, and the morphology of, this stream.

495. **Mueller-Dombois, D.** 1987. Natural dieback in forests. BioScience 37(8):575-583.

The author discusses a variety of factors involved in stand-level dieback of forests around the world. Major diebacks are discussed by geographic area—Europe, North America, and the Pacific. Analysis of diebacks for separate tree species indicates that pollution does not stand out as a major cause of large scale diebacks. Complexity of abiotic and biotic causes gave rise to the decline-disease theory. This theory includes three successive operating groups: 1) disease-initiating long-term factors (climatic change, air pollution, genetics, soil conditions); 2) short-term inciting factors (mechanical injury); and 3) long-term contributing factors (biotic agents).

The decline-disease theory is discussed and compared to the natural dieback theory. The author concludes with a discussion on the evolutionary implications of recurring forest dieback. **

496. **Muona, O.** 1990. Population genetics in forest tree improvement. *In* Plant population genetics, breeding, and genetic resources. A.H. D. Brown, M.T. Clegg, A.L. Kahler, and B.S. Weir (editors). Sinauer Assoc. Inc., Sunderland, MA, pp. 282-298.

Research on population genetics of forest trees has concentrated on measuring the level and distribution of genetic variability, in particular at isozyme loci, and on quantifying reproductive patterns using marker loci. Most temperate conifer populations are highly variable at isozyme loci, but there is little differentiation between populations due to efficient gene flow by pollen dispersal. In contrast, adaptive quantitative characters are often more differentiated due to varying selection pressures. Partial self-characters are often more differentiated due to varying selection pressures. Partial selfing occurs in most species, but

there is no evidence of inbreeding at the adult stage, as inbred zygotes are eliminated in juvenile life stages. Intense fertility selection takes place during the reproductive cycle in conifers. Reproductive patterns in angiosperm trees ae poorly known. The findings have bearing in many areas of tree breeding, e.g., estimation of genetic parameters, design of seed orchards, planning of breeding populations for long-term genetic improvement, and gene conservation.

497. **Murphy, D.D.** and **B.A. Wilcox.** 1986. On island biogeography and conservation. Oikos 47(3):385-387.

The authors discuss the relevance of Island Biogeographic theory to conservation and the design of nature reserves. The conclusion of other researchers, Lahti and Ranta (1985), that Island Biogeography theory has little relevance to reserve design is challenged. The authors assert that the theory has important practical advice about the design of nature reserves. All else being equal, they note, larger reserves will support more species. The authors also assert that the most significant problem facing conservationists is the fragmentation of single large areas into several small areas. **

498. **Murphy, M.L.** and **J.D. Hall.** 1981. Varied effects of clear-cut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon. Can. J. Fish. Aquat. Sci. 38(A):137-145.

Assemblages of aquatic vertebrate and insect predators were inventoried in streams in old-growth and logged coniferous forests in the western Cascades of Oregon to assess effects of clear-cut logging on stream communities. Effects associated with logging depended on stream size, gradient, and time after harvest. Clear-cut sections where the stream was still exposed to sunlight (5-17 yr after logging) generally had greater biomass, density, and species richness of predators than old-growth (>450-yr-old) forested sections. Increases were greatest in small (first-order), high gradient (10-16%) streams, where clear-cut sites had both greater periphyton production and coarser streambed sediment than old-growth sites of similar size and gradient. Effects on predators were mixed in larger, low gradient streams, where clear-cut sites showed accumulation of sediment and relatively small increases in periphyton production. Second-growth logged sections (12-35 yr after logging), reshaded by deciduous forest canopy, had lower biomass of trout and fewer predator taxa than old-growth sites.

499. **Murphy, M.L., J. Heifetz, S.W. Johnson, K.V. Koski,** and **J.F. Thedinga.** 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan streams. Can. J. Fish. Aquat. Sci. 43:1521-1533.

To assess short-term effects of logging on juvenile *Oncorhynchus kisutch, Salvelinus malma, Salmo gairdneri*, and *Salmo clarki* in southeastern Alaska, we compared fish density and habitat in summer and winter in 18 streams in old-growth forest and in clearcuts with and without buffer strips. Buffered reaches did not consistently differ from old-growth reaches; clear-cut reaches had more periphyton, lower channel stability, and less canopy, pool volume, large woody debris, and undercut banks than old-growth reaches. In summer, if areas had underlying limestone, clear-cut reaches and buffered reaches with open canopy had more periphyton, benthos, and coho salmon fry (age 0) than old-growth reaches. In winter, abundance of parr (age 0) depended upon the amount of debris. If debris was left in clear-cut reaches, or added in buffered reaches, coho parr were abundant (10-22/100 m^2). If debris had been removed from clear-cut reaches, parr were scarce (<2/100 m^2). Thus, clear-cutting may increase fry abundance in summer in some streams by increasing primary production, but may reduce abundance of parr in winter if debris is removed. Use of buffer strips maintains or increases debris, protects habitat, allows increased primary production, and can increase abundance of fry and parr.

500. **Myers, N.** 1986. Tackling mass extinction of species: a great creative challenge. Univ. Cal., Coll. Nat. Resources, Dep. For. Res. Manage., Berkeley, CA. 40 p.

This lecturer discusses the issues relevant to mass extinction, species and genetic variability, past, present, and future extinction rates, tropical forests, and climatic change. He addresses the economic values currently at stake and the repercussions for the future of evolution. Possible future approaches include a triage strategy for threatened species and a shift in research emphasis. **

501. **Myren, R.T.** and **R.J. Ellis.** 1984. Evapotranspiration in forest succession and long-term effects upon fishery resources: a consideration for management of old-growth forests. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 183-186.

Evapotranspiration of rapidly growing forests may markedly reduce the minimum streamflows during the summer. In many streams of southeast Alaska, the minimum summer streamflows limit spawning success of pink and chum salmon and may limit the habitat of species such as coho salmon that rear in streams. Extrapolating from the literature leads to the conclusion that converting significant portions of old-growth watersheds to rapidly growing second-growth forests risks permanently reducing summer low flows of the streams and, thus, their ability to produce salmon. It is recommended that this risk be considered in managing the forests and that effects on streamflow of converting old-growth forests to second-growth forests be included in studies of logging in southeast Alaska.

502. **Nagorsen, D.W.** and **R.L. Peterson.** 1981. Distribution, abundance and species diversity of small mammals in Quetico Provincial Park, Ontario. Nat. Can. 108:209-218.

During 1977-79 we sampled mammals in upland conifer, upland mixed, lowland conifer, lowland mixed and wet meadow habitats in Quetico Provincial Park using 22 transects of snap traps. A total of 1,980 small mammals representing five species of shrews and eight species of small rodents were captured. The 13 species demonstrated marked habitat segregation. Although species composition and species abundance differed among habitats, the structure of these mammalian communities was similar and a few dominant mammals accounted for more than 90% of the total captures. Greatest abundance was in the lowland mixed habitat; fewest captures and lowest species diversity occurred in the lowland conifer habitat. Omnivores accounted for 63% to 89% of the total captures in forest habitats; an equal proportion of insectivores, herbivores and omnivores occurred in the wet meadow habitat. These differences in abundance, species diversity and trophic groups of mammals were attributed to vegetation and available food resources.

503. **Naiman, R.J.** 1982. Characteristics of sediment and organic carbon export from pristine boreal forest watersheds. Can. J. Fish. Aquat. Sci. 39:1699-1718.

Estimates of the amount of material moving annually from terrestrial ecosystems to the ocean are largely based on an incomplete understanding of events occurring throughout the hydrologic year, and only a vague comprehension of in-stream processes controlling that export. Discharge, suspended sediment, particulate organic matter (POM; >0.5μm), dissolved organic carbon (DOC; <0.5 μm diameter), and the percentage of organic matter were measured from 1979 to 1981 in five pristine Quebec streams: First Choice Creek (1st order; watershed area: 0.25 km^2), Beaver Creek (2nd order; 1.83 km^2), Muskrat River (5th order; 204 km^2), Matamek River (6th order; 673 km^2), and the Moisie River (9th order; 19 871 km^2). All streams, with the exception of First Choice Creek, have a strong spring freshet when 43-55% of the annual discharge occurs. By describing sediment and organic carbon export throughout the annual hydrologic cycle, I showed that during the 2-mo spring freshet 71-92% of the annual sediment load is exported but only 59-65% of the annual POM load, and only 47-51% of the annual DOC load. Sediment yield is relatively constant between watersheds (1.5-7.6 $gm \cdot m^{-2} \cdot yr^{-1}$), as is POM export (1.0-6.7 g ash-free dry-weight

[AFDW]·m^{-2}·yr^{-1}); however, export DOC varies from 3.1 g C·m^{-2}·yr^{-1} in First Choice Creek to 48.4 g C·m^{-2}·yr^{-1} in Beaver Creek. There appears to be rapid loading of carbon between 1st- and 2nd-order streams in boreal forests, followed by biological and physical processing as watershed area increases. Thus, for the Moisie River watershed, export of total organic carbon (TOC) is reduced to only 4.7 g C·m^{-2}·yr^{-1}. Export of coarse particulate organic matter (>1 mm) is negligible (normally <0.1 mg·L^{-1}), as is oxidation of the suspended load (<0.5%·d^{-1}). Effects of summer storms, natural diel variations, and depth of sample from the water column are shown to have a minimal influence on concentrations. Rating curves (kg·d^{-1} vs. discharge) are developed to estimate the annual yield of sediment, POM, and DOC, and to evaluate long-term variations. From the results I suggest that in-stream processing and retention devices exert considerable control over the quantity and nature of suspended organic material. Physical processes such as the discharge regime and stream power are relatively less important in determining organic concentrations, but more important in determining sediment concentrations.

504. **Naiman, R.J.** and **J.R. Sedell.** 1981. Stream ecosystem research in a watershed perspective. Verh. Internat. Verein. Limnol. 21:804-811.

Studies of stream segments will, of their own accord, produce interesting and often significant results. However, placement of data in larger perspective yields new insights into basic ecosystem processes. Had the physical analyses not been combined with the biological studies, it would have been possible to conclude that (1) annual export of seston varied widely among watersheds, (2) that in a relative sense periphyton production is trophically important only in middle order (3rd-6th) streams because of their abundance and, (3) that high quality off-channel areas created by woody debris were not an especially rare feature of the drainage network. Examples presented here demonstrate that extension of site specific data to watershed dimensions adds perspective to our understanding of these basic ecosystem components. This same approach can be applied to other ecosystem components (e.g., woody debris, detritus, macrophytes, invertebrates, etc.) to produce a three-dimensional picture of their distribution and importance in the watershed. Without this added perspective, it is clear that the overview needed for understanding the dynamics of total watershed ecosystems would be difficult to accomplish.

505. **Namkoong, G.** and **J.H. Roberds.** 1974. Extinction probabilities and the changing age structure of Redwood forests. Am. Nat. 108(961):355-368.

Survival of coastal redwoods in coastal California is modelled as a stochastic process of individual tree and neighborhood-wide survival and regeneration probabilities. Age-dependent seed and sprout production capacities, as well as probabilities of death and site availability, are estimated for various levels and kinds of site disturbances which may occur in the future. Analyses of these processes indicate that, in the remaining areas of old-growth, coast redwoods have a small probability of extinction due to natural processes within neighborhoods. Management to control mortality and increase successful reproduction can increase the probabilities of survival and the chances of maintaining an all-aged structure. However, large areas can be destroyed by many agencies in addition to clear cutting, and their frequency may well increase in the future. While supplemental planting can easily prevent extinction, the survival processes in redwoods which are now or are soon to be converted to completely young-age class trees are not yet well known. A conservative strategy requires heavy restrictions on the conversion of old-growth, all-aged forest neighborhoods into young, even-aged neighborhoods. (Author's summary)

506. **Nault, J.** 1988. Radial distribution of thujaplicins in old growth and second growth western red cedar (*Thuja plicata* Donn). Wood Sci. Tech. 22:73-80.

Radial distribution of thujaplicins in western red cedar (*Thuja plicata* Donn) trees of varying ages was studied in order to assess relative decay resistance of their wood. Samples were extracted with ethanol:benzene (1:2), and the extractives were analyzed for thujaplicin

content by a new method utilizing capillary gas chromatography of their methylated derivatives. The combined concentration of thujic acid and methyl thujate was also determined for each sample. Distribution of extractives, thujaplicins and thujic acid, generally increased from pith to outside heartwood, then decreased in the sapwood. Maximum extractive and thujaplicin contents were also related to tree age. This suggests that products made from the wood of younger trees will be less resistant to decay than similar products made from the wood of old trees.

507. **Newbold, J.D., D.C. Erman,** and **K.B. Roby.** 1980. Effects of logging on macroinvertebrates in streams with and without buffer strips. Can. J. Fish. Aquat. Sci. 37:1076-1085.

The impact of logging with and without buffer strip protection on stream macroinvertebrates was examined through comparisons of community structure in commercially logged and control watersheds throughout northern California. A nonparametric test of community dissimilarities within matched blocks of two control and one or two treated stations showed significant ($P<0.05$) logging effects on unprotected streams when Euclidean distance and mutual information were used as dissimilarity indices, but not when chord distance was used. Shannon diversity in unprotected streams was lower ($P<0.01$) than in control (unlogged) streams; densities of total macroinvertebrate fauna and of Chironomidae, *Baetis*, and *Nemoura* were higher in unprotected streams than in controls ($P<0.05$). Streams with narrow buffer strips (<30 m) showed significant effects by the Euclidean distance test, but diversity varied widely and was not significantly different from that in either unprotected or control streams. Macroinvertebrate communities in streams with wide buffers (30 m) could not be distinguished from those of controls by either Euclidean distance or diversity; however, diversity in wide-buffered streams was significantly greater than in streams without buffer strips, indicating effective protection from logging effects.

508. **Newton, M.** and **E.C. Cole.** 1987. A sustained-yield scheme for old-growth Douglas-fir. West. J. Appl. For. 2(1):22-25.

From analysis of two natural Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) stands, 120 and 140 years old, we conclude that managed stands can meet established criteria for old-growth Douglas-fir and simultaneously produce near maximum yields of good-quality timber. With the management approach outlined here average annual volume growth may approach that of shorter-rotation culture, but in logs of a size and quality normally found only in older stands, and with minimal impact on high-risk watersheds or old-growth habitat. This possibility encourages development of silvicultural systems that can achieve such goals in a variety of timber types.

509. **Newton, R.** 1989. Large scale sustainable forestry as a holistic discipline. Trumpeter 6(2):63-65.

The author outlines how forests could be returned to the category of resources that can sustain environments on a large scale. He suggests “islands of development” within a permanent forest, outlining eight management principles. Moving from large area logging to smaller woodlot or alternative development options will allow the re-creation of healthy forests over the province. **

510. **Nixon, B.** 1988. Approval process for preservation of caribou old-growth winter habitat clarified. For. Plan. Can. 4(4):22-25.

The author discusses the issue of ministry responsibility for wildlife, and explains the role of the Ministry of Forests’ Integrated Resources Branch, established in March 1987. A letter from Jim Bullen, then director of the IRB, explains the organization and responsibilities of the branch. **

511. **Nordyke, K.A.** and **S.W. Buskirk.** 1988. Evaluation of small mammals as ecological indicators of old-growth conditions. *In* Proc. Symp. on Management of Amphibians, Reptiles and Small Mammals in North America. R.C. Szaro, K.C. Severson, and D.R. Patton (technical coordinators). July 19-21, 1988, Flagstaff, AZ. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-166, pp. 353-367.

The use of small mammals as ecological indicators of old-growth conditions was evaluated from trapping studies conducted in forest stands reflecting a range of old-growth conditions in southeastern Wyoming. The relationship between abundance of *Clethrionomys gapperi* and old-growth conditions was expressed in a quadratic function. *Tamias minimus* and *Peromyscus maniculatus* were negatively correlated with old-growth conditions. *C. gapperi* is the most likely candidate for a small mammal ecological indicator of old-growth conditions in spruce-fir stands.

512. **Norse, E.A.** 1990. Ancient forests of the Pacific Northwest. The Wilderness Soc., Washington, DC. 327 p.

The major theme running through Norse's book is that we are approaching the almost complete destruction of unique, complex forest ecosystems that we do not fully understand, and replacing them with forest types which may yield less in resource values than will the harvested old growth. Norse has used language that a layperson can comprehend, yet content that meets the rigorous requirements of the professional ecologist.

The book consists of a variety of topics organized into nine chapters. Some of the topics included are the global nature of the problem, historical resource use, definition and internal functioning of old-growth ecosystems, and the importance of old growth to biological diversity (genetic, species, ecosystem). Threats to old-growth forests from harvesting, pollution and the greenhouse effect, and the sustainability of forests in the Pacific Northwest, are discussed. An additional 12 essays by professional ecologists focusing on their field of specialization are included. **

513. **Norse, E.A., K.L. Rosenbaum, D.S. Wilcove, B.A. Wilcox, W.H. Romme, D.W. Johnston,** and **M.L. Stout.** 1986. Conserving biological diversity in our national forests. The Wilderness Soc., Washington, DC.

The book addresses one of the most important environmental issues faced by our planet: loss of biological diversity. Fundamental changes in the management of our national forest, wildlife refuges, and parks are required for conservation of biological diversity. This book addresses the topic in nine chapters, covering: 1) the importance of biological diversity; 2) some important concepts of conservation biology; 3) wildlands and ecosystem management; 4) consequences of habitat fragmentation; 5) forest management and biological diversity; 6) national forest planning; 7) what to look for in a forest plan; 8) conserving rare species in national forests; and 9) maintaining biological diversity in large wildlands: the greater Yellowstone ecosystem. **

514. **Norton, B.G.** 1986. The preservation of species. Princeton Univ. Press, Princeton, NJ. 305 p.

Three main issues surrounding the preservation of species are explored in this book. Part I discusses the scope of the problem, its global character, the magnitude of current and projected extinction rates as compared to major extinction events of the past, and socioeconomic and cultural factors. Part II takes a look at the values and objectives which policy analysts must consider as reasons for preserving species. These include utilitarian values humans derive from species diversity, intrinsic values of other species, and aesthetic values. Part III provides guidelines for those agencies and individuals working for the protection of biological diversity. Basing decisions on inadequate scientific information, developing positive incentives for private landowners, and defining areas of consensus and conflict across disciplines are three crucial areas discussed here. **

515. **Noss, R.F.** 1983. A regional landscape approach to maintain diversity. BioScience 33(11):700-706.

Land managers have traditionally assumed that achieving maximum local habitat diversity will favor diversity of wildlife. Recent trends in species composition in fragmented landscapes suggest, however, that a more comprehensive view is required for perpetuation of regional diversity. A regional network of preserves, with sensitive habitats insulated from human disturbance, might best perpetuate ecosystem integrity in the long term.

516. ———————. 1987a. Corridors in real landscapes: a reply to Simberloff and Cox. Conserv. Biol. 1(2):159-164.

Habitat corridors have become popular in land-use plans and conservation strategies, yet few data are available to either support or refute their value. Simberloff and Cox (1987) have criticized what they consider an uncritical acceptance of corridors in conservation planning.

Any reasonable conservation strategy must address the overwhelming problem of habitat fragmentation. Although Simberloff and Cox use island analogies to illustrate advantages of isolation, these analogies do not apply directly to problems in landscape planning. Genetics also does not offer unequivocal advice, but the life histories of wide-ranging animals (e.g., the Florida panther) suggest that the maintenance or restoration of connectivity in the landscape is a prudent strategy. Translocation of individuals among reserves—considered by Simberloff and Cox a viable alternative to natural dispersal—is impractical for whole communities of species that are likely to suffer from problems related to fragmentation.

Many of the potential disadvantages of corridors could be avoided or mitigated by enlarging corridor width or by applying ecologically sound zoning regulations. Corridors are not the solution to all of our conservation problems, nor should they be used as a justification for small reserves. But corridors can be a cost-effective complement to the strategy of large and multiple reserves in real-life landscapes.

517. ———————. 1987b. From plant communities to landscapes in conservation inventories: a look at the Nature Conservancy (USA). Biol. Conserv. 41:11-37.

The Nature Conservancy (TNC-USA) has developed an efficient system for inventory and evaluation of "elements-of-diversity". The major components of this system are a "fine filter" for species inventory and a "coarse filter" for community-type inventory. As in traditional vegetation science, community sampling and classification are restricted to relatively homogeneous stands and avoid edges, ecotones, and disturbed areas. TNC employs a habitat-based system of natural communities to complement plant community classification. This system is used to identify stands that cumulatively encompass the full range of variation within each defined natural community type. Ecological relationships among community-types in real landscapes, however, are not accounted for.

This paper reviews some important ecological functions of heterogeneous landscapes, which are not necessarily protected by conservation strategies that focus on separate, homogeneous community-types. Recommendations to expand TNC's coarse filter to landscapes include: (1) Disturbance regime and regeneration patterns should be evaluated for each major community-type, and for each site representing a type or group of types; (2) Functional combinations of community-types and developmental stages (landscape mosaics) should be addressed in the TNC system; (3) Landscape context (e.g., surrounding habitat types and connectivity) for a site is as important as the habitat content (e.g., the rarity or quality of community-types present). Attention to landscape level patterns and processes will be helpful for evaluating large sites that are composed of many community-types, and in setting selection and stewardship for sites of any size that are surrounded by dissimilar habitat.

518. ———————. 1987c. Protecting natural areas in fragmented landscapes. Nat. Areas J. 7(1):2-13.

Natural areas usually are selected for protection according to the elements contained within them. A focus on content alone, however, is incomplete because the structure and use of the surrounding landscape will determine whether a "protected area" will be able to maintain the most threatened elements and allow for their continued evolution. In fragmented landscapes, few if any natural areas comprise intact ecosystems. A complementary focus on landscape context includes not only consideration of external threats (reviewed here), but also how each individual natural area combines with other landscape elements to determine regional, and ultimately, global diversity.

Although few remaining natural areas are large enough to contain natural disturbance regimes and natural community mosaics within their boundaries, or to meet the needs of wide-ranging animals, an integrated network of protected areas and buffer zones of low-intensity land use may approximate the natural pattern. Conservation networks can be designed on spatial scales ranging from townships to biomes. Restoration of wilderness ecosystems in human-dominated landscapes is a particularly challenging task but must be attempted if natural diversity is to be maintained in the long term. Examples are presented of macro-reserves and networks proposed for Florida and Ohio.

519. ————————. 1988. Strategies for conservation of old growth. For. Plan. Can. 5(4):8-11.

Using the "natural" disturbance processes operating in an old-growth forest as a guide, managers can alter forestry practices to reduce negative environmental impact. Tree-fall gaps and large-scale disturbances such as catastrophic fire have significant effects on the structure and function of an established forest. The author compares the results of some current forest management practices with results of these natural disturbance events. The effect of roads and opening size and shape on fragmentation and edges, and the need for buffer zones and wilderness areas for scientific and ecological values are also discussed here. **

520. ————————. 1989. Who will speak for biodiversity? Conserv. Biol. 3(2):202-203.

The author discusses whether conservation biologists are pure or applied scientists, and outlines their potential role in environmental activism. **

521. **Noss, R.F.** and **L.D. Harris.** 1986. Nodes, networks, and MUMs: preserving diversity at all scales. Environ. Manage. 10(3):299-309.

The present focus of practical conservation efforts is limited in scope. This narrowness results in an inability to evaluate and manage phenomena that operate at large spatiotemporal scales. Whereas real ecological phenomena function in a space-time mosaic across a full hierarchy of biological entities and processes, current conservation strategies address a limited spectrum of this complexity. Conservation typically is static (time-limited), concentrates on the habitat content rather than the landscape context of protected areas, evaluates relatively homogeneous communities instead of heterogeneous landscapes, and directs attention to particular species populations and/or the aggregate statistic of species diversity. Insufficient attention has been given to broad ecological patterns and processes and to the conservation of species in natural relative abundance patterns (native diversity).

The authors present a conceptual scheme that evaluates not only habitat content within protected areas, but also the landscape context in which each preserve exists. Notes of concentrated ecological value exist in each landscape at all levels in the biological hierarchy. Integration of these high-quality nodes into a functional network is possible through the establishment of a system of interconnected multiple-use modules (MUMs). The MUM network protects and buffers important ecological entities and phenomena, while encouraging movement of individuals, species, nutrients, energy, and even habitat patches across space and time. An example is presented for the southeastern USA (south Georgia-north Florida), that uses riparian and coastal corridors to interconnect existing

protected areas. This scheme will facilitate reintroduction and preservation of wide-ranging species such as the Florida panther, and help reconcile species-level and ecosystem-level conservation approaches.

522. **Nyberg, J.B.** 1987. Man-made forests for deer: challenge or dilemma? For. Chron. 63(3):150-154.

As young forests in many areas of Canada enter the middle and later stages of their rotations, new concerns are arising over the future of deer populations. Analysis of silvicultural impacts on deer habitat requirements indicates that the food, cover, and water needs of deer can be met in young forests, but that most uniformly treated stands will be lacking in one or more components. Mosaics of young stands, each 20-40 ha in area and at different stages of management, will provide good habitat in many areas. In areas with snowy winters, however, deer need to find all habitat components much more closely interspersed.

523. **Nyberg, J.B., F.L. Bunnell, D.W. Janz,** and **R.M. Ellis.** 1986. Managing young forests as black-tailed deer winter ranges. B.C. Min. For., Victoria, BC. Land Manage. Rep. 37. 44 p.

During snowy winters, black-tailed deer (*Odocoileus hemionus columbianus*) in coastal British Columbia appear to survive best in old-growth forests. Because biologists regard these old-growth winter ranges as unique and irreplaceable, the B.C. Ministry of Environment has requested no logging of the most heavily used patches. However, reserving the timber from logging forever would mean losing important economic benefits, so alternatives for ensuring deer survival have been suggested. Of these, the use of specialized silvicultural treatments of young Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) stands appears most promising.

On winter ranges, deer need shallow snowpacks that melt quickly, abundant understory vegetation and arboreal lichens for forage, and overhead canopies and ground-level thickets for cover. With modifications to the structure and species composition of forests, most of these features can be produced in immature stands. However, the potential for enhancing lichen establishment and growth remains uncertain.

To serve as winter ranges, young forests will need to be patchier than most intensively managed stands, and in some patches, tree densities will need to be lower than normal. Initial prescriptions for creating winter ranges should aim to produce a 60/40 ratio of cover to forage-producing areas. By selecting suitable stands, planning treatment regimes carefully and beginning treatments early, managers can probably provide suitable winter ranges in 40- to 80-year-old stands. These ranges may be poorer (lower in carrying capacity) than prime old-growth winter ranges, but by managing larger areas, managers can compensate for lower quality with greater quantity under most winter conditions.

524. **Nyberg, J.B., A.S. Harestad,** and **F.L. Bunnell.** 1987. "Old growth" by design: managing young forests for old-growth wildlife. Trans. N. Am. Wildl. Nat. Resour. Conf. 52:70-81.

The current, rapid loss of wildlife habitat in old-growth forests requires the management of second-growth forests for old-growth characteristics. Developing silvicultural prescriptions that meet habitat requirements for single species is already under way, yet similar work must be planned for other wildlife. To develop a planning framework, one requires knowledge of four elements: 1) specific habitat features required by a given species; 2) functional relationships within the forest conditions which can produce these features; 3) silvicultural practices and stand dynamics which generate required features; and 4) behavior of the species which affects use of the habitat features. A planning scheme that incorporates these elements is outlined. Examples are provided, describing the habitat features required by the species, as well as current management capabilities. Species discussed are black-tailed deer, cavity-nesting birds, small mammals, the spotted owl, and various species complexes. The authors discuss the implications for wildlife and forest management,

concluding that preservation is a necessary first step to maintaining wildlife habitat, although the current social and economic environment require that second-growth stand management also become an important management option. **

525. **Nyberg, J.B.** and **D.W. Janz.** (technical editors). 1990. Deer and elk habitats in coastal forests of southern British Columbia. B.C. Min. For. and Min. Environ., Victoria, BC. Spec. Rep. Ser. No. 5.

The objective of this report is to provide most of the information managers need to understand how deer and elk interact with the forests on the south coast of British Columbia. Large areas of forest land on British Columbia's south coast are directly disturbed or influenced by human activities (mainly logging and silviculture practices) every year. These practices can damage or improve deer and elk habitat. Changes in methods used to integrate management plans for timber and wildlife habitat are long overdue. The authors believe the first steps towards such change are to improve communication between timber and wildlife managers. This report contains sections describing the ecology of black-tailed deer and Roosevelt elk, a description of the interactions of timber management with deer and elk, a description of techniques for managing habitat, and instructions on applying the handbook to habitat management planning. The report also contains appendices on understory types, special habitats, Latin and common names of species, and a glossary. **

526. **Oberlander, G.T.** 1956. Summer fog precipitation on the San Francisco Peninsula. Ecology 37(4):851-852.

The author provides a brief account of a study of summer fog precipitation on the San Francisco Peninsula. Gauges were installed along a 3-mile tree stretch of Cahill Ridge for approximately 1 month to measure the amount of precipitation resulting from fog drip. The 58.8 inch accumulation of precipitation from underneath the tan oak represented a higher amount of precipitation in a month than for the entire rainy season. Adjacent grasslands had dry soil on days when there were enormous amounts of precipitation in the forests. It was concluded that these trees play an important role in maintaining ground water levels and the lower seepages found at Cahill Ridge. Fog drip was found to be most evident under trees that are unprotected by any hills from the wind from the Pacific Ocean. The first line of trees to seaward side receive the greatest amount of moisture from fog drip, and trees further east and inland receive gradually declining amounts. **

527. **Odum, E.P.** 1984. Diversity and the forest ecosystem. *In* Proc. Workshop on Natural Diversity in Forest Ecosystems. J.L. Cooley and J.H. Cooley (editors). Nov. 29-Dec. 1, 1982, Athens, GA. Inst. Ecol., Univ. Georgia, Athens, GA, pp. 35-41.

This paper emphasizes six aspects of diversity that are important from the overall or ecosystem point of view: 1) diversity above and below species level; 2) landscape diversity; 3) diversity and stability; 4) invisible diversity; 5) life support value of forests; and 6) diversity and urbanization. **

528. **Old-Growth Definition Task Group.** 1986. Interim definitions for old-growth Douglas-Fir and mixed-conifer forests in the Pacific Northwest and California. J. F. Franklin, F. C. Hall, C. Maser, J. Nunan, J. Poppino, C. J. Ralph, and T. A. Spies (members). U.S. Dep. Agric. For. Serv., Pac. NW Res. Stn., Portland, OR. PNW-447. 7 p.

Interim definitions of old-growth forests are provided to guide efforts in land-management planning until comprehensive definitions based on research that is currently underway can be formulated. The basic criteria for identifying old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and mixed-conifer forests in western Washington and Oregon and California are given.

529. **Oliver, C.D., A.B. Adams, and R.J. Zasoski.** 1985. Disturbance patterns and forest development in a recently deglaciated valley in the northwestern Cascade Range of Washington, U.S.A. Can. J. For. Res. 15:221-232.

Advances and retreats of the east Nooksack glacier and snow avalanches and rock falls have created a mosaic of midelevation forests in the Nooksack valley, ranging in age from 7 to over 800 years since a major disturbance. Trees, shrubs, and herbaceous species invaded disturbed areas simultaneously. Forest development followed a general pattern: (i) species invasion for about 60 years; (ii) tree and shrub exclusion by a dense forest canopy; (iii) understorey regrowth as the canopy later opened; and (iv) an old-growth, uneven-aged condition in very old stands. Species composition in each stand was strongly related to the type of disturbance which initiated the stand.

530. **Orchard, S.A.** 1984. Amphibians and reptiles of B.C.: an ecological review. B.C. Min. For., Res. Br., Victoria, BC. WHR - 15. 268 p.

No all-inclusive reference of British Columbia's herpetofauna exists to date. This report has therefore been designed to complement, rather than overlap, already existing publications in British Columbia's herpetofauna. The three major parts of the report present: 1) an overview of the biology of reptiles and amphibians; 2) distribution maps and species notes (on habitat, range, food, predators, status, etc.) for selected reptiles and amphibians; and 3) a summary of the status of British Columbia's reptiles and amphibians, and recommendations for species that require special management attention. **

531. **Orchard, S.A.** and **A.P. Harcombe.** 1988a. Species-habitat relationship models for amphibians. Vol. 8. *In* Wildlife habitat handbooks for the Southern Interior Ecoprovince. A. P. Harcombe (technical editor). B.C. Min. Environ. and Min. For., Victoria, BC. Wildl. Hab. Res. WHR-35; Wildl. Rep. No. R-22. 45 p.

This volume provides detailed tabular information on the habitats and habitat complexes used by amphibian species of the Southern Interior Ecoprovince. This area covers the south-central portion of British Columbia dominated by the three driest biogeoclimatic zones: Interior Douglas Fir, Ponderosa Pine, and Bunchgrass.

Tables are organized by species, then habitat complex. The habitat is further divided into seral stages and the species life requisites are given for each of these stages. **

532. ————————. 1988b. Species-habitat relationship models for reptiles. Vol. 7. *In* Wildlife habitat handbooks for the Southern Interior Ecoprovince. A.P. Harcombe (technical editor). B.C. Min. Environ. and Min. For., Victoria, BC. Wildl. Hab. Res. WHR-34; Wildl. Rep. No. R-21. 47 p.

This volume provides detailed tabular information on the habitats and habitat complexes used by reptile species of the Southern Interior Ecoprovince. This area covers the south-central portion of British Columbia dominated by the three driest biogeoclimatic zones: Interior Douglas Fir, Ponderosa Pine, and Bunchgrass.

Tables are organized by species, then habitat complex. The habitat is further divided into seral stages and the species life requisites are given for each of these stages. **

533. **Parsons, J.J.** 1960. "Fog drip" from coastal stratus, with special reference to California. Weather 15:58-62.

This article reports the extent of precipitation in the form of fog at a particular location, the crest of the Berkeley Hills. It is suggested that significant amounts of moisture be obtained in this manner by devices designed specifically for that purpose. Examples of such techniques are given. **

534. **Pastor, J., R.H. Gardner, V.H. Dale, and W.M. Post.** 1987. Successional changes in nitrogen availability as a potential factor contributing to spruce declines in boreal North America. Can. J. For. Res. 17(11):1394-1400.

This paper examines the hypothesis that the depression of soil nitrogen availability by litter from black and white spruce (*Picea mariana* and *P. glauca*), which is low in nitrogen and high in recalcitrant compounds, may lead directly to spruce decline or predispose the forest to dieback from other factors. A set of model simulations based on principles and information developed independently of current episodes of spruce decline demonstrates the importance of this mechanism to cycles of boreal forest declines. The model also shows that if litter of red spruce (*P. rubens*) has a similar effect on the nitrogen cycle, then the effect of acid deposition on red spruce decline must be considered in light of this intrinsic property of spruce ecosystems. Because of the confounded nature of ecosystem variables, a neutral modeling approach is a necessary framework for exploring the combined effects of nutrients, drought, changing climate, and pollution on forest diebacks, for directing site selection and field measurements, and for synthesizing results of field and laboratory experiments in an ecosystem context.

535. **Pastor, J.** and **W.M. Post.** 1988. Response of northern forests to CO_2-induced climate change. Nature 334(6177):55-58.

Climate changes resulting from increases in atmospheric CO_2 are expected to alter forest productivity and species distributions. But forest response to climate change depends in part on changes in soil water and nitrogen availability which limit tree growth. Here we report an investigation into the possible responses of northeastern North American forests to a warmer and generally drier climate by driving a linked forest productivity/soil process model with climate model predictions corresponding to a doubling of CO_2. The greatest changes occurred at the current boreal/cool temperate forest border. Simulated productivity and biomass increased on soils that retained adequate water for tree growth and decreased on soils with inadequate water. Simulated changes in vegetation composition altered soil nitrogen availability, which in turn amplified the vegetation changes. The simulated responses of the forests were results of a positive feedback between carbon and nitrogen cycles, bounded by negative constraints of soil moisture availability and temperature.

536. **Patil, G.P.** and **C. Taillie.** 1982. Diversity as a concept and its measurement. J. Am. Statist. Assoc. 77(379):548-561.

This paper puts forth the view that diversity is an average property of a community and identifies that property as species rarity. An intrinsic diversity ordering of communities is defined and is shown to be equivalent to stochastic ordering. Also, the sensitivity of an index to rare species is developed, culminating in a crossing-point theorem and a response theory to perturbations. Diversity decompositions, analogous to the analysis of variance, are discussed for two-way classifications and mixtures. The paper concludes with a brief survey of genetic diversity, linguistic diversity, industrial concentration, and income inequality.

537. **Paton, P.W.C.** and **C.J. Ralph.** 1988. Geographic distribution of the marbled murrelet in California at inland sites during the 1988 breeding season. U.S. Dep. Agric. For. Serv., Pac. SW For. Range Exp. Stn., Arcata, CA. Contract FG7569 (FY 1987-8). 35 p.

We report on an intensive research effort to determine the present status of the Marbled Murrelet (*Brachyramphus marmoratus*) at inland sites in California. This seabird is, in large part, an inhabitant of the coastal redwood forests of the northern half of the state, and little is known of its ecology away from the ocean. We identified old and mature forests as potential habitat for the species using remote sensing techniques. Then, we conducted systematic surveys of stands selected from the above inventory, quantifying the relative abundance of detections of birds, their behavior, and various vegetative aspects of the stands. A total of 283 morning counts were conducted on 127 transects, with murrelets detected on 53% (66) of the transects. In addition, stationary counts were conducted on 37

mornings and 31 evenings. Eighty percent of the murrelet detections occurred from 30 minutes before to 30 minutes after sunrise. Morning censuses had five to six times more detections then evening censuses at the same point during the same 24 hour period. About 25% of the detections were visual observations, the rest were auditory. Flock size was small, single birds and pairs accounted for 80% of all detections in which birds were seen. Bird distribution was patchy and restricted to the old-growth redwood forests in Del Norte, Humboldt, San Mateo, and Santa Cruz Counties. No birds were detected in Mendocino, Sonoma, and Marin Counties with the exception of one possible detection in Mendocino County. Areas with relatively high detection rates of murrelets included: Jedediah Smith State Park; Redwood Experimental Forest; Prairie Creek State Park; the Redwood Creek drainage and Lost Man Creek drainage of Redwood National Park; Pacific Lumber Company lands northeast of Carlotta; Humboldt Redwoods State Park; Butano State Park; Portola State Park; and Big Basin State Park. The farthest inland that murrelets were detected was Grizzly Creek State Park, 39 km from the ocean.

538. **Pearce, D.W.** and **R.K. Turner.** 1990. The extinction of species. *In* Economics of natural resources and the environment. D.W. Pearce and R.K. Turner (editors). The Johns Hopkins Univ. Press, Baltimore, MD, pp. 262-270.

The authors present an economic explanation for the extinction of species. Extinctions are occurring at an unprecedented rate, they argue, due to 1) non-steady state exploitation, and 2) habitat loss. The authors note that there is good reason for concern of species extinction even in terms of a man-centered ethic that confers no rights on any other species. Some relevant arguments for species preservation within this context (e.g., for source of medicine, importance of genetic diversity in plant-based foods, and for scientific purposes) are listed. Species are disappearing at a rapid rate for three reasons: 1) because they can be "harvested" at extremely low costs; 2) because the discount rates of hunters and poachers tend to be high—hunters have no incentive to curb their killing rate to preserve species for future use; and 3) because common-property and open-access conditions increase chances of extinction. Three additional factors are important: 1) "harvesting" one species may lead to the extinction of another dependent species; 2) although the market price of a species may be zero, its habitat may be valuable, leading to its exploitation; and 3) as prey species are eliminated, predator species are also eliminated. **

539. **Pearson, A.F.** and **D.A. Challenger.** 1990. Proc. Symp. on Forests: Wild and Managed. Differences and Consequences. Jan. 19-20, 1990, Univ. B.C., Vancouver, BC. Univ. B.C., Fac. For., Students for Forestry Awareness, Vancouver, BC. 196 p.

This proceedings consists of the following papers: Dr. J.F. Franklin, Old-Growth Forests and the New Forestry; Dr. M. Hemstrom, New Forestry—How Will It Look on the Landscape?; Dr. G.E. Grant, Hydrologic, Geomorphic, and Aquatic Habitat Implications of Old and New Forestry; Dr. M. Amaranthus, Rethinking the Ecology and Management of Temperate Forests: the Living Soil; Dr. M. Carlson and Dr. A. Yanchuck, Maintaining Genetic Diversity in Future Man-Made Forests—What Are We Doing Today?; Dr. T. Schowalter, Differences and Consequences for Insects; Dr. A. Hansen, Lessons From Natural Forests; Dr. K. Lertzman, From Stands to Landscapes: Processes and Consequences of Spatial Structure; Dr. V. Puleo, "Just Do It"; Mr. M. Lambert, New Harvesting Perspectives for the New Forestry; Dr. F. Bunnell, Forestry Wildlife: W(h)ither the Future?; Dr. J. Kimmins, Designing Disturbance in the B.C. Landscape: The Prediction of Ecological Rotations. **

540. **Peet, R.K.** 1974. The measurement of species diversity. Ann. Rev. Ecol. Syst. 5:285-307.

Conclusions regarding diversity measurements that seem of major usefulness are summarized in the following outline:

A. Richness indices, based directly on species number: 1) Species number per sample measures richness as here defined and is the most basic and general diversity measurement. It is, however, affected by arbitrary choice of sample size and potential error in determining the number of species; 2) The rate of increase in number of species with increase in sample size can be measured in one of several forms. Such a measure escapes the arbitrary choice of a standard sample size, but depends on knowledge of the underlying relation of species number to sample size and the assumption that their relation remains constant among the samples being compared.

B. Heterogeneity indices, based on a combination of richness and equitability: 1) An infinite number of potential indices is available. The response curve formed by graphing the component of such an index which is summed over all species can provide basic information on the effects of different types of changes in sample composition. Response curves can also be used to distinguish different types of heterogeneity indices; 2) Type I heterogeneity indices are defined as being most sensitive to changes in the importance of the rare species in the sample. The most frequently encountered example is the Shannon formula. Use of the exponentiated form of the Shannon index is suggested for interpretational reasons; 3) Type II heterogeneity indices are most sensitive to changes in the most common species. The best known example is the Gini or complemented Simpson index. The reciprocal of Simpson's index is suggested for general application.

C. Equitability indices, based on the evenness of the distribution of importance between species: 1) Use of simple scaled heterogeneity indices or related indices (such as Pielou's J or Lloyd & Ghelardi's ε to measure equitability is not possible unless the total number of species in the sampling universe is known, a rare occurrence in ecology. In general, the use of scaled indices is not recommended; 2) Hill's ratios provide a new and potentially useful method of examining community diversity, but this approach has not yet been fully explored. (From author's conclusion)

541. **Perry, D.A.** 1988. Landscape pattern and forest pests. N.W. Environ. J. 4(2):213-228.

Relatively little is known as to why the ancient forests of the Pacific Northwest are so remarkably productive and stable. With increased harvesting of these forests and the establishment of new forests, forest biologists and managers have become concerned about whether these newly established forests will be as productive and sustainable over the long term. The transition from wild to managed forest is accompanied by many uncertainties. This paper examines one aspect of this transition: how changes in spatial structure (the pattern of forest communities and age classes across the landscape) might influence forest stability. The author discusses how forest management alters landscape patterns and cites examples of pest problems of the Northwest that have arisen as a result of changes in landscape pattern. The question of how landscape pattern might influence the susceptibility of forests to a major "pest"—catastrophic wildfire—is addressed. In closing, the author offers four basic principles that should guide future landscape management strategies. **

542. **Peterken, G.F.** 1974. Developmental factors in the management of British woodlands. Quarterly J. For. 68:141-149.

The origin and past management of any wood significantly affect its value for wildlife, research and education, and less directly influence its value for amenity and recreation. Land agents and woodland managers, at all levels, should take this into account when formulating policies, by minimising clearance, giving special treatment to special sites, fostering management continuity, and by retaining records of management activities.

543. **Peterken, G.F.** 1981. Woodland conservation and management. Chapman & Hall, London. 328 p.

Part 1 (six chapters) describes the origins, ecology and management of ancient woodland (especially coppice and wood pasture), high forest and recent secondary woodland in the UK, and the application of island theory to changes in the woodland flora. Part 2 (5

chapters) proposes a system of classification for semi-natural stand types, and describes their characteristic vegetation, management history, corresponding succession types, and relationships with European classifications. Part 3 (3 chapters) outlines the objectives and priorities of nature conservation in UK woodlands, with detailed examples of survey and monitoring techniques and assessment methods for nature conservation. Part 4 (6 chapters) describes principles of conservation management with particular reference to semi-natural woodland, including the integration of conservation with economic forestry. **

544. **Peters, R.L.** 1990. Effects of global warming on forests. For. Ecol. Manage. 35:13-33.

In the geologic past, natural climate changes have caused large-scale geographical shifts in species ranges, changes in the species composition of biological communities, and species extinctions. If the widely predicted greenhouse effect occurs, natural ecosystems will respond in similar ways as in the past, but the effects will be more severe because of the extremely rapid rate of the projected change. Moreover, population reduction and habitat destruction due to human activities will prevent many species from colonizing new habitat when the old becomes unsuitable. The synergy between climate change and habitat destruction would threaten many more species than either factor alone.

These effects would be pronounced in temperate and arctic forests, where temperature increases are projected to be relatively large. Localized species might face extinction, while widespread forest trees are likely to survive in some parts of their range. New northward habitat will become suitable even as die-offs of tree species occur to the south. However, it may be difficult for many species to take advantage of this new habitat because dispersal rates for tree species are very slow relative to the rate of warming, and therefore ranges of even many widespread species are likely to show a net decrease during the next century. Range retractions will be proximally caused by temperature and precipitation changes, increases in fires, changes in the ranges and severity of pests and pathogens, changes in competitive interactions, and additional effects of non-climatic stresses such as acid rain and low-level ozone. Changes in species composition will have large effects on local and regional economies and biological diversity.

545. **Peters, R.L.** and **J.D.S. Darling.** 1985. The greenhouse effect and nature reserves. BioScience 35(11):707-717.

This paper identifies problems caused by climate change that affect biological communities; examines the difficulties faced by species in biological reserves; and suggests management options. Conservation plans, such as the siting and design of nature reserves, must reflect knowledge of how climate change affects biological communities, the authors stress. They also note that species and communities restricted to reserves, or which live in reserve-like conditions, will be most affected by climate change. Shifting of entire biomes in response to climate change will put these species and communities at risk. The authors suggest a number of types of species and communities that may be particularly at risk, and discuss what this means for reserve management. **

546. **Peterson, B.** and **G. Gauthier**. 1985. Nest site use by cavity-nesting birds of the Cariboo Parkland, British Columbia. Wilson Bull. 97(3):319-331.

We studied nest site use by 6 species of cavity nesters in southcentral British Columbia. Discriminant function analysis was performed using nest site characteristics that differed significantly among 4 species (European starlings, *Sturnus vulgaris;* Tree swallows, *Tachycineta bicolor;* Northern Flickers, *Colaptes auratus*; and Buffleheads, *Bucephala albeola*). Cavity volume and, to a lesser extent, entrance area were the most important variables characterizing nest sites. Habitat variables were relatively unimportant except for canopy height, which also explained a significant amount of variance. The analysis correctly classified only 62% of the cases, reflecting the high overlap in cavity use, especially between Buffleheads and starlings. We tested the prediction of Erskine and McLaren (1976) that competition for nest sites would increase in this community following its invasion by

starlings 30 years ago by comparing nest site characteristics found in this study with similar data collected in 1959. Swallows now use significantly smaller cavities, bluebirds tend to use smaller but deeper cavities, and all species use cavities with smaller entrance areas. It is not clear, however, if these changes resulted from an intensification of competition or from a change in the resource available. (Author's summary)

547. **Peterson, G.L.** and **C.F. Sorg.** 1987. Toward the measurement of total economic value. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-148. 44 p.

Considerable progress has been made in recent years in the valuation of nonpriced goods. However, emphasis has been on those things most readily measurable. Valuation of wildlife benefits, for example, has aimed at consumptive, onsite recreation use (i.e., hunting and fishing). The danger in these partial estimates of value is that measuring only the on-site consumptive use of wildlife may presume to measure total value. This report examined the task of measuring off-site non-consumptive wildlife values by considering values that include: total value, option value, existence value, quasi-option value, and bequest value. Discrepancies in definitions, measurement problems, and research needs are addressed in this collection of papers.

548. **Peterson, S.R.** 1982. A preliminary survey of forest bird communities in northern Idaho. N.W. Sci. 56(4):287-298.

Bird communities were examined in the hemlock (*Tsuga heterophylla*)/pachistima (*Pachistima myrsinities*) and grand fir (*Abies grandis*)/pachistima (*Pachistima myrsinities*) habitat types of northern Idaho in 1975 and 1976. Highest number of species and highest densities of breeding birds utilized the tall shrub communities or the shrub communities mixed with conifers. Bird diversity was relatively low in recent clearcuts or very early successional stages, then rose rapidly and reached an asymptote. Several examples are given to illustrate species replacement as vegetative communities changed.

549. **Petticrew, B.G.** and **R.M. F.S Sadleir.** 1974. The ecology of the deer mouse *Peromyscus maniculatus* in a coastal coniferous forest. I. Population dynamics. Can. J. Zool. 52:107-118.

A 3-year live-trapping study of deer mice was carried out on separate 1-hectare (ha) grids located in a mature forest, a recently logged area, and a young plantation. Despite apparent gross differences in the habitats, populations on the recently logged area were similar in numbers, survival, and recruitment to those in the mature forest. There were greater differences in population parameters between years than between these two areas. Populations of deer mice in the young plantation were lower in numbers and eventually went to extinction in the summer of 1970. This appeared to be due rather to the presence of numerous *Microtus oregoni* in this area than to the habitat being less suitable for deer mice.

On the basis of this and previous studies it is proposed that the numbers of deer mice in a population are regulated as follows. During breeding seasons the number of males and juveniles are regulated by agonistic male behavior while the numbers of females may be a function of the length of the breeding season. During non-breeding seasons the changes in numbers of all deer mice are regulated by the length of such seasons.

550. **Pfister, R.D., B.L. Kovalchik, S.F. Arno,** and **R.C. Presby.** 1977. Forest habitat types of Montana. U.S. Dep. Agric. For. Serv., Intermtn. For. Range Exp. Stn., Ogden, UT. Gen. Tech. Rep. INT-34. 174 p.

A land-classification system based upon potential natural vegetation is presented for the forests of Montana. It is based on an intensive 4-year study and reconnaissance sampling of about 1,500 stands. A hierarchical classification of forest sites was developed using the habitat type concept. A total of 9 climax series, 64 habitat types, and 37 additional phases of habitat types are defined. A diagnostic key is provided for field identification of the types

based on indicator species used in development of the classification. In addition to site classification, descriptions of mature forest communities are provided with tables to portray the ecological distribution of all species. Potential productivity for timber, climatic characteristics, and surface soil characteristics are described for each type. Preliminary implications for natural resource management are provided, based on field observations and current information.

551. **Pickett, S.T.A.** and **J.N. Thompson.** 1978. Patch dynamics and the design of reserves. Biol. Conserv. 13:27-37.

Island biogeographic theory has been applied to the design of nature reserves. However, immigration, which is important in maintaining species equilibrium on true islands, will not contribute significantly to the maintenance of equilibrium on reserves in the future because of the disappearance of recolonisation sources. Consequently, extinction becomes the dominant population process, and the internal disturbance dynamics become the critical design feature of reserves. The design of reserves should be based on "minimum dynamic area", the smallest area with a natural disturbance regime which maintains internal recolonisation sources and hence minimises extinctions. Determination of minimum dynamic area must be based on knowledge of disturbance-generated patch size, frequency, and longevity, and the mobilities of the preserved species. These features have not all been expicitly considered in the previous island biogeographic design recommendations.

552. **Pickett, S.T.A.** and **P.S. White.** 1985. The ecology of natural disturbance and patch dynamics. Academic Press Inc., Toronto, ON. 472 p.

The editors have organized this text into three main sections. Part 1 provides an introduction and some definitions of terms used throughout the text. Part 2 presents several chapters which discuss patch dynamics in nature. Specifically, the authors describe: disturbance regimes in temperate forests; stand dynamics, gap dynamics and community structure in tropical forests; shrubland fire regimes; intertidal and subtidal disturbance and patch dynamics; and vertebrate response to disturbance and environmental patchiness. Part 3 describes a variety of plant and animal adaptations to patchy environments. Part 4 includes a number of papers that discuss the various implications of patch dynamics for the function of ecosystems and the organization of communities. **

553. **Pielke, R.A.** and **R. Avissar.** 1990. Influence of landscape structure on local and regional climate. Landscape Ecol. 4(2/3):133-155.

This paper discusses the physical linkage between the surface and the atmosphere, and demonstrates how even slight changes in surface conditions can have a pronounced effect on weather and climate. Observational and modeling evidence are presented to demonstrate the influence of landscape type on the overlying atmospheric conditions. The albedo, and the fractional partitioning of atmospheric turbulent heat flux into sensible and latent fluxes is shown to be particularly important in directly affecting local and regional weather and climate. It is concluded that adequate assessment of global climate and climate change cannot be achieved unless mesoscale landscape characteristics and their changes over time can be accurately determined.

554. **Pielou, E.C.** 1990. Depletion of genetic richness is not "harmless" consequence of clearcutting. For. Plan. Can. 6(4):29.

This paper examines the impact of clearcut logging on forest biological diversity. The author points out that when a forest is clearcut much more than the trees are removed—all the ground vegetation is destroyed as well. Because a great many plant populations exist as separate, isolated populations, clearcutting eliminates entire local populations of certain understory plant species and thus greatly reduces the genetic diversity of forest vegetation. Because it is impossible to foresee the long-term effects of this loss of genetic diversity, it is

essential to conserve natural ecosystems intact with all of their species and genetic diversity. Smaller clearcuts and individual tree selection are suggested as positive alternatives to clearcutting. **

555. **Pike, L.H.** 1978. The importance of epiphytic lichens in mineral cycling. Bryologist 81(2):247-257.

Mineral capital in epiphytic lichens varies considerably from forest to forest depending primarily on the biomass of lichens present and can be at least as high as 27 kg ha^{-1} for N, 3.6 kg ha^{-1} for P, 9 kg ha^{-1} for K, 9.4 kg ha^{-1} for Ca and 1.7 kg ha^{-1} for Mg. For three ecosystems, comparing Douglas fir, balsam fir and oak woodland, lichens seldom accounted for more than 10% of the annual, above-ground turnover of a mineral. Lichens were relatively more important in the cycling of N than of P and K and of least importance in the cycling of Ca and Mg. Quantities of minerals leached from lichens appear to be small compared to quantities released through biomass turnover. Lichens may influence entry of minerals into ecosystems through nitrogen fixation and interception of aerosols. Although atmospheric inputs may be sufficient to meet N, Ca and Mg requirements of epiphytic lichens, P and K appear to be obtained primarily as leachates from other canopy components. Minerals that have been taken up by lichens may subsequently reach the surrounding plant or animal communities via litterfall, leaching, bacterial incorporation or non-cellular particle formation.

556. **Pike, L.H., W.C. Denison, D.M. Tracy, M.A. Sherwood,** and **F.M. Rhoades.** 1975. Floristic survey of epiphytic lichens and bryophytes growing on old-growth conifers in western Oregon. Bryologist 78(4):389-402.

Using direct-aid climbing techniques for sampling trunks and branch systems, we found 74 species of lichens and 32 species of bryophytes growing as epiphytes in a 450-year-old Douglas fir forest in western Oregon. Six epiphyte zones are described: base, moist side of trunk, dry side of trunk, upper trunk, axes of branch systems and branchlets of branch systems. The flora of each zone is compared with that of the rest of the tree and with that found on understory vegetation.

557. **Pike, L.H., R.A. Rydell,** and **W.C. Denison.** 1977. A 400-year-old Douglas fir tree and its epiphytes: biomass, surface area, and their distributions. Can. J. For. Res. 7:680-699.

Methods have been developed to yield total tree estimates of biomass for various components of a tree (trunk, axes, twigs, and needles) and its community of epiphytes (microorganisms, lichens, and bryophytes). Trees were sampled with the help of climbing techniques modified from mountain climbing. Two stages of sampling were involved. First, all units of the population were described so that their weights could be predicted. Second, several units were chosen with probability of selection dependent upon predicted weight and sampled in detail. Biomass estimates from the sampled units were expanded to tree totals with information gathered during the first sampling stage. Internal structure of the crown (tree components and epiphytes) is illustrated by maps of trunk and branch systems and by diagrams of horizontal and vertical distributions. The internal structure was also derived from the first sampling stage.

These methods have been applied to nine old-growth Douglas fir trees [*Pseudotsuga menziesii* (Mirb.) Franco]. Data from a single 400-year-old tree (1.46 m dbh, 77 m in height) in the H.J. Andrews Experimental Forest in the western Cascade Mountains of Oregon are presented. Biomass and surface area estimates are as follows: trunk, 26,870 kg, 223 m^2; axes (>4 cm), 1530 kg, 81 m^2; living twigs (<4 cm), 480 kg, 373 m^2; dead twigs, 78 kg, 104 m^2; needles, 198 kg, 2,860 m^2; lichens, 13.1 kg; and bryophytes, 4.7 kg. Total cell volume of microepiphytes on twigs was estimated to have been 300 cm^2 and total cover by microepiphytes on needles was estimated to have been 191 m^2.

558. **Pike, L.H., D.M. Tracy, M.A. Sherwood,** and **D. Nielsen.** 1972. Estimates of biomass and fixed nitrogen of epiphytes from old-growth Douglas-fir. *In* Proc. Symp. on Research on Coniferous Forest Ecosystems. J.F. Franklin, L.J. Dempster, and R.H. Waring (editors). March 23-24, 1972, Bellingham, WA. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR, pp. 177-187.

Epiphytes are sampled concurrently with measurements of surface area of trunk and branch systems of old-growth Douglas-fir (*Pseudotsuga menziesii*). Crude predictions of epiphyte biomass in branch systems are corrected by more detailed sampling of a subset of branch systems. Nitrogen analyses enable conversion of epiphyte biomass to the total amount of nitrogen present in the epiphytes.

559. **Pimm, S.L.** and **M.E. Gilpin.** 1989. Theoretical issues in conservation biology. *In* Perspectives in ecological theory. J. Roughgarden, R.M. May, and S.A. Levin (editors). Princeton Univ. Press, Princeton, NJ, pp. 287-305.

Taking note of the four main causes of the loss of biological diversity (habitat loss, overexploitation of resources, introduction of alien species, and secondary effects of extinction), the authors discuss the theories and models which guide and inform conservation biology. The majority of the paper concerns those theories and models which predict the impact of habitat loss on biological diversity. Conservation biology is a crisis discipline, the authors note, and as such decisions must be made in the absence of good data and complete knowledge. Given this, the theories and models which inform conservation biology are the best guide to meet the challenges of the environmental crisis. This paper provides an evaluation of the strengths and weaknesses of these theories. **

560. **Piper, J.K.** 1986. Germination and growth of bird-dispersed plants: effects of seed size and light on seedling vigor and biomass allocation. Am. J. Bot. 73(7):959-965.

I examined germination and seedling growth in nine species of fleshy-fruited plants from Washington and Idaho to assess their relative responses to sun and shade. I allowed seeds to germinate over a period of 500 days, and grew the seedlings in a greenhouse for 35 days prior to harvest. Cumulative percentage germination of six species approximated logistic curves. Species with larger seeds were more shade-tolerant, which resulted largely from greater biomass allocation to roots by these species. Seedlings of *Rosa gymnocarpa, Sorbus scopulina, Symphoricarpos albus, Clintonia uniflora*, and *Streptopus amplexifolius* grew larger in open sun than in shade (35% open sun), where those of *Actaea rubra, Disporum trachycarpum, Smilacina racemosa*, and *Smilacina stellata* showed no differences. Percentage root biomass was higher in sun than in shade for *R. gymnocarpa, S. scopulina, S. albus, C. uniflora*, and *S. amplexifolius*, but lower for *S. stellata*). In *C. uniflora, S. racemosa*, and *S. stellata*, seeds from unripe fruits failed to germinate. The results suggest that light gaps resulting from periodic disturbance of canopy influence recruitment of bird-dispersed species differentially and thereby contribute to maintaining high species richness and diversity in understories of temperate coniferous forests.

561. **Platt, W.J.** and **D.R. Strong.** 1989. Gaps in forest ecology. Ecology 70(3):537-576.

This paper is an introduction to the Special Feature issue on the study of forest gaps including treefall gaps and larger gaps caused by natural disturbances. Gaps in the canopy increase light levels and change other characteristics of the environment sufficiently to influence the dynamics of populations of trees. Thus, forest dynamics are driven by disruption, with heterogeneity in disturbances hypothesized to produce forests that are inherently heterogeneous and ever-changing. T.C. Whitmore's essay provides a useful background perspective of the gap paradigm.

The roles of disturbance heterogeneity are addressed by several contributors: T.A. Spies and J.A. Franklin, T.T. Veblen, and C.G. Lorimer. Latitudinal variation in the responses of trees to gaps is addressed by J.R. Runkle. N.V.L. Browkaw and S.M. Scheiner address the role of

gap and species characteristics in dynamic processes that influence the forest mosaic. Application to forest management, both in temperate and tropical regions, is addressed by C.G. Lorimer and G.S. Hartshorn.

Other contributions to this forum challenge the classical gap paradigm that dichotomizes forests as binary gaps and non-gaps. Variation in light levels in gaps, beneath the forest canopy, and in responses of trees to the conditions occurring before and after gap formation, is addressed by C.D. Canham, T.L. Poulson and W.J. Platt. In two separate papers, J.H. Connell and E.W. Schupp, H.F. Howe, C.K. Augspurger, and D.J. Levey discuss the processes that influence tree replacement within gaps. M. Martinez-Ramos, E. Alvarez-Guylla, and J. Sarukhan discuss the relationship between population dynamics of a species and the species life history and local environmental conditions.

562. **Pojar, J.** 1980. Threatened forest ecosystems of British Columbia. *In* Proc. Symp. on Threatened and Endangered Species and Habitats in British Columbia and the Yukon. R. Stace-Smith, L. Johns, and P. Joslin (editors). March 8-9, 1980, Richmond, BC. B.C. Min. Environ., Fish Wildl. Br., Victoria, BC, pp. 28-38.

This paper presents an overview of threatened forest ecosystems in British Columbia. The author distinguishes between "depleted" and "threatened" forest ecosystems and notes that most of the latter occur (or occurred) near centers of human population. Specific threatened ecosystems are identified in the following areas: southeastern Vancouver Island and the Gulf Islands, the Lower Fraser Valley, the dry Interior, and the central Interior. Ecosystems threatened by logging, mining, and hydroelectric development are also described. Numerous forest types which have been seriously depleted by logging and which can now be (or soon could be) considered threatened are also described. Finally, the impact of introduced black-tailed deer on vegetation on the Queen Charlotte Islands is described. In closing, the author notes that the conservationists' problem in British Columbia is often not so much threatened species as it is threatened biotypes or genotypes; and that genetic diversity of forest ecosystems has likely shrunk considerably, mainly because of the widespread conversion of old-growth forest to industrial tree farms with a limited genetic base. **

563. ————————. 1988. Wildlife habitats in northern British Columbia and how they are changing. *In* Proc. Symp. on The Wildlife of Northern British Columbia. Past, Present and Future. R.J. Fox (editor). Nov. 27-29, 1987, Smithers, BC. Spatzisi Assoc. for Biolog. Res., Smithers, BC, pp. 18-33.

Northern British Columbia is a big diverse area well-known for its wildlife. The character of the environment and its fauna derives from several key factors including climate, topography, altitude, glacial history, and disturbance. This environmental complex is expressed in various ways in different areas. A simple way to order the habitat variation is to divide the northern part of the province into three broad ecological regions (Coast, Interior, North), then partition each region into a few climatic zones and physiographic units. Some important wildlife habitats and typical species are then showcased for each region, by zone and by physiographic unit.

Forestry in the broad sense (including logging, roads, post-logging site treatments, and silvicultural stand management) is the major modifying factor in both Coast and Interior regions. Perhaps the most significant effect of forestry on wildlife habitat is the far-reaching change in age-class structure of the predominant coniferous forest cover. This effect is more pronounced on the Coast than in the Interior, where stand-altering natural catastrophes have historically played a greater role. Wildfire, insect outbreaks, agriculture, and hydroelectric development are also major agents of change in the Interior. In the North, major changes to wildlife habitat result from wildfire, mining and oil/gas extraction, creation of access and transportation corridors, and hydroelectric schemes.

564. **Pojar, J.** and **A. Banner.** 1984. Old-growth forests and introduced black-tailed deer on the Queen Charlotte Islands, British Columbia. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 247-257.

The flora of the Queen Charlotte Islands is well-known, but until recently the vegetation and soils have been little studied. Deer were introduced to the islands in the early 1900s and, in the absence of predation, increased in numbers. The deer affected the vegetation but the extent was unknown. We have classified the forests of the Coastal Western Hemlock Zone on the Queen Charlottes into ten major ecosystem associations. The old-growth forests usually consist of mixtures of western hemlock (*Tsuga heterophylla*) (most often the dominant species), western redcedar (*Thuja plicata*), and Sitka spruce (*Picea sitchensis*). Shrub and herb layers are generally poorly developed (except for western hemlock regeneration) but typified by shrubby Ericaceae and ferns. A thick carpet of mosses usually covers the forest floor. Podzols and Folisols are the most common soils, and surface organic layers typically are fairly thick, moist, acid Mors. Striking differences in understory vegetation exist between old-growth forests on the Queen Charlottes and comparable forests in adjacent parts of British Columbia and Alaska. Browsing by deer appears to be largely responsible for these differences.

565. **Prescott, C.E., J.P. Corbin,** and **D. Parkinson.** 1989. Input, accumulation, and residence times of carbon, nitrogen, and phosphorus in four Rocky Mountain coniferous forests. Can. J. For. Res. 19:489-498.

Annual aboveground litterfall in forests of *Pinus contorta* Loud., *Picea glauca* (Moench) Voss, *Picea engelmannii* Parry ex Engelm., and *Abies lasiocarpa* (Hook.) Nutt. in southwestern Alberta ranged from 286 to 321 g/m^2/year. The mass of litter accumulated on the forest floor ranged from 6.3 to 11.0 kg/m^2. Residence times of organic matter in the forest floor were 11 years in a 90-year-old *P. contorta* stand, 16 years in a 120-year-old *P. glauca* - *P. contorta* stand, and 23 years in a 350-year-old *P. engelmannii* - *A. lasiocarpa* stand. Residence times of litter in the L layer of the forest floor were longer in a recently clearcut area than in the older forests. Residence times of individual nutrients in the forest floors were in the order N P C. Litter in the pine forest had lower concentrations of both N and P than did litter in the spruce-pine forest; litter in the spruce-fir forest had relatively high N and low P concentrations. Differences in nutrient concentrations of litter among sites reflected differences in the nutrient-use efficiency of the vegetation, suggesting that the species composition of vegetation is important in determining availability of nutrients in the floor of these forests.

566. **Preston, C.M., P. Sollins,** and **B.G. Sayer.** 1990. Changes in organic components for fallen logs in old-growth Douglas-fir forests monitored by ^{13}C nuclear magnetic resonance spectroscopy. Can. J. For. Res. 20:1382-1391.

^{13}C cross-polarization magic-angle spinning nuclear magnetic resonance (CPMAS NMR) spectroscopy was used to characterize heartwood from decaying fallen boles of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and western red cedar (*Thuja plicata* Donn). The sample decay classes I to V had been previously assigned based on field observations. Solid-state ^{13}C CPMAS NMR spectra were analyzed to determine the proportion of C of the following chemical types: carbohydrate, lignin, aliphatic, and the sum of carboxyl plus carbonyl. For both Douglas-fir and western hemlock, the proportion of carbohydrate C increased slightly in the early stages of decay. This was followed by a substantial increase in lignin C, while carbohydrate C declined to about 10% of total C. By contrast, the spectra for western red cedar generally showed little change with increasing decay class. One exceptional sample of western red cedar class IV was highly decomposed, indicating complete loss of carbohydrate C, and some loss of lignin side-chain C. For all three species, signals from alkyl and carbonyl C were weak, but tended to increase slightly with decomposition, most likely because of the selective preservation of waxes and resins (alkyl C), and oxidation. Accumulation of chitin was not observed, and there was little evidence for lignin decomposition or for formation of humic polymers. ^{13}C CPMAS NMR offers a simple and information-rich alternative to wet chemical analyses to monitor changes in organic components during decomposition of woody litter.

567. **Raedeke, K.J.** 1988. Streamside management: riparian wildlife and forestry interactions. Univ. Wash., Seattle, WA, Contrib. No. 59. 277 p.

This book is a compilation of a number of papers relating to managing riparian forest habitats. Five broad topics are included: 1) characteristics of forest systems; 2) ecological relationships of riparian systems and associated uplands; 3) comparisons of managed and unmanaged riparian communities; 4) riparian forest management practices and polices; and 5) social and economic factors influencing riparian forest management decisions. **

568. **Raedeke, K.J., R.D. Taber,** and **D.K. Paige.** 1988. Ecology of large mammals in riparian systems of Pacific Northwest forests. *In* Streamside management: riparian wildlife and forestry interactions. K.J. Raedeke (editor). Univ. Wash., Seattle, WA, Contrib. No. 59, pp. 113-132.

Many species of wildlife, including some large mammals, are either considered dependent on riparian habitat or find optimum habitat in these systems. In this review, we relate the ecological needs of large, free-living mammals to characteristics of the riparian environment in order to determine these species' degrees of need and the particular habitat characteristics important in meeting their ecological requirements. The following species are considered to be "large mammals" of potential concern in this context: Virginia opossum, snowshoe hare, Nuttell's and eastern cottontail, mountain beaver, beaver, muskrat, nutria, red fox, grey fox, fisher, mink, striped skunk, western spotted skunk, river otter, bobcat, elk/wapiti, mule/blacktailed deer, white-tailed deer, and moose. Species not listed are either considered "small mammals" treated elsewhere in this volume (Cross 1988), or not considered closely tied to riparian ecosystems. Based on our review of species habitat accounts in the literature, we have evaluated the relative overall importance of riparian habitat in forested environments for each species. Native species considered dependent on riparian areas or that find optimum habitat there are beaver, muskrat, raccoon, mink, river otter, elk, and mule deer. Native species more abundant in riparian areas than in adjacent uplands are snowshoe hare, grizzly bear, western spotted skunk, white-tailed deer, and moose. The introduced Virginia opossum and nutria are also considered riparian species. The other species listed use riparian areas but are as abundant in other habitats. The habitat features of riparian systems found to be of ecological significance to large mammal species were abundance of prey species and carrion, productivity of the shrub/herb layer, early spring phenological development of food plants, reduced snow accumulations in winter, aquatic habitat, and lineal continuity of habitat. Lower-order streams, generally found at higher elevations, were judged less important for large mammals than were mid-order and higher-order streams. Riparian habitat along streams of orders 1 to 3 was found to be insufficient to meet the needs of most large mammals. Lowland riparian, once highly productive wildlife habitat, is now largely modified by human use and less suitable for wildlife.

569. **Raising the profile: threatened, endangered and sensitive species: a communications analysis and strategy**. 1988. U.S. Dep. Agric. For. Serv., Wildl. Fish., Cent. Environ. Study. 29 p.

In May 1988, a TES (Threatened, Endangered, Sensitive) Task Force was created to study ways to enhance the TES effort within the U.S. Forest Sevice. The members of the Task Force identified a number of issues relating to the Forest Service's responsibilities and opportunities to achieve their mandate of species protection and conservation. To elevate the role of the Forest Service and the TES program, the Task Force concluded that communications/marketing and the TES program content and structure needed improvement. This report describes the strategies required to meet the communications needs of the program. **

570. **Raphael, M.G.** 1984. Wildlife populations in relation to stand age and area in Douglas-fir forests of northwestern California. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 259-274.

Preliminary findings are presented from the first year of a 3-year-old study of wildlife populations on 136 plots located within 46 Douglas-fir stands varying from 50 to 350 years old and from 5 to 450 ha in area. Wildlife abundance was estimated using variable circular-plot bird censuses; pitfall traps for small mammals (primarily insectivores), reptiles, and amphibians; live-trap grids for small mammals; baited track-stations for larger mammals; and intensive searches for amphibians. Vegetation and wildlife data were compared among 3 stand age-classes (sawtimber, 150 years; mature, 150-250; and old-growth, 250), and 5 stand size-classes, averaging about 10, 25, 50, 100, and 200 ha.

Vegetation analysis showed significant differences among the 3 age-classes; differences among bird, mammal, and herp communities were less distinct. Based on comparisons of richness and relative abundance of wildlife species, old growth differed from sawtimber but not from mature stands. Density estimates of 17 bird species, 4 salamanders, and 10 mammals were positively correlated with stand age.

An analysis of the effects of stand area showed that more wildlife species were found in larger stands, but this increase could be explained by the greater sampling effort in those stands. Species richness of large stands could be duplicated by combining species found in a random assemblage of 10-ha stands. Some wildlife species were not found in the smallest stands; management for these species cannot rely on retention of only small reserves. I identified 10 species which are more abundant in both older and larger stands. These species should be studied further to determine their true dependency on old growth.

571. **Raphael, M.G.** and **R.H. Barrett.** 1984. Diversity and abundance of wildlife in late successional Douglas-Fir forests. *In* New Forests for a Changing World: Proc. 1983 SAF National Conven. K.A. Sabol (editor). Oct. 16-20, 1983, Portland, OR. Soc. Am. For., Bethesda MA. SAF Publ. 84-03, pp. 34-42.

A preliminary analysis of data gathered over the past 2 years of a 3-year survey of amphibians, reptiles, mammals, and birds in late successional Douglas-fir forests in northwestern California provided the following results. Sampled stands ranged from 55 to 315 years old. Older stands had higher basal areas of Douglas-fir, tanoak and dead trees (snags). Duff depth and downed wood volume were also greater in older stands. Species richness of birds, mammals, and amphibians did not vary significantly among seral stages; however, we found more reptile species in the youngest stage. Total bird abundance was equal among the 3 stages. Amphibians and mammals were most abundant in the oldest stage; reptiles were more abundant in the youngest stage. Of a total of 150 species recorded, the abundance of 15 were positively correlated with stand age; 18 were negatively correlated. Our data indicate that wildlife communities are different among the successional stages we examined. We speculate that elimination of the older stages will result in population declines of those species most strongly associated with them.

572. **Reed, R.D.** 1989. Habitat management: some drainage-wide considerations. *In* Proc. of Watershed '89, Conf. on the Stewardship of Soil, Air, and Water Resources. E.B. Alexander (editor). March 21-23, 1989, Juneau, AK. U.S. Dep. Agric. For. Serv., Alaska Reg., Juneau, AK. R10-MB-77, pp. 3-4.

Watershed planning is critical for adequate protection of fish and wildlife habitat during timber harvesting. Two types of planning are commonly used, watershed-level and stand-level. Both provide unique opportunities for the land manager. Watershed-level provides the greatest flexibility for retention of large areas thus providing options for protection of species sensitive to human disturbance or requiring large home ranges.

Stand-level planning is site-specific, labor intensive and offers probably the best opportunity to integrate timber harvest and fish and wildlife habitat protection in those areas where timber harvest will occur.

573. **Reed, W.J.** 1990. The decision to conserve or harvest old-growth forest. Univ. Victoria, Victoria, BC. Working Pap. 142. 39 p.

The decision as to whether to harvest or conserve old-growth forest is formulated as a stochastic decision problem in continuous time. Uncertainty in future amenity values for standing forest and in future timber revenues for harvested forest are included in the model, along with the risk of catastrophic destruction by fire, pest infestation, etc. It is shown how the decision problem can be expressed as an optimal stopping problem for Brownian motion processes, and the optimal decision rule is shown to depend on how the ratio of current timber value to amenity value compares with some critical level. The effects of changes in uncertainty and other parameters on the optimal rule are discussed. Also it is shown how the cost-benefit analysis and certainty-equivalence procedures lead to premature harvesting. The expected survival time of the forest using the optimal decision rule and other sub-optimal rules is discussed.

574. **Reese, K.P.** and **J.T. Ratti.** 1988. Edge effect: a concept under scrutiny. Trans. N. Am. Wildl. Nat. Res. Conf. 53:127-136.

The concept that edge habitats are beneficial to wildlife populations is a widely held and firmly established maxim in ecology. The term "edge effect" has recently acquired a different connotation than the more traditional meaning. The objective of this paper is to review recent work involving aspects of edge ecology, with particular reference to avian species. These studies are revealing patterns that may change approaches to the management of edge habitats. (From introduction)

575. **Rehfeldt, G.E.** 1989. Ecological adaptations in Douglas-fir (*Pseudotsuga menziesii* var. *glauca*): a synthesis. For. Ecol. Manage. 28:203-215.

Measurements of 3rd-year height of 228 seedling populations, grown in four separate studies in two of the same common gardens, were used to summarize patterns of genetic variation for Douglas-fir across 250 000 km^2 of forested lands in Idaho and Montana, U.S.A. Because each study was conducted in different years with a different set of populations, measurements were transformed to standard deviates and then were scaled according to the performance of populations common between studies. Genetic variation in 3rd-year height was related to the elevation and geographic location of the seed source by a regression model that accounted for 87% of the variance among populations. In addition, 3rd-year height of 169 of the populations was strongly correlated (r=0.80) to freezing injury observed in previous studies. Both variables showed that populations from elevationally or geographically mild sites were tall but had low freezing tolerance. Populations from harsh sites were short and cold-hardy.

In Douglas-fir, adaptation to heterogeneous environments can be viewed as physiological specialization for a relatively small portion of the environmental gradient; populations separated by a relatively short distance along the environmental gradient (e.g., 20 frost-free days) tend to be different genetically.

576. **Rencz, A.N.** and **A.N. Auclair.** 1980. Dimension analysis of various components of black spruce in subarctic lichen woodland. Can. J. For. Res. 10:491-497.

Parabolic and logarithmic regressions were used to relate tree diameter to the biomass of root, root crown, bole, branch, needle, cone, and epiphytic lichens for a sample of 15 *Picea mariana* (Mill) trees occupying lichen woodland in the subarctic of eastern Canada. In 22 of 27 regressions both models yielded r^2 values >0.82. Biomass estimates of total tree and individual component dry weights resulted in estimates with less than 6.5% difference

between biomass estimates by logarithmic versus parabolic equations. For this data set the logarithmic model appeared more appropriate than the parabolic form. Validity of the regressions was judged on r^2, analysis of variance, and examination of residuals. Equations generated in this study were considered to be inapplicable to *P. mariana* growing in closed forest. Problems in extrapolation were discussed.

577. **Rice, R.E.** 1990. The importance of forest inventories to the conservation of biological diversity. *In* Proc. Symp. on State-of-the-Art Methodology of Forest Inventory. July 1990, U.S. Dep. Agric. For. Serv., Pac. NW For. Range Res. Stn., Portland, OR, pp. 467-474.

Conserving biological diversity is becoming an increasingly important focus of national and international concern. The U.S. Forest Service is uniquely situated to contribute to this effort. With 191 million acres in 42 states, the U.S. Virgin Islands, and Puerto Rico, most major ecosystems found in North America are represented somewhere on a national forest or national grassland. In addition, while all federal agencies are bound to protect threatened and endangered species, the Forest Service is alone in having a legal mandate to preserve biological diversity. The agency's inventory and analysis staff could play a particularly important role in advancing this mandate. Adequate inventories are necessary to assess the impact of forest management on biodiversity and to devise and implement effective conservation strategies. To date, however, resource inventories have focused primarily on information of interest to commercial timber production. Current threats to diversity, the implications of failing to counter those threats, and the potential the Forest Service has to contribute to the conservation of diversity, all argue for a prompt and vigorous expansion of the agency's focus. A proposal is made to establish an independent conservation inventory that would emphasize priority species, habitats, and threats to biological diversity.

578. **Riggs, L.A.** 1990. Conserving genetic resources on-site in forest ecosystems. For. Ecol. Manage. 35:45-68.

Genetic diversity and its structure (its organization in space and time) are the critical raw materials from which many other aspects of diversity are derived. These genetic resources represent information about unique and successful relationships among genes and between complexes and environments. Only a fraction of this information has been mined through research. The balance, and the genetic materials themselves, are most effectively conserved for future use by on-site (in-situ) preservation, management, or restoration of populations, communities and entire landscapes.

While we have far to go on the road to understanding biodiversity, research progressing in an array of disciplines offers ample justification to maintain evolved patterns and processes that underlie biodiversity, mediate the efficiency of ecosystem "services", and influence the availability of genetic raw material for bioresource development, restoration, and use. As biotechnologies advance, we will appreciate more fully the true costs of constructing genetic moieties into fully functional organisms, and maintaining populations of these under controlled conditions or combining them in self-perpetuating systems. Intact populations and ecosystems will be ever more valuable sources of the genetic resources and contextual information required for this enterprise.

Three elements are required to realize the values of biodiversity: genetic materials; environments; and information about the functional relationships of the first two. Effective conservation involves uniting these elements. Thorough review of historical, scientific, socioeconomic, and practical information about particular elements of biodiversity is necessary to assess the constraints on and oportunities for conservation activities. The California Gene Resources Program activities from 1980 to 1983 are examples of this kind of undertaking. Computerized information systems can assist managers and researchers in uniting these elements and facilitating both conservation of, and access to, genetic resources. The California Forest Genetic Sources Catalog, a microcomputer database application developed by GENREC for the Wildland Resources Center, is one such application.

Well-constructed databases coupled with knowledge-based decision aids will become indispensable as in-situ preserves and managed areas are integrated with ex-situ collections and research findings into effective genetic-resource conservation systems.

579. **Ritcey, R., D. Low, A. Harestad, R.W. Campbell,** and **A.P. Harcombe.** 1988. Species-habitat relationship models for mammals. Vol. 5. *In* Wildlife habitat handbooks for the Southern Interior Ecoprovince. A. P. Harcombe (technical editor). B.C. Min. Environ. and Min. For., Victoria, BC., Wildl. Hab. Res. WHR-32; Wildl. Rep. No. R-19. 252 p.

This volume provides detailed tabular information on the habitats and habitat complexes used by mammal species of the Southern Interior Ecoprovince. This area covers the south central portion of British Columbia dominated by the three driest biogeoclimatic zones: Interior Douglas Fir, Ponderosa Pine, and Bunchgrass.

Tables are organized by species, then habitat complex. The habitat is further divided into seral stages and the species life requisites are given for each of these stages. **

580. **Ritcey, R., D. Low, R.R. Howie,** and **A.P. Harcombe.** 1988. Species-habitat relationship models for birds. Vol. 6. *In* Wildlife habitat handbooks for the Southern Interior Ecoprovince. A. P. Harcombe (technical editor). B.C. Min. Environ. and Min. For., Victoria, BC. Wildl. Hab. Res. WHR-33; Wildl. Rep. No. R-20. 194 p.

This volume provides detailed tabular information on the habitats and habitat complexes used by bird species of the Southern Interior Ecoprovince. This area covers the south central portion of British Columbia dominated by the three driest biogeoclimatic zones: Interior Douglas Fir, Ponderosa Pine, and Bunchgrass.

Tables are organized by species, then habitat complex. The habitat is further divided into seral stages and the species life requisites are given for each of these stages. **

581. **Roberts, L.** 1988. Hard choices ahead on biodiversity. Science 241(B):1759-1761.

Internationally known ecologist, Thomas Lovejoy, has called for an immediate and massive effort to map the biological diversity of the planet. The goal is to quickly identify areas rich in biodiversity—areas that contain many species or rare species—so that they can be protected. Six or eight taxonomic groups—freshwater fish, for example—would be the focus, and areas of high diversity or high endemism (i.e., areas where there are species found nowhere else) would be located. It would be assumed that these areas would also be areas of high diversity for other freshwater organisms. While there appears to be widespread support for this "quick and dirty" approach, there are some who disagree with the fundamental strategies of conservation. The greatest challenge has come from James Brown of the University of New Mexico who argues that all species need not be saved. **

582. **Robinson, S.K.** 1988. Reappraisal of the costs and benefits of habitat heterogeneity for nongame wildlife. Trans. N. Am. Wildl. Nat. Resour. Conf. 53:145-155.

This paper summarizes the findings of a case history study on the effects of habitat heterogeneity on non-game birds in central Illinois. The goals were to evaluate avian abundance in a variety of upland habitats and to assess the impact of habitat modifications on nongame wildlife. To achieve these goals, data from this study are used to address local community patterns such as species richness and density along a successional gradient and in habitats managed for maximum heterogeneity. Also examined are the effects of habitat heterogeneity on the distribution of habitat specialists, and on reproductive success. Data from bird censuses were compiled to give regional population estimates, especially for rare, patchily distributed species. Capture data supplemented the census data and nest monitoring was conducted. Results on community patterns of breeding birds, the problem of retaining habitat specialists, the problem of interspecific competition, and the problem of local reproductive failure are discussed. The author concludes by offering suggestions for management of non-game wildlife to increase reproductive success, and management of habitat specialists. **

583. **Robison, E.G.** and **R.L. Beschta.** 1990a. Coarse woody debris and channel morphology interactions for undisturbed coastal streams in southeast Alaska, U.S.A. Earth Surface Processes and Landforms 15:149-156.

Coarse woody debris and channel morphology were evaluated for five low-gradient streams that ranged from first to fourth order (0.7 to 55 km^2 watershed area). Debris volumes were directly related to variations in bankfull width. Woody debris was associated with 65 to 75 percent of all pools and the relative proportion of types of pools (ie. plunge, lateral scour, etc.) varied with stream size. High variability in channel depths and widths was common. The results provide benchmark values of woody debris loadings and channel morphology for undisturbed coastal Alaskan stream systems.

584. ——————. 1990b. Identifying trees in riparian areas that can provide coarse woody debris to streams. For. Sci. 36(3):790-801.

The natural fall of trees into mountain streams provides coarse woody debris that can improve fish habitat and influence stream morphology. Geometric and empirical equations, based on tree size and distance from the stream, were used to determine the conditional probability of a tree's adding coarse woody debris to a stream. Additional equations were developed to relate this probability to basal area factor. For conditions in the Pacific Northwest, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) was selected to illustrate how the equations can be used for varying tree sizes and probabilities. After selecting a probability and determining the basal area factor by these equations, resource managers can use prisms or wedge devices before timber harvesting in riparian areas to identify specific trees that can potentially add woody debris to the stream.

585. **Rodway, M.S.** 1990. Status report on the marbled murrelet *Brachyramphus marmoratus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. 59 p.

The Marbled Murrelet (*Brachyramphus marmoratus*) is widespread in nearshore habitat throughout British Columbia. Populations in British Columbia have been reliably censused only in Barkley and Clayoquot sounds on the west coast of Vancouver Island. Overall numbers are unknown. Using those census results and counts from less rigorous surveys, an estimated population of 45,000 breeding birds is suggested. Surveys were conducted seven to 17 years ago and populations may have changed since.

Marbled Murrelets are known to nest on the ground and in trees. Only tree nests have been found south of Alaska. No nests have been found in British Columbia, but available evidence indicates that nesting occurs in old-growth forests within 70 km of the ocean. Characteristics of tree nests observed in Alaska and California indicate specific nest site requirements—broad mossy platforms on large limbs, in a forest with an open crown structure allowing easy access and egress—that are met only in old-growth or older mature forests with suitably sized trees. Reproductive potential is low; sexual maturity is delayed and a maximum of one young is produced per season. Nonbreeders comprise about 15% of the population. Maintaining population structure requires high reproductive success and long-lived adults. Recovery rates from depressed population levels would be slow.

Considering the predicted decline of the species due to loss of nesting habitat from logging, the mortality from gill-net fisheries and increasingly frequent oil spills, and the multiple factors currently impacting the population, it is recommended that Marbled Murrelets be designated a "threatened" species of Canada.

Recommendations highlight the need for information on basic aspects of the species biology, including at-sea distribution, abundance, seasonal movements, breeding distribution, nesting habitat requirements, and foraging ecology. Management options include establishing larger reserves of suitable old-growth forest, modifying forest practices so as to maintain old-growth characteristics, changing gill-net fishing boundaries or timing of fishing openings, enforcing safe oil shipping regulations, and providing effective oil spill clean-up equipment and response. (From author's abstract)

586. **Roemer, H.L., J. Pojar,** and **K.R. Joy.** 1988. Protected old-growth forests in coastal British Columbia. Nat. Areas J. 8(3):146-159.

An account of the old-growth forests in national parks, provincial parks, and provincial ecological reserves is given for coastal British Columbia. The total area of coastal old growth in conservation areas is estimated at 185,600 ha. The largest areas of old growth are located at Strathcona, Tweedsmuir, Naikoon, and Garibaldi provincial parks, in Pacific Rim National Park and in South Moresby National Park Reserve. The most common old-growth forest cover types are redcedar-western hemlock and western hemlock-amabilis fir, followed by other western hemlock combinations. The six major parks and the fourteen major cover types are described. These cover types are discussed in terms of distribution, species make-up, ecology, and representation in parks. There is a great need for information on forest cover in most parks and an urgent requirement for thorough old-growth inventories inside and outside protected areas in British Columbia.

587. **Rolston, H., III.** 1989. Values deep in the woods. Trumpeter 6(2):39-41.

The author discusses a variety of values to be found in the natural forest: endangered species and ecosystems; natural history; life support; forest primeval; scientific study; aesthetics; recreation/creation; character-building opportunities; non-human intrinsic values; and religious values. He notes that these have been considered "soft" values as opposed to the "hard" values of economics. Dollar values have *no* significance in the woods. Compared to economics, he maintains, the above listed values are "deep" values. **

588. **Romme, W.H.** 1982. Fire and landscape diversity in subalpine forests of Yellowstone National Park. Ecol. Monogr. 52(2):199-221.

Fire history was determined by fire scar analysis in a 73-km^2 subalpine watershed in Yellowstone National Park, Wyoming, USA. Evidence was found for 15 fires since 1600, of which 7 were major fires that burned more than 4 ha, destroyed the existing forest, and initiated secondary succession. Most of the upland forest area was burned by large, destructive fires in the middle and late 1700's. Fire frequency in this area is partly controlled by changes in the fuel complex during succession. Fuels capable of supporting a crown fire usually do not develop until a stand is 300-400 yr old, and ignitions prior to that usually extinguish naturally. A destructive crown fire is likely whenever lighting ignites small fuels during warm, dry, windy weather. On the extensive subalpine plateaus of Yellowstone Park a natural fire cycle of 300-400 yrs contributes to fire-free periods and this, rather than human suppression, apparently is the major reason for small number and size of fires in the area during the last 180 years. On the basis of fire history data, the sequence of vegetation mosaics in the last 200 yr was reconstructed for the watershed. Landscape diversity was highest in the early 1800's following the large fires in the 1700's. During a 70 year period when no major fires occurred the landscape was dominated by even-aged forests. Landscape diversity has increased somewhat during the last half-century as a result of two small fires and the effects of the mountain pine beetle. In conclusion, data indicates that at times overall landscape diversity may actually be higher with a fire control policy than with a natural fire regime. At other times, fire significantly increases landscape diversity, as would be expected.

589. **Romme, W.H.** and **D.H. Knight.** 1981. Fire frequency and subalpine forest succession along a topographic gradient in Wyoming. Ecology 62(2):319-326.

Differences in fire frequency and the rate of secondary succession following fire have had a major effect on the present composition of forest vegetation in a 4500-ha undisturbed watershed in the subalpine zone of the Medicine Bow Mountains, southeastern Wyoming, USA. Periodic fire coupled with slow secondary succession has perpetuated lodgepole pine forest on the upland, while mature Engelmann spruce-subalpine fir forests have developed in sheltered ravines and valley bottoms where fire is less frequent and succession following

fire is more rapid and/or more direct. A graphic model is presented showing the relationship between topographic position, fire-free interval, and the occurrence of mature forests dominated by spruce and fir.

590. **Rosenberg, K.V.** and **M.G. Raphael.** 1986. Effects of forest fragmentation on vertebrates in Douglas-fir forests. Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates. J. Verner, M.L. Morrison, and J.C. Ralph (editors). Univ. Wisc. Press, Madison, WI, pp. 263-272.

In this study, most terrestrial vertebrates were inventoried in Douglas-fir (*Pseudotsuga menziesii*) forests in northwestern California during 1981-1983. Using relative abundance or frequency data from 46 forest stands and 136 study plots within those stands, we tested for associations among vertebrate species and seven measures of forest fragmentation, including stand area, insularity, and proximity to adjacent clearcuts or pure hardwood patches. Fragmentation was assessed on three hierarchical scales; plot, stand, and 1000-ha block surrounding each stand. Stands ranged from complete islands (100% insularity) to continuous forest, and half the plots contained some clearcut edge.

Bird and amphibian species richness increased significantly in more fragmented stands and in plots containing more edge. Twenty bird species were detected relatively frequently (10%) along plot edges during variable circular-plot counts, and another 20 species were detected rarely on edges (1%). Partial correlation analyses and analyses of variance among five classes of stand area and insularity indicated that relatively few species exhibited negative responses to forest fragmentation. Those showing greatest sensitivity included fisher (*Martes pennanti*), gray fox (*Urocyon cinereoargenteus*), spotted owl (*Strix occidentalis*), and pileated woodpecker (*Dryocopus pileatus*), with ringtail (*Bassariscus astutus*), northern flying squirrel (*Glaucomys sabrinus*), and Pacific giant salamander (*Dicamptodon ensatus*) also of potential concern.

Recentness of fragmentation in Douglas-fir forests precludes making definite conclusions about species' tolerances, and we will probably see further changes as the break-up of this habitat continues. However, we suggest the incorporation of conservative minimum stand-size characteristics (i.e., 20 ha) into a current working definition of old-growth forest.

591. **Rothacher, J.** 1963. Net precipitation under a Douglas-fir forest. For. Sci. 9(4):423-429.

Under dense stands of old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and associated species typical of Douglas-fir forests of western Oregon and Washington, throughfall averaged 76 percent of gross summer precipitation. Throughfall varied with storm size from near 0 percent in storms under 0.05 inch to about 82 percent in storms over 3 inches. Density of old-growth stands, which ranged from 75 percent to 92 percent, had some influence on interception. However, since estimates of density are not generally available, a relationship based on storm size was determined to be more useful. A linear relation, which fits the data best, explained 96 percent of the variation in throughfall in summer months. Throughfall in winter months increased to an average of about 86.3 percent. A precise relationship with storm size was not determined, but in storms producing 8 inches or more gross precipitation, throughfall was estimated to approach 96 percent. Stemflow was relatively unimportant for nearly all species. Weighted average stemflow measured in the 1959-60 water year was only slightly more than 0.27 percent of the total precipitation.

592. **Rothacher, J., C.T. Dyrness,** and **R.L. Fredricksen.** 1967. Hydrologic and related characters of three small watersheds in the Oregon Cascades. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. PNW-36. 35 p.

Data collected from three small, undisturbed watersheds in the Douglas-fir region on the western slopes of the Oregon Cascade Range will provide the basis for determining changes that occur as the result of planned logging. These drainages, ranging from 149 to 250 acres,

are representative of rough, mountainous topography in the western Cascades. Temperature and rainfall are typical of a maritime climate with wet, relatively mild winters and dry, cool summers. A mean annual precipitation of 90 inches produces an average annual streamflow of 50-57 inches. Streamflow after peak storms may be over 1 800 times the low summer flow. In spite of a heavy stand of timber, soil moisture remains above wilting point throughout the summer.

Dense vegetation and a relatively stable soil combine to give water of high purity. Sedimentation occurs in a cyclical manner both on an annual and on a storm basis. Under undisturbed forest conditions, even storms exceeding 135 cubic feet per second per square mile seldom produce more than 200 parts per million of suspended sediment. Sediment load peaks rapidly during storms and recedes soon afterwards to modest concentrations. Concentrations exceeding 10 parts per million occur for only 1 to 2 percent of the time during a typical winter. Chemical content of the water is low, reflecting the igneous bedrock. Total dissolved solids range from 20 to 120 parts per million. Bicarbonate makes up over half of the solute load. Calcium, silica, and sodium make up another 41 percent. In an average year, about 160 tons of chemicals per square mile of drainage are carried by streamflow from these watersheds. Water temperature reflects the seasonal variation in air temperature and has reached a maximum of only 64° F. (Author's summary)

593. **Rowe, J. S.** 1972. Forest regions of Canada. Dep. Environ., Can. For. Serv., Ottawa, ON. Publ. No. 1300.

Forest Regions of Canada provides a general description of the forest geography of this land, from the east to west coasts and from the USA borders to the arctic and alpine tundra. Previous editions were those of 1937 when W.E.D. Halliday published "A Forest Classification for Canada" and of 1959 when the title "Forest Regions" was adopted and the map refined to its present form.

In this latest edition, a new text supersedes that of 1959 although the map is unchanged. The revision is not a major one; it updates available information and corrects certain inaccuracies of the earlier editions. Increased ecological knowledge has refined many of the areal descriptions, while taxonomic studies have introduced a number of new tree names.

As in previous editions, descriptive data on soils, geology and climate are included in text and appendices. Maps have been added to this material showing aspects of climate and physiography which have particular ecological relevance to Canadian forest types and their distributions. (From author's foreword)

594. **Rudolph, S.G.** 1990. Ancient forests as genetic reserves for forestry. *In* Ancient forests of the Pacific Northwest. E.A. Norse (editor). The Wilderness Soc., Washington, DC, pp. 129-132.

The temperate forests of western North America are not impoverished of biological diversity, but rather are a wellspring of diversity within species. This genetic variation confers adaptation to local conditions such as topography, microclimate, and competition. It is also valuable in defense against pests and pathogens, as well as in allowing for continued evolution in response to changing conditions. Current forestry practices are reducing this diversity both within and among populations. The best way to conserve genetic variability is through *in-situ* preservation—reserves or seed production areas. Old-growth "virgin" stands are the first priority for preservation because they contain the most useful genetic variation. Ancient forests, and the genetic resources they represent, are irreplaceable. Preserving these forests may be the only way to preserve our forests and timber industries in an economically and ecologically uncertain future. **

595. **Ruggiero, L.F.** 1989a. Dependence and persistence: two keys unlocking our understanding of habitat needs. For. Watch 10(5):15-19.

Casual use of the word dependency by the press, particularly in political debate over wildlife and old growth, has led to some confusion about wildlife habitat relationships. This article discusses and defines two terms (dependence and persistence) important to the understanding of the habitat needs required for maintaining biological diversity. The issues surrounding the Northern Spotted Owl are discussed as example. The author concludes that, although we have identified species that are closely associated with old growth, additional research is needed before precise recommendations for the management of these species can be made. It is also important to consider the requirements for populations to persist over time, and it is here that it becomes crucial to recognize the difference between existence and persistence. The author also briefly discusses the role that late-successional forests play in meeting ecological needs of wildlife. **

596. ——————. 1989b. Old-growth Douglas-fir forests: wildlife communities and habitat relationships. For. Plan. Can. 5(5):18-21.

Highlights are presented from the "Old-Growth Douglas-fir Forests: Wildlife Communities and Habitat Relationships" symposium, March 29-31, 1989, Portland, Oregon. The focus is the issue of maintaining biological diversity, recognizing the difference between existence and persistence, and maintaining ecotypes. Papers also address the issue of managed versus natural forest landscapes; all the stages of forest development that are beyond (industrial) rotation; and the role that late successional forests play in meeting the ecological needs of wildlife. **

597. ——————. 1990. Directions in old-growth research, the wildlife component. For. Plan. Can. 6(1):39-40.

This paper is taken from a research proposal submitted by Leonard Ruggiero in 1985 to study wildlife habitat relationships in western Washington and Oregon west of the Cascades and in ecologically similar areas in Alaska and northern California. Justification of the proposal lies primarily in the legal mandate to maintain viable populations of wildlife species within the National Forests. This mandate, along with the increasing pressure to harvest what remains of the old-growth forests, necessitates long term research on the species-habitat relationships of those species dependent upon late stages of forest development. These studies should include the validity and extent of the habitat dependency, conservation status of the species, population dynamics, and species response to habitat fragmentation and current forestry practices. Models of population viability must be developed before the species habitat research can be incorporated into management strategies. The author concludes that these studies will be used to assist in the evaluation and use of management indicator species.

598. **Ruggiero, L.F.** and **A.B. Carey.** 1984. A programmatic approach to the study of old-growth forest — wildlife relationships. *In* New Forests for a Changing World: Proc. 1983 SAF National Conven. K.A. Sabol (editor). Oct. 16-20, 1983, Portland, OR. Soc. Am. For., Bethesda, MD. SAF Pub. 84-03, pp. 341-347.

The USDA Forest Service's Old-Growth Forest Wildlife Habitat Research and Development Program was chartered to develop information that would help managers comply with the National Forest Management Act. The focus is on Pacific Northwest Douglas-fir old-growth forests (west of the Cascade Range from Canada to California) — their uniqueness, contribution to ecological diversity, and value to wildlife. The research approach consists of geographic stratification by five physiographic provinces with replicated community studies covering a broad range of moisture, temperature, and seral stages within each province. Ecological relationships evident from community studies will form the basis for species-specific studies wherein specific hypotheses will be tested and mechanisms of association elucidated. Studies of forest fragmentation will be integrated with other results to formulate recommendations for managing viable populations of plants and animals.

599. **Ruggiero, L.F., R.S. Holthausen, B.G. Marcot, K.B. Aubry, J.W. Thomas,** and **E.C. Meslow.** 1988. Ecological dependency: the concept and its implications for research and management. Trans. N. Am. Wildl. Nat. Res. Conf. 53:115-126.

These authors cover many aspects related to the application of ecological principles to wildlife management. Recently, more and more non-game species have been included in this management. The focus of the paper is on the definition of biological needs or requirements of a species. The term "ecological dependency" was coined to stress the dynamic and interactive nature of the concept in both space and time. Also, questions about dependency must address population attributes and not individual attributes. The paper goes on to discuss the importance of explicit delineation of distinct ecotypes and cautions the limitations of experimental design and interpretation. The preference versus need question is then addressed. "What specific elements of old growth are necessary to maintain a particular species and can these elements be provided in young forests?" The authors conclude that, whenever possible, consideration should be given to population performance across the full range of available environments, and this should be evaluated in conjunction with measures of habitat preference. **

600. **Runkle, J.R.** 1981. Gap regeneration in some old-growth forests of the eastern United States. Ecology 62(4):1041-1051.

Tree replacement in gaps was studied in old-growth mesic forest stands in western Pennsylvania, Ohio, and the southern Appalachian Mountains. Predictions of future overstory composition, based on sapling composition in small gaps (average 200 m^2), were compared to current canopy composition. Both Markov analyses and simple average sapling composition of gaps support the hypothesis that regeneration in small gaps was sufficient to perpetuate the current canopy species composition of the stands studied. In some cases the saplings most likely to replace a dead canopy tree were of the same species. In other cases, especially low-diversity beech - sugar maple stands, each species seemed to enhance significantly the success of the other species.

601. ————. 1985. Disturbance regimes in temperate forests. *In* The ecology of natural disturbance and patch dynamics. S.T.A. White and P.S. Pickett (editors). Academic Press, Inc., Toronto, ON, pp. 17-34.

The author defines a disturbance regime as the characterization of "the pattern of death of the dominant individuals (canopy trees) in a community." The components of a disturbance regime for forests are: 1) average disturbance rates; 2) distribution of disturbance in space; 3) distribution of disturbance in time; 4) severity of disturbance; 5) rates of recovery from disturbance; and 6) the multiple-gap episodes. Natural disturbance regimes are described for two specific temperate forests of the Southern Appalachians and the Allegheny Plateau, Pennsylvania. These natural disturbance regimes are then compared to artificial disturbance regimes, such as clearcutting and selection felling. **

602. **Sadoway, K.L.** 1988. Effects of intensive forest management on breeding birds of Vancouver Island: problem analysis. B.C. Min. For. Lands and Min. Environ. Parks, Victoria, BC. IWIFR-25. 148 p.

The purpose of this report is to identify research questions and priorities regarding the habitat requirements and the effects of intensive forest management on the non-ungulate wildlife of Vancouver Island. (From author's introduction)

603. **Salo, E.O.** and **T.W. Cundy.** 1987. Streamside management: forestry and fishery interactions. Univ. Wash., Seattle, WA. Contrib. No. 57. 471 p.

This publication contains proceedings of the symposium, "Streamside Management: Forestry and Fishery Interactions" held at the University of Washington in 1986. One of the main purposes of the symposium and the publication was to inform both the forestry and the fishery communities of the extent and limit of each other's knowledge. The 15 papers contained in this publication are divided into three topics: 1) variables related to fish habitat; 2) forest management of the streamside zone; and 3) case studies showing effects of timber harvest on fishery resources. In addition, transcripts of three of the symposium's panel discussions are included. These panel discussions deal with economic and social considerations of forestry and fishery management, the best management practices in streamside zone, and the policy perspective of streamside management. **

604. **Salwasser, H.** 1990. Conserving biological diversity: a perspective on scope and approaches. For. Ecol. Manage. 35:79-90.

Biological diversity is the variety of life. It encompasses the spectrum of biological organization from gene to biomes, and the spectrum of geographic locations from microsites to the biosphere. Significant losses of biological diversity could affect the future well-being of human life. Extinction of species and simplification of ecosystems diminish future resource options and the ability of natural areas to provide life-supporting ecological services.

Major factors that affect biological diversity include conversion of wild areas to agriculture, industry, and other human uses; toxics, pollution, and global climate change; overuse of species by humans; fragmentation of habitats and populations; restoration of species and ecosystems; and management of wild areas for sustainable use of natural resources. The last two factors are useful in countering the potential negative effects of the others.

Reasons for conserving as much of the variety of life as possible include its intrinsic values and its roles in providing current and future resources and in overall environmental quality. Biological diversity, however, is so complex and intangible that its conservation cannot be approached without focusing on specific elements and processes, principal among which are populations of species, communities, ecosystems, and biomes.

In the setting of goals for biological diversity we must address specific, achievable objectives for the principal elements of concern in an area. Those goals must be integrated in three major ways. First, they must be integrated into overall conservation plans of public-resource management agencies and private-sector organizations which collectively determine ecological conditions and trends in the area. Obviously, those plans must also be coordinated among the agencies, and the needs of people must be taken into consideration. Second, goals and actions must be integrated up and down geographic scales so that actions taken at individual sites or stands contribute to goals for watershed conditions, which are in turn part of a regional landscape that both sustains the variety of life and meets human resource needs. And third, goals and actions must integrate across the biological spectrum of genetic resources, species, communities, ecosystems, and biomes. This increased need for integration and coordination is a daunting challenge that is fraught with scientific, technological, and political barriers and uncertainties. Nevertheless, it must be done, and soon.

The USDA Forest Service is working to refine its roles in an evolving national strategy for conserving biological diversity. This is occurring through individual forest plans, major resource programs, research priorities, public dialogue on policies and priorities, and domestic and international cooperative assistance.

605. **Salwasser, H., S.P. Mealey,** and **K. Johnson.** 1984. Wildlife population viability: a question of risk. Trans. N. Am. Wildl. Nat. Resour. Conf. 49:421-439.

This paper discusses how the U.S. Forest Service interprets the requirement to maintain viable populations of all vertebrates on national forests and grasslands, and reviews biological concepts presently in use to plan habitat management to meet the requirement. The main purpose of this paper is to present a process for using empirical knowledge and ecological theories to plan and manage habitats, and to design a monitoring system that reflects the risk that alternative amounts and distributions of habitat will fail to provide for population viability of a given species. This process is illustrated by the case of the spotted

owls of Willamette National Forest in Oregon, and is presented as six steps. It emphasizes the use of factual information to develop a land use plan, as well as of the theories and concepts needed to assess the level of protection that would be provided by the plan. The authors believe that this process is responsive to the "save all the parts" land ethic, yet provides managers with the flexibility to reach other resource goals. **

606. **Salwasser, H., K. Siderits, and H.L. Holbrook.** 1984. Applying species-habitat relationships in managing for national forest wildlife diversity. *In* Proc. Workshop on Natural Diversity in Forest Ecosystems. J.L. Cooley and J.H. Cooley (editors). Nov. 29-Dec. 1, 1982, Athens, GA. Inst. Ecol., Univ. Georgia, Athens, GA, pp. 173-181.

Many of the concepts useful in managing national forests for wildlife diversity were well known as early as the 1930s. Recently, the featured species and species richness approaches have been melded into a comprehensive habitat approach to managing for wildlife diversity (i.e., species and community richness, abundances, and patterns). The Forest Service is continuing development of its Wildlife and Fish Habitat Relationship program to support information needs for managing all wildlife and fish habitats. National forest plans, being developed as a result of the National Forest Management Act of 1976, are the principal "testing ground" for use of new analytical tools and concepts.

607. **Salwasser, H.** and **J.C. Tappeiner, II.** 1981. An ecosystem approach to integrated timber and wildlife habitat management. Trans. N. Am. Wildl. Nat. Resour. Conf. 46:473-487.

This paper discusses four aspects of the integration of wildlife habitat needs with timber management: 1) philosophies and laws; 2) historical approaches; 3) application at the field level; and 4) thoughts about the realities of ecosystem management. Recent shifts in how society values resources have led to increased emphasis on multiple resource management at the ecosystem level. Review of historical approaches resulted in the development of six principles of wildlife integration with timber management. Principles concerning management areas, resource goals, habitat criteria, activity scheduling, stand prescriptions, and monitoring and revisions of management goals are outlined. The authors conclude that the key goal in implementing large scale plans in ecosystem management, is to maintain future options while meeting current objectives. **

608. **Salwasser, H., J.W. Thomas,** and **F. Samson.** 1984. Applying the diversity concept to national forest management. *In* Proc. Symp. on Natural Diversity in Forest Ecosystems. J.L. Cooley and J.H. Cooley (editors). Nov. 29-Dec. 1, 1982, Athens, GA. Inst. Ecol., Univ. Georgia, Athens, GA, pp. 60-69.

Diversity in national forest management is related to Aldo Leopold's land ethic. It encompasses attention on the effects of decisions at all levels, from national and regional land allocations and resource goals to specific objectives of a stand management prescription. Diversity is a relative term, most useful when the variety, relative abundance, and pattern of biotic elements in resource ecosystems are compared among alternatives or to prior conditions. It is least useful when considered as an abstract index without regard to tangible "things." The actual diversity of a national forest will be determined by the combination of habitat standards for viable populations of vertebrates, habitat objectives for selected wildlife, and objectives for all other resources. Straightforward displays, maps, graphs, and tables of future forest diversity conditions are urged.

609. **Samson, F.B., P. Alaback, J. Christner, T. DeMeo, A. Doyle, J. Martin, J. McKibben, M. Orme, L. Suring, K. Thompson,** and **B.G. Wilson.** 1989. Conservation of rain forests in southeast Alaska: report of a working group. Trans. N. Am. Wildl. Nat. Res. Conf. 54:121-133.

This paper summarizes concepts developed for the long-term management of North American rain forests and considers the recent landscape emphasis in the conservation of biological diversity. The approach taken by the researchers was to: 1) provide a working

definition of old-growth forests in southeast Alaska; 2) identify provinces based on geographic factors that affect old-growth habitat types; and 3) make recommendations for size, shape, and distribution of timber harvest to maintain old growth and breeding populations of wildlife, and to enhance biological diversity on intensively managed lands. Islands of southeast Alaska are given special consideration. **

610. **Samson, F.B.** and **F.L. Knopf.** 1982. In search of a diversity ethic for wildlife management. Trans. N. Am. Wildl. Nat. Resour. Conf. 47:421-431.

This paper discusses the importance of the concept of diversity in formulating principles of wildlife management and reviews the beta and gamma diversity measures with the objective of incorporating them into the comprehensive planning process in resource management. Two criteria are used in the review of these diversity measures: 1) the ecological, geographical, and organizational level of resolution; and 2) the current, long-range, and biotic usefulness of each measure of diversity. Thus, emphasis is placed on the use of diversity in management situations rather than in a theoretical or mathematical framework.

The authors conclude by proposing a methodology for future wildlife management, based on current ecological knowledge within the context of the three levels of diversity. The three main features are: 1) to minimize practices promoting site-specific diversity; 2) to emphasize between-habitat diversity at the management unit level; and 3) to implement a "top down" or gamma-beta-alpha diversity approach at the regional/national decision-making levels. **

611. **Santantonio, D., R.K. Hermann,** and **W.S. Overton.** 1977. Root biomass studies in forest ecosystems. Pedobiologia :1-31.

A root-biomass study was conducted in an old-growth stand of conifers in the western Cascade Mountains of Oregon. The root systems of three Douglas-firs with diameters at breast height of 94, 110, and 135 cm were excavated and weighed to provide a basis for regression equations for estimating the biomass of roots larger than 10 mm in diameter. Biomass of roots less than 10 mm in diameter was estimated from soil cores taken within the stand. The design for sampling small roots was specifically developed to cope with the problems of sampling in old-growth stands. Total root biomass was estimated as 209 t/ha. Nutrient analyses of root samples provided estimates of the nutrient capital contained in the roots of an old-growth stand. The fairly consistent relation of root-system biomass to stem diameter at breast height for trees between 10 and 50 cm breast height appears also to hold for old-growth Douglas-fir. (Authors' summary)

612. **Sargent, N.E.** 1988. Redistribution of the Canadian boreal forest under a warmed climate. Climatolog. Bull. 22(3):23-34.

A scenario of climate under atmospheric CO_2 levels double those of the present is used to derive a scenario of corresponding changes in the distribution of boreal forest in Canada. Box's model of the response of vegetation to climate is used to obtain more credible results than those obtained by earlier authors using Holdridge's scheme. It appears that the area climatically suitable for boreal forest would advance by 0.7×10^8 ha north of its northern edge and retreat 1.7×10^8 ha north of its southern edge.

613. **Satterlund, D.R.** and **H.F. Haupt.** 1967. Snow catch by conifer crowns. Water Resour. Res. 3:1035-1039.

Trees were continuously weighed during snow storms to measure snow catch. Graphing snow catch vs snowfall gave a uniform sigmoid form. A general equation for snow catch is given, based on the Lotka growth function. The first snowflakes fall through the branches and needles; only a few adhere, giving a low growth rate. As snow bridges across needles develop, more and more snow is caught on the ever-growing platforms. The catch rate therefore increases until heavy snow loads cannot be borne, and the excess slides off. The

size, form, and wetness of the snowflakes determine the catch rate; the form, surface area, and strength of branches determine the ultimate snow load. This process is fundamentally different than rain interception. **

614. **Scheffer, T.C.** and **E.B. Cowling.** 1966. Natural resistance of wood to microbial deterioration. Ann. Rev. Phytopath. 4:147-170.

A thorough review of the natural resistance of wood to microbial deterioration is presented. The main organisms involved in wood deterioration are: fungi that destroy all wall substances; wood-staining fungi and molds; and bacteria that degrade parenchyma cells. Resistance of wood to decay varies according to tree species, to genetic differences among trees of the same species, and to location of wood within an individual tree. Toxic extractable substances deposited during formation of the heartwood are the main source of decay resistance in wood. These substances are mostly phenols, tannins, and terpenoids. It is believed that these substances inhibit the enzymatic and oxidative-phosphorulative activities by which fungi, molds, and microbes break down wood. Other decay-resistant properties of wood, such as the presense of lignin, the crystallinity of cellulose, and the low N content of wood, are also described. **

615. **Schmidt, R.L.** 1970. A history of pre-settlement fires on Vancouver Island as determined from Douglas-fir ages. *In* Tree Ring Analysis With Special Reference to Northwest America: Proc. of a Conf. on Biology of Tree-Ring Formation, Methods of Measurement of Tree-Rings, Methods of Analysis, and Uses of Tree-Ring Data, February 19 and 20, 1970. J.H.G. Smith and J. Worrall (editors). Univ. B.C., Fac. For., Vancouver, BC. Bull. No. 7, pp. 107-108.

Results of the study indicated a series of major fires which occurred 150, 230, 310, 360, 410, 560, 760, and 870 years ago. It is thought that the fires which occurred 150, 310, and 410 years also covered much of the area now dominated by Douglas-fir along Vancouver Island's coast. The fires 310 and 410 years ago probably covered as much as 2 million acres on Vancouver Island. The forests from these age-classes are also well represented on the B.C. mainland and in the United States. **

616. **Schoen, J.W.** 1990. Bear habitat management: a review and future perspective. Int. Conf. Bear Res. Manage. 8:143-154.

Throughout the world, bears are declining in numbers and range as habitat is reduced and bear-human interactions increase. Although ursids are widely distributed and inhabit a variety of habitats, they possess a number of biological characteristics that make them particularly vulnerable to conflict with humans. The habitat concept is discussed relative to the unique characteristics of bears. Because bears are wide-ranging species of landscapes, habitat relationships must be evaluated on a broader context than habitat types per se. Human activities and land uses must be factored into bear habitat relationships. Forest clearing and road building, in particular, are common problems for the conservation and management of many bear populations. An understanding of the processes of habitat fragmentation and population extinction is necessary for maintaining viable bear populations in the face of increasing habitat destruction and isolation. Several management tools and research needs for bear habitat management are discussed.

617. **Schoen, J.W.** and **M.D. Kirchhoff.** 1990. Seasonal habitat use by Sitka black-tailed deer on Admiralty Island, Alaska. J. Wildl. Manage. 54(3):371-378.

We measured seasonal habitat use by 30 radio-collared Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) on northern Admiralty Island in southeastern Alaska from February 1979 to July 1982. Habitat use varied seasonally as deer moved from low-elevation (<300 m), heavily forested winter ranges to higher elevation (>600 m) summer ranges in open canopy subalpine and alpine habitats. Deer used old-growth forest almost exclusively during winter and spring, and high-volume old growth (>74 mbf/ha) was used in much greater

proportion than its abundance. To minimize the impacts of timber harvesting on deer populations, emphasis should be placed on maintaining stands of high-volume old growth on low-elevation deer winter ranges.

618. **Schoen, J.W., M.D. Kirchhoff,** and **J.H. Hughes.** 1988. Wildlife and old-growth forests in southeastern Alaska. Nat. Areas J.8(3):138-145.

The archipelago and coastal mainland that comprise southeastern Alaska include millions of hectares of old-growth forest, most of which is administered by the U.S. Forest Service. This old-growth forest includes a mosaic of different stand types that vary in form, function, and value to different species of wildlife. Certain types of old growth, particularly low elevation, high-volume stands (productive sites with large trees), are rare in the national forest and are heavily used by numerous wildlife species including the Sitka black-tailed deer (*Odocoileus hemionus sitkensis*), brown bear (*Ursus arctos*), and bald eagle (*Haliaeetus leucocephalus*). Scheduled clearcut logging of old-growth timber on the Tongass National Forest will not affect a large percentage of the land area but will have significant and long-lasting effects on our inventory of certain old-growth types and their associated wildlife species. Old growth should be recognized as a diverse and complex mosaic of forest types. Maintenance of adequate populations of many wildlife species in southeastern Alaska will require maintaining the natural diversity of forest types that comprise the old-growth ecosystem.

619. **Schoen, J.W., M.D. Kirchhoff,** and **O.C. Wallmo.** 1984. Sitka black-tailed deer/old-growth relationships in southeast Alaska: implications for management. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 315-319.

Population levels of Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) are expected to decline as harvest of old-growth forests in southeast Alaska proceeds. The extent of this decline will vary in accordance with the quantity and quality of old-growth harvested. Old growth in southeast Alaska is likened to a fine-grained mosaic of habitat patches that deer utilize selectively - seasonally and annually. Impacts of timber harvesting on long-range carrying capacity for deer and other wildlife in southeast Alaska will be difficult to assess until wildlife old-growth habitat relationships are better understood. This paper reviews the relationship of deer to forest habitat in southeast Alaska and outlines current forest-management practices. Two approaches for allocation of old growth as deer habitat are compared: (1) allocation by stand, and (2) allocation by watershed. We conclude that allocation by watershed is the more appropriate management approach in southeast Alaska.

620. **Schoen, J.W., O.C. Wallmo,** and **M.D. Kirchhoff.** 1981. Wildlife-forest relationships: is a reevaluation of old growth necessary? Trans. N. Am. Wildl. Nat. Resour. Conf. 46:531-544.

The authors discuss the historical background to the claim that "good timber management is good wildlife management." Using white-tailed deer as an example, they point out the errors in this historical old-growth - wildlife relationship, concluding that "old-growth" was inadequately defined and may well have been confused with mature even-age second-growth. Under this definition, "old-growth" could well be seen as low in biotic diversity. The authors briefly describe some current work on old-growth - wildlife relationships again using deer as an example. Birds and mammals dependent on old growth are also discussed. They emphasize the need to maintain habitat diversity to provide for biotic diversity, and end with a plea for more and continued research. **

621. **Schoenberger, M.M.** and **D.A. Perry.** 1982. The effect of soil disturbance on growth and ectomycorrhizae of Douglas-fir and western hemlock seedlings: a greenhouse bioassay. Can. J. For. Res. 12:343-353.

In a greenhouse bioassay of soils from the central Oregon Cascades, Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) seedlings had the most total and ectomycorrhizal root tips when grown in soil from an unburned clear-cut and the least when grown in soil from (i) a 20-year plantation that had been clear-cut and burned in the late 1950's and (ii) one old-growth forest. Tip formation was intermediate in soil from a second old-growth forest, a recently burned clear-cut, and a 40-year-old natural burn. Root weights followed the same trend, but top weights did not differ among the various soils. Ectomycorrhizal and total root tips of western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) were lowest in soils from the plantation and recently burned clear-cut. Unlike Douglas-fir, western hemlock's tip production was not greater in the unburned clear-cut than in the old-growth forest soils. In this species, both top and root weights varied according to soil, with the largest seedlings produced in soil from the unburned clear-cut. With both species, there was a significant interaction between ectomycorrhizal type and soil type. *Cenococcum geophilum* Fr. predominated on western hemlock and was reduced in soils from the burned clear-cut and plantation. In comparison with the mean for all soils, ectomycorrhizal types that predominated on Douglas-fir were enhanced in the unburned clear-cut soil and reduced in one old-growth soil, an effect apparently related to litter leachate.

622. **Schoenwald-Cox, C.M.** and **J.W. Bayless.** 1986. The boundary model: a geographical analysis of design and conservation of nature reserves. Biol. Conserv. 38:305-322.

It is widely recognised that nearly all parks and reserves are too small to protect their biological diversity. In response to this problem, we have been developing a multidisciplinary "boundary model" that focuses upon the processes of exchange across the administrative edges of nature reserves. The model incorporates known dynamics from various disciplines and describes the interactions of these forces across the boundary. These disciplines include biogeograpy, ecology, and human effects, influences and attitudes in an understanding of reserve boundary vulnerability and effectiveness. The boundary model recognises the development of edges in association with the establishment of the administrative boundary. However, it discerns between "natural" and "generated" edges that are based upon the differing stimuli for their development and change. Segmentation of the boundary is recognised as a manifestation of environmental heterogeneity. The boundary model suggests that exposure of the reserve is a major determinate of potential vulnerability. Effectiveness of reserve protection is hypothesised to be more dependent upon what crosses the boundary than upon any internal processes alone.

623. **Schoonmaker, P.** and **A. McKee.** 1988. Species composition and diversity during secondary succession of coniferous forests in the Western Cascade Mountains of Oregon USA. For. Sci. 34(4):960-979.

Species diversity and community composition were studied at 23 sites on similar western hemlock/Douglas-fir forest habitats, in undisturbed old-growth stands and stands at 2, 5, 10, 15, 20, 30, and 40 years after clearcutting, broadcast burning, and planting with Douglas-fir. Vegetation was sampled with three 5 x 60 m transects at each site. Invading herbs, then invading and residual shrubs, and finally conifers dominated through the first 30 years. Late seral species, which account for 99% of cover in old-growth stands, are nearly eliminated immediately following disturbance, but account for almost 40% of vegetative cover after 5 years, 66% after 10 years, 83% after 20 years, and 97% at 40 years. After an initial drop following disturbance, species diversity trends weakly upward with heterogeneity peaking at 15 years and richness at 20 years. This initially high diversity (higher than that of old-growth stands) is short-lived. After the tree canopy closes, species diversity declines reaching its lowest values at 40 years. Only two species were eradicated after disturbance, both mycotrophs. Pacific Northwest old-growth forests are relatively poor in species, but moderately high in heterogeneity values.

624. **Schowalter, T.D.** 1985. Adaptations of insects to disturbance. *In* The ecology of natural disturbance and patch dynamics. S.T.A. Pickett and P.S. White (editors). Academic Press, Inc., Toronto, ON, pp. 235-252.

Insects adapt to a heterogeneous environment through the mechanisms of host selection and dispersal. Condition and structure of vegetation and litter influence the host selection and dispersal methods. Disturbance within a community is reflected in insects' response to changes in host chemistry and abundance. Significant community disturbances can generate equally significant disturbances in insect populations and behavior, and these disturbances can result in extensive damage to local vegetation while creating a situation predisposed to suffer other types of disturbance.

The ability of insects to respond to changing conditions within patches contributes to the individual's fitness, and also appears to stabilize the productivity of the ecosystem in two ways. First, insect behavior which results in changes in species/biomass relations and/or plant age structure can regulate plant-soil nutrient-light relations. Second, the impact of a disturbance can be mitigated by the reliability of insect behavior in a natural ecosystem. The role of insects in regulating the frequency and severity of disturbances supports the view that natural ecosystems are cybernetic systems with inherent mechanisms by which ecosystem productivity is stabilized. **

625. ————————. 1988a. Insects and old growth. For. Plan. Can. 5(4):5-7.

The author discusses the maintenance of insect diversity as a possible insurance (using predatory insects and spiders) against pest hazards in managed forests. **

626. ————————. 1988b. Pest response to simplification of forest landscapes. N.W. Environ. J. 4(2):342-343.

Changes in forest landscapes influence pest population dynamics and site productivity. The ability of potential pests to find and exploit suitable resources is affected by changes in landscape patterns such as patch size, intersection by corridors, and variety of stand types and ages. Old-growth forests, with their complex array of tree and predator species, large stand size, and high age class diversity, are less conducive to pest outbreaks than are simplified forests created through current harvest and regeneration practices. Roads provide access to the forest for a number of potential pests, including Port Orford cedar root rot, blackstain root disease, gypsy moth and spotted knapweed. Planting a single tree species eliminates predators and physical barriers to dispersing pests, such as aphids and bark beetles. The potential for future insect and disease acitivity, and changes in markets for different tree species, favors diverse stands over monocultures. Future site productivity depends, in part, on how landscaping pattern affects pest epidemiology. **

627. ————————. 1989. Canopy arthropod community structure and herbivory in old-growth and regenerating forests in western Oregon. Can. J. For. Res. 19:318-322.

This paper describes differences in canopy arthropod community structure and herbivory between old-growth and regenerating coniferous forests at the H.J. Andrews Experimental Forest in western Oregon. Species diversity and functional diversity were much higher in canopies of old-growth trees compared with those of young trees. Aphid biomass in young stands was elevated an order of magnitude over biomass in old-growth stands. This study indicated a shift in the defoliator/sap-sucker ratio resulting from forest conversion, as have earlier studies at Coweeta Hydrologic Laboratory, North Carolina. These data indicated that the taxonomically distinct western coniferous and eastern deciduous forests show similar trends in functional organization of their canopy arthropod communities.

628. **Schowalter, T.D., W.W. Hargrove,** and **D.A. Crossley, Jr.** 1986. Herbivory in forested ecosystems. Ann. Rev. Entomol. 31:177-196.

The study of plant/insect relationships is in its infancy, yet it is already clear that valid generalizations will be rare. Problems of scale, previous history, specificity of response, separation of cause and effect, and confounding variables plague those who would characterize plant/herbivore interactions. In forested ecosystems, practical problems of canopy access and random sampling in the heterogeneous volume represented by the canopy confound experimental design. Short- and long-term responses to herbivory can be very different, even opposite.

A need for carefully designed, critical, long-term manipulative experiments is obvious. Searching for single-factor explanations will often be futile. Even if one factor is largely causal, this may be extremely difficult to establish unambiguously. Classical scientific method, where all variables but one are held constant, is clearly impossible in most instances. New emphasis on multivariate, factorial, and discriminant techniques may prove more profitable.

Despite these problems, undeniable progress has been made toward understanding herbivory in forested systems. The less-restrictive perception of herbivore/plant interaction as a mutualistic non-zero-sum game (*sensu* Axelrod) represents one example of such progress, as does the viewpoint that considers plants as heterogeneous resources in time and space. We anticipate that future research will continue to provide stimulating results. (From author's summary)

629. **Scott, J.M., B. Csuti, J.E. Estes, K. Smith,** and **S. Caicco.** 1988. Beyond endangered species: an integrated conservation strategy for the preservation of biological diversity. Endangered Species UPDATE 5(10):43-48.

The authors argue that focusing conservation efforts on protecting critically endangered species is neither efficient nor cost-effective. While recognizing that programs to protect such species must not be abandoned, the authors recommend a conservation program based on protecting intact, functioning ecosystems. Such an approach, they argue, will save more species in the long run. They stress that "gaps" in the conservation safety net must be identified (gap analysis). To find these gaps, the authors recommend an approach that analyzes reserves with respect to vegetation types and species richness. Data on species distribution, centers of species richness, centers of endemism, vegetation types, and land-ownership boundaries can be combined through GIS to provide an idea of "gaps" in the existing natural reserve system. **

630. **Scott, J.M., B. Csuti, J.D. Jacobi,** and **J.E. Estes.** 1987. Species richness: a geographic approach to protecting future biological diversity. BioScience 37(11):782-788.

Rapid loss of individual species necessitates a new approach to species preservation. A conservation movement dedicated to the preservation of natural diversity, as opposed to a single species, has grown considerably in this century. This article suggests using geographic information systems technology to determine what species are at risk of extinction, and which ecosystems, rather than individual species, should be managed. **

631. **Scott, V.E.** 1978. Characteristics of ponderosa pine snags used by cavity-nesting birds in Arizona. J. For. 76:26-28.

In the Southwest, ponderosa pine (*Pinus ponderosa* Laws.) snags are important as nest sites for cavity-nesting birds. A study in Arizona found that birds selected snags that were greater than 15 inches in d.b.h. and taller than 75 feet. Preferred snags had more than 40 percent bark cover and had been dead six or more years.

632. ——————. 1979. Bird response to snag removal in ponderosa pine. J. For. 79:26-28.

In an Arizona study the population of cavity-nesting birds declined by 52 percent on a plot in ponderosa pine (*Pinus ponderosa* Laws.) when conifer snags were removed during a timber harvest but when some quaking aspen (*Populus tremuloides* Michx.) snags were left

standing, birds increased by 23 percent. There was also a 31-percent increase on an unharvested control plot. Population of violet-green swallows (*Tachycineta thalassina*) decreased from 20.7 pairs per 100 acres to 2.2 pairs on the plot where snags were removed. There was no significant change in populations of open-nesting birds, but gray-headed juncos (*Junco caniceps*) and American robins (*Turdus migratorius*) increased on all plots.

633. **Scrivener, J.C.** and **B.C. Andersen.** 1984. Logging impacts and some mechanisms that determine the size of spring and summer populations of coho salmon fry (*Oncorhynchus kisutch*) in Carnation Creek, British Columbia. Can. J. Fish. Aquat. Sci. 41:1097-1105.

Natural patterns in emergence times, seaward movements, instream distributions, densities, and growth of coho salmon fry (*Oncorhynchus kisutch*) between March and September are contrasted with patterns observed during and after logging in the Carnation Creek watershed. After streamside logging in 1976-77, fry emerged up to 6 wk earlier and moved seaward more quickly than during years before logging. These observations are attibuted to higher water temperatures during the winter and to emergence during a period of more frequent freshets. Increased fry movement from the stream could result in habitat being underutilized. In sections affected by intense streamside logging, the deposition of "fine" logging debris led to increased fry densities during the summers of 1977 and 1978. After major freshets in November 1978, which removed this fine debris and affected channel morphology in these sections, fry densities declined below those observed prior to logging. Growth rate of fry was inversely correlated with density in all stream sections. Growth rates, after correction for density, tended to be greater in all sections after the adjacent streamside was logged. Larger fry and more variable numbers of fry remained in the stream in September after logging than before logging. Their increased size is attributed to the longer growing season afforded by earlier emergence. This complex of interacting factors determines the number and size of fry in autumn and it can influence the production of smolts the following spring.

634. **Sedell, J.R.** and **J.L. Froggatt.** 1984. Importance of streamside forests to large rivers: the isolation of Willamette River, Oregon, U.S.A., from its floodplain by snagging and streamside forest removal. Verh. Inter. Verein. Limnol. 22:1828-1834.

The pristine riparian forest extended 1.5-3 km on either side of the river. The pristine river was a series of multiple channels, sloughs, and backwater areas. Historically, the floodplain and valley had extensive marshes. Numerous downed trees helped to create and maintain shoals, multiple channels, oxbow lakes, and complex aquatic habitats at the outside bends in the river. After 80 years of snag removal and riparian forest destruction, there now exists one main channel, few downed trees, relatively simple and homogeneous habitat for aquatic vertebrates, and a four-fold decrease in river shoreline.

The few floodplain areas with extensive riparian forests along our major rivers must be treated as the last reserves of species and habitats approximating the condition of pristine rivers. These relics of the past will hold the key to relating inferences from the historical record to quantitative differences between what we now perceive as the normal conditions and how the river interacted with the terrestrial ecosystem and its massive quantites of wood inputs in the past. (Author's conclusion.)

635. **Sedell, J.R.** and **F.J. Swanson.** 1984. Ecological characteristics of streams in old-growth forests of the Pacific Northwest. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). 12-15 April, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 9-16.

Forest vegetation strongly affects aquatic habitat in streams and rivers of all sizes. Streams associated with old-growth forests are dominated by large tree-sized woody debris. Large woody debris traps sediment and creates a great diversity of habitat for both fish and aquatic invertebrates. Woody debris slows the routing of finer organic matter, and allows organisms time to more fully process these materials before they are moved downstream. The

structural influences of woody debris differ little between streams flowing through old-growth and through natural, young, post-wildfire stands. Large logs may reside in a channel for a century, or more, and provide a variety of benefits to the aquatic ecosystem until the post-wildfire stand matures to the point of contributing large debris to the channel. The United States has few remaining examples of the full, natural interaction of rivers with adjacent forests except in Alaska and national parks. Undisturbed streams in old-growth forests are restricted to small, high-gradient examples in relatively inaccessible and mountainous areas. A rich archival record documents man-imposed changes in forest influences on rivers in a variety of regions and geological and topographic settings. These old records — from fur trappers, the U.S. Army Corps of Engineers, and others — describe natural river systems greatly influenced by numerous downed trees, and large jams of floated debris.

636. **Sedell, J.R., F.J. Triska, J.D. Hall, N.H. Anderson, and J.H. Lyford.** 1974. Sources and fates of organic inputs in coniferous forest streams. *In* Integrated research in the coniferous forest biome. R.H. Waring and R.L. Edmonds (editors). U.S. International Biolog. Prog., Univ. Wash., Seattle, WA. Conif. For. Biome Bull. No. 5, pp. 57-69.

A study of the quality and magnitude of particulate organic inputs was undertaken in two streams in the Oregon Cascades. Objectives included estimation of litterfall and lateral movement of organic debris into a stream, estimation of litter breakdown rates, and construction of a first-approximation organic material budget.

In this study, approximately 65% of the litterfall input consisted of Douglas-fir and hemlock needles, which fall throughout the year. Deciduous inputs occurred primarily mid-October through November and consisted principally of vine maple and bigleaf maple. The total estimate of litter input is approximately 2.5 $g/m^2/day$. Both streams have the capacity to process all types of leaf litter within a year. Needles, the most refractory leaf litter, are processed by microbes and, once conditioned, are consumed readily by invertebrate shredders. Thus the large amounts of needle litter that enter the stream in late summer and fall constitute a food source usable by stream detritivores after deciduous litter has decomposed.

Leaf-pack experiments have revealed the danger of extrapolation of biological information from smaller to larger streams. Faster processing times for larger streams have been suggested by information on weight loss, invertebrate biomass, and leaf quality. Changes in litter quality were determined by increases in the percentage of lignin content.

Information on litterfall and lateral movement, in conjunction with previously collected data, led to a first-approximation particulate organic matter budget for watershed 10. When compared with a similar budget from a very different stream system, processing capabilities of the two streams were remarkably similar. In both streams almost 99% of the particulate organic material entered from terrestrial systems. About two-thirds of the organic inputs entering each stream were processed within the system, indicating the processing role of small forest streams.

637. **Sedjo, R.A.** 1990. The global carbon cycle: are forests the missing sink? J. For. 88(10):33-34.

Carbon in the atmosphere is currently increasing by about 3 billion tons per year. The major source is fossil fuel burning. A secondary source is forest clearing in the tropics. Several studies have estimated that temperate forests are also a source of atmospheric carbon. This author suggests that forest ecosystems, particularly in temperate regions, may be a sink rather than a source of atmospheric carbon. Evidence to support this comes from studies which indicate that forest biomass and area are increasing in North America, Europe and the Soviet Union. Carbon stored in forest soils is also listed as a potential sink for atmospheric carbon. The author notes that substantial amounts of carbon are also sequestered in long-lived solid wood products and in slowly degrading paper in landfills. A more careful assessment of the nature and magnitude of these sources may explain the discrepancy between predicted and measured CO_2 buildup. **

638. **Shaffer, M.L.** 1981. Minimum population sizes for species conservation. BioScience 31(2):131-134.

Conservationists will be increasingly pressured to preserve many species, and to do so efficiently. Scientists must soon come to a consensus on standards to be applied in determining what constitutes a minimum viable population for successful species preservation. The most promising approaches to determining minimum population and land area requirements lie in the extension of the analysis of biogeographic distribution patterns and species-specific turnover rates, the use of population data in computer simulations to test extinction possibilities, and the use of mathematical models to select significant characteristics affecting survival probabilities. Genetic determinants on minimum viable population sizes remain unclear. **

639. **Shands, W.E.** 1988. Beyond multiple use: managing National Forests for distinctive values. Am. For. 94(3&4):14-15, 56-57.

Has the concept of multiple use on the National Forests become obsolete? This forest policy writer thinks it has, and that it should be replaced, or at least reinterpreted, before it sounds the death toll for any more National Forest land. He suggests multiple use be replaced with management for the unique values of each National Forest, providing a range of values and uses, but not competing with what is offered by other public and private lands in the region. He suggests that the time is right, with the 1990 Resources Planning Act Assessment, for such a concept to be evaluated.

640. **Shen, S.** 1987. Biological diversity and public policy. BioScience 37(10):709-712.

This article examines a report on technologies to maintain biological diversity, released by the U.S. congressional Office of Technology Assessment (OTA) in March 1987. The OTA report recognizes that the earth's biological diversity is being reduced, and notes the need for more data. The report points out weaknesses in U.S. efforts at conserving biological diversity and suggests three ways for Congress to improve this situation: 1) by passing a biological diversity act; 2) by mandating a national conservation strategy; and 3) amending existing legislation to make conservation of biological diversity an explicit goal of the U.S. government. The report also notes that U.S. leadership in international conservation has waned, and suggests ways to reverse this trend. In closing, the author notes that policy makers, scientists, educators, and the public should come together to overcome obstacles to conserving biological diversity. **

641. **Sheppard, P.R.** and **E.R. Cook.** 1988. Scientific value of trees in old-growth natural areas. Nat. Areas J. 8(1):7-12.

Many applications of dendrochronology (tree-ring analysis) depend on long time series of ring-width data, obtained only from old trees. The clear value of old trees is in the opportunity to study long-term phenomena by looking back in time instead of waiting for hundreds of years to elapse. Dendrochronologists consider old-growth forests to be vitally important, especially those managed to preserve natural processes. With rigorous analysis, including specialized time-series statistical procedures, tree rings can be enlightening for various fields within the biological, chemical and physical sciences.

642. **Sheridan, W.L.** 1969. Effects of log debris jams on salmon spawning riffles in Saginaw Creek. U.S. Dep. Agric., For. Serv., Alaska Reg., Juneau, AK. 12 p.

A preliminary study of the effects of logging debris jams on salmon spawning habitat was made in Saginaw Creek on Kuiu Island in June 1968. This study showed that about 27 percent of the area in one lineal mile of this stream had been eliminated as spawning area by log jams. Recommendations are made for judicial removal of jams and leaning trees, especially while a logging operator is in the watershed. Discounted benefit cost ratio is 34:1 for removal of a log jam and 342:1 for removal of leaning trees.

643. **Sherwood, M.** and **G. Carroll.** 1974. Fungal succession on needles and young twigs of old-growth Douglas fir. Mycologia 66:199-506.

The pattern of presence and abundance of fungi on needles and twigs of old-growth Douglas fir (*Pseudotsuga menziesii*) in the Oregon Cascades exhibits a well-defined successional sequence which was documented by counting thalli and fruiting bodies under a dissecting microscope. Detailed information on the distribution of fungi in this habitat suggests that their mode of nutrition has yet to be elucidated.

644. **Shevelev, N.N.** 1977. Interception of vertical and horizontal precipitation in the forests of the Central Ural. Soviet Hydrol. Selected Papers 16(4):313-318.

The influence of the dark coniferous forests of the Central Ural on some components of the hydrologic budget, including the interception of vertical precipitation (rain and snow) and horizontal precipitation (fog, rime, and dew), is investigated. The relation between the interception of vertical and horizontal precipitation by the forest canopy at elevations from 400 to 700 m above sea level is analyzed.

645. **Shmida, A.** and **M.V. Wilson.** 1985. Biological determinants of species diversity. J. Biogeogr. 12:1-20.

We consider four categories of biological mechanisms of determinants which cause and maintain species diversity: niche relations, habitat diversity, mass effects and ecological equivalency. Two of these determinants are original to this paper: mass effect, the establishment of species in sites where they cannot be self-maintaining; and ecological equivalency, the coexistence of species with effectively identical niche and habitat requirements. The mode of action and ecological implications of each biological determinant are discussed using a schematic method for measuring alpha (community), beta (differentiation), and gamma (regional) diversities. The importance of mass effects and ecological equivalency to species richness is documented with several types of field data from Israel and California, U.S.A.

Floristic richness and, in particular, the richness of floristic transitions, are discussed and interpreted by use of the biological determinants of diversity. Contact transitions between distinct floras are rich predominantly because of mass effects. Transitions induced by marked environmental changes are rich because of the combined influences of habitat diversity and mass effects.

The rate at which species richness increases with sample area is related to the combined effects of all four biological determinants. This complexity explains the failures of simple species-area models. The relative intensity of each determinant is related to area: niche relations are most important at within-community and landscape scales, and ecological equivalency most important at regional scales. We suggest that understanding patterns of species diversity will be enhanced by the partitioning of total species richness into the richness caused by each of the four ecologically distinct determinants of diversity.

646. **Shugart, H.H., Jr.** and **D.C. West.** 1981. Long-term dynamics of forest ecosystems. Am. Sci. 69:647-652.

Forests are dynamic ecosystems that typically pass through a series of seral stages to reach a "climax" state. Some forests, however, which experience frequent disturbance or are restricted in area remain in a state of non-equilibrium. In this paper the authors describe a form of computer modeling—gap modeling—that simulates forest dynamics and sheds light on equilibria or non-equilibria states of forests. Gap models calculate competition among trees in a small area, usually a tree fall gap. While biomass in a small forest patch, such as a gap, fluctuates greatly as canopy trees die and are replaced by understory trees, this fluctuation more closley resembles a quasi-equilibrium when many patches are combined over a landscape. This is described by the "shifting-mosaic steady-state" concept of

ecosystem dynamics. Of particular interest to managers is recognition that some forest landscapes are too small to reach any form of equilibrium. It becomes difficult to maintain consistent plant or animal habitat levels in such small patches. **

647. **Shumway, S.E.** 1981. Climate. *In* Forest soils of the Douglas-fir region. P.E. Heilman, H.W. Anderson, and D.M. Baumgartner (editors). Wash. State Univ., Pullman, WA, pp. 87-92.

The author describes the climate of the Pacific coast of North America from northern California to southern Alaska. This area is referred to as the Douglas-fir region (DFR). It has a cool, maritime type climate, often described as "winter wet - summer dry." The major factors influencing the climate of the region are a Pacific high pressure cell, an Aleutian low pressure cell, and the various coastal mountain ranges which form a barrier to continental air masses. July and August are the two driest months in the region. The three wettest months vary from July to September in Alaska, and October to December in Port Hardy, B.C., to January to March in Los Angeles, Cal. Precipitation in the region is high, especially from northern Oregon through British Columbia, and varies considerably with altitude and exposure. The intensity of precipitation is generally modest but heavy rainfalls do occur. Fog precipitation is a significant source of moisture in coastal areas. Temperatures are moderated by the Pacific ocean remaining relatively warm in winter and cool in summer. The mountains provide an effective barrier to colder winter and warmer summer air masses in the east. January is the coldest month and July/August the warmest. Evapotranspiration rates in the dry summer months leave the region in a state of drought. Heavy winds, glaze storms, and dense snowpacks can damage forests in the region. **

648. **Sidle, W.B.** and **L.H. Suring.** 1986. Management indicator species for the national forest lands in Alaska. U.S. Dep. Agric. For. Serv., Juneau, AK. Tech. Publ. R10-TP-2. 51 p.

This paper describes a cooperative effort of the USDA Forest Service, Alaska Department of Fish and Game, U.S. Fish and Wildlife Service and National Marine Fisheries Service to identify Management Indicator Species (MIS) for the National Forest lands in Alaska. National and Regional direction of MIS was developed into a five-step screening process to evaluate 451 species of wildlife, fish, and shellfish of the Alaska Region. Species recommended as MIS included 26 for the Alaska Region, 30 for the Chugach National Forest, and 29 for the Tongass National forest. Recommendations were developed for applying MIS in project implementation. Results of MIS evaluations will be provided to interdisciplinary planning teams to guide their selection of MIS for use in Regional, Forest, and project level planning.

649. **Silvester, W.B., P. Sollins, T. Verhoeven,** and **S.P. Cline.** 1982. Nitrogen fixation and acetylene reduction in decaying conifer boles: effects of incubation time, aeration, and moisture content. Can. J. For. Res. 12:646-652.

Free-living microaerophiles fixed $^{15}N_2$ and reduced acetylene in fallen tree boles at two old-growth *Pseudotsuga menziesia* stands in western Oregon. Acetylene reduction was most rapid under an atmosphere of 2-10% O_2, whereas under prolonged anaerobic conditions it was at or below detection limits. Acetylene reduction rates increased up to fourfold during long-term incubations in acetylene (>12 h). Ratios of acetylene reduction to N_2 fixation frequently exceeded 6.0 during such long-term incubations but averaged 3.5 when samples were incubated <7 h; consequently, long-term incubation of low-activity material in acetylene should be avoided. A preliminary survey indicated that N_2 fixation by free-living organisms in fallen boles was less than other potential N inputs to fallen boles and to the forest ecosystem.

650. **Simpson, K.** and **G.P. Woods.** 1988. Movements and habitats of caribou in the mountains of southern British Columbia. B.C. Min. Environ. Parks, Wildl. Br., Victoria, BC. Wildl. Bull. No. B-57. 36 p.

The authors found that previous habitat management guidelines for caribou may be incomplete because the importance of early-winter and spring ranges was not considered. Logging may create short term food sources for caribou but, because immature regenerating forests are not used, caribou habitats and populations will likely be reduced in the long term. Recent construction of logging roads into previously inaccessible areas will increase harvests. Loss of habitat from logging and flooding the reservoir may also reduce the caribou population. The high natural mortality and vulnerability of caribou, as well as the potential for poaching losses, emphasize the need for conservative harvest quotas and access management. Determining seasonal habitat requirements, defining and mapping key habitats and developing long term range management plans should receive top priority.

651. **Singh, T.** 1988. Potential impacts of climatic change on forestry. Canada Committee on Ecological Land Classification, Newsletter 17:4-5.

The author briefly discusses some of the many impacts that climatic change is likely to have on forestry. These include the displacement of ecosystems resulting from a shift in boundaries of northern and southern forests, and a corresponding shift from south to north for agricultural purposes. An increase in frequency of forest fires will be one of the main mechanisms by which ecosystem boundaries will shift. The intensity and frequency of insect and disease infestations will be affected by lowered resistance of tree species, and by changes in insect and disease populations resulting from shifts in plant communities and species composition. Changes in temperature along elevational gradients will result in shifting treelines; changes in snow accumulation and melt patterns will, in turn, affect streams, rivers, and soil moisture. Rising temperatures will increase rates of evapotranspiration and evaporation, alter precipitation patterns, and increase the frequency of drought worldwide. These changes will directly affect the regeneration and survival of forest seedlings, growth and yield of the maturing trees, and the density of the wood produced and, consequently, timber quality. The author recommends long-term research studies, a consideration of policy implications, and strategic planning for the future. **

652. **Singh, T.** and **J.M. Powell.** 1986. Climatic variation and trends in the boreal forest region of western Canada. Climatic Change 8:267-278.

Long-term climatic trends were studied for the boreal forest region of western Canada. Mean monthly and annual temperature and precipitation data obtained between 1872 and 1981 were analyzed for the three subregions (forest-grassland, predominantly forest, and forest-tundra). Highly significant differences ($P<0.01$) were detected in the mean monthly temperature among the subregions for each month, and similar differences were found for most of the months for precipitation. Long-term records showed statistically highly significant slightly increasing temperature and precipitation trends for the economically important predominantly forest subregion.

653. **Sirmon, J.M.** 1985. A regional forester speaks out on old growth. Am. For. 91:29-30, 70-71.

In this article the author tackles some of the key questions related to management of old-growth forests in the Pacific Northwest. These questions are: What is old growth? How much is there? How much is left and how much is enough? Arriving at one definition of old growth is problematic, notes the author. He provides a generic definition used for planning purposes and several more specific definitions. These latter definitions support specific biases, suggests the author, and are thus less useful than generic ones. The author quotes a Society of American Foresters' report of 1983 which calculates that there are approximately 4.7 million acres of stands at least 200 years old in the Douglas-fir region of western Oregon and Washington. A total of 2.9 million acres of old growth are located the region's national forests. The same report notes that there are at least 0.3 million acres of old growth withdrawn from timber harvest in national forests and a further 0.8 million acres in national

parks. The author claims that current harvest levels will not threaten old growth for at least 15-20 years. He recommends support of the existing forest planning process as the best way to allocate the remaining old-growth resource. **

654. **Skolimowski, H.** 1989. Forests as sanctuaries. Trumpeter 6(2):41-45.

The author discusses the spiritual relationship between the forest and the human race from a historical perspective. **

655. **Society of American Foresters.** 1984. Scheduling the harvest of old growth: a position of the Society of American Foresters and Report of the SAF Task Force on scheduling the harvest of old-growth timber. Soc. Am. For., Bethesda, MD. 44 p.

This article has two parts: 1) a position paper of the Society of American Foresters (SAF) on old-growth forests in the Pacific Northwest; and 2) a report of the SAF task force on scheduling the harvesting of old-growth timber. Part 1 introduces and discusses policies regarding the harvest of old growth, the definition of old growth, and forest inventory, and makes several recommendations. Part 2 addresses the scheduling of old-growth harvesting in the Pacific Northwest. Issues discussed in greater detail are characteristics, inventories, management, and harvest policy of old-growth forests. The report concludes with four recommendations on the harvest of old-growth timber. An appendix contains a review of regulations governing timber harvest scheduling on lands administered by the USDA Forest Service and the USDI Bureau of Land Management. **

656. ———————. 1989. Old-growth forests in the Pacific Northwest. J. For. 87:59.

The Society of American Foresters presents its position on old-growth forests in the Pacific Northwest. The Society recommends that public land managers develop policies to maintain old-growth ecosystems, to keep management options open, and to allow the harvest of unreserved old-growth forest. Their recommendations for the development of these policies are directed towards: refinement of the definition of old-growth forests and improvement of forest inventories essential to the allocation and management of old-growth forests; considerations to be addressed for allocation of land to be maintained in an old-growth state; and appropriate methods for land management on public lands. **

657. **Sollins, P.** 1982. Input and decay of coarse woody debris in coniferous stands in western Oregon and Washington. Can. J. For. Res. 12:18-28.

At 10 locations in Oregon and Washington, tree mortality resulted in dry-matter transfer of 1.5-4.5 Mg/ha/year of boles and branches to the forest floor and 0.3-1.3 Mg/ha/year of large-diameter roots directly to the mineral soil. The first value is about the same as that reported for leaf fall in similar stands; the second value generally is smaller than that reported for fine root turnover. Results are based on measurements by the U.S. Forest Service spanning 16-46 years and areas as large as 42 ha. Values based on intervals of 10 years were highly variable and potentially misleading.

At an old-growth Douglas-fir stand in Washington, fallen boles accounted for 81 Mg/ha, standing dead for 54 Mg/ha. Density of fallen boles averaged from 0.14 to 0.27g/cm^3 depending on decay state. Values were lower than some previously reported because (1) our sample included small-diameter fallen boles that tend to decay rapidly, and (2) we measured density with techniques that minimized compaction and shrinkage.

The decay rate at the old-growth stand, calculated indirectly by dividing bole mortality (megagrams per hectare per year) by the amount (megagrams per hectare) of fallen and standing dead woody material, was 0.028/year. This rate, three to five times those previously calculated directly from change in density alone, was almost identical to values calculated elsewhere from change in both volume and density. Decay rates based on change in density alone include only respired and leached material and exclude the large amount of

material lost in fragmentation. This study shows the value of permanent plots, undisturbed by salvage logging, for retrospective studies of decomposition, nutrient cycling, and productivity.

658. **Sollins, P., S.P. Cline, T. Verhoeven, D. Sachs,** and **G. Spycher.** 1987. Patterns of log decay in old-growth Douglas-fir forests. Can. J. For. Res. 17:1585-1595.

Fallen boles (logs) of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Faf.) Sarg.), and western red cedar (*Thuja plicata* Donn) in old-growth stands of the Cascade Range of western Oregon and Washington were compared with regard to their physical structure, chemistry, and levels of microbial activity. Western hemlock and western red cedar logs disappeared faster than Douglas-fir logs, although decay rate constants based on density change alone were 0.010/year for Douglas-fir, 0.016/year for western hemlock, and 0.009/year for western red cedar. We were unable to locate hemlock or red cedar logs older than 100 years on the ground, but found Douglas-fir logs that had persisted up to nearly 200 years. Wood density decreased to about 0.15 g/cm^3 after 60-80 years on the ground, depending on species, then remained nearly constant. Moisture content of logs increased during the first 80 years on the ground, then remained roughly constant at about 250% (dry-weight basis) in summer and at 350% in winter. After logs had lain on the ground for about 80 years, amounts of N, P, and Mg per unit volume exceeded the amount present initially. Amounts of Ca, K, and Na remained fairly constant throughout the 200-year time span that was studied (100-year time span for Na). N:P ratios converged toward 20, irrespective of tree species or wood tissue type. C:N ratios dropped to about 100 in the most decayed logs; net N was mineralized during anaerobic incubation of most samples with a C:N ratio below 250. The ratio of mineralized N to total N increased with advancing decay. Asymbiotic bacteria in fallen logs fixed about 1 kg N/ha/year, a substantial amount relative to system N input from precipitation and dry deposition (2-3 kg/ha/year).

659. **Sollins, P., K. Cromack, Jr., F.M. McCorison, R.H. Waring,** and **R.D. Harr.** 1981. Changes in nitrogen cycling at an old-growth Douglas-fir site after disturbance. J. Environ. Qual. 10(1):37-42.

Effects of disturbance on the N cycle in a 450-year-old Douglas-fir stand (*Pseudotsuga menziesii*) were studied in an experiment in which herbicides were used to kill all vegetation while minimally disturbing the litter layer and soil. Nitrogen concentration in falling foliage was greater on the treated area than on a control area, as was soil moisture. Nitrate and Kjeldahl N concentrations in the soil were greater on the treated than on the untreated area, but only at or below the bottom of the rooting zone ($\geq$ 1-m depth). On the untreated area, nitrate was present in solution in significant amounts only at the 2-m depth.

660. **Sollins, P., C.A. Glassman,** and **C.N. Dahm.** 1985. Composition and possible origin of detrital material in streams. Ecology 66(1):297-299.

Stream detritus consists in part of fragmented plant material, microbial biomass and by-products, and precipitated dissolved organic material. Streams, however, also transport and store mineral-soil particles on which large amounts of organic matter are already adsorbed when the particles enter the stream. In the present study, we used a density fractionation technique to provide initial data on the composition of detritus from several small streams. We also compared density and chemistry of the stream and floodplain detritus with those of materials that might serve as a source for the detritus: soil from the forest adjacent to the floodplain and submerged waterlogged wood and foliage. (From authors' introduction)

661. **Sollins, P., C.C. Grier, F.M. McCorison, K. Cromack, Jr., R. Fogel,** and **R.L. Fredriksen.** 1980. The internal element cycles of an old-growth Douglas-fir ecosystem in western Oregon. Ecol. Monogr. 50(3):261-285.

Information on primary production, decomposition, hydrology and element cycling was integrated in annual budgets of accumulation and flux among components of a mature Douglas-fir forest ecosystem. Annual N input in precipitation and dust was 2.0 kg/ha, and an estimated 2.8 kg/ha were fixed by cyanophycophilous lichens in the canopy. Annual N loss to groundwater was 1.5 kg/ha. N appeared to be accumulating in the ecosystem. An annual decrease of ≈2.8 kg/ha in vegetation was offset by estimated increases of 5.0 kg/ha in fallen logs and 2.8 kg/ha in soil organic matter. Microparticulate litterfall provided a large input of N to the forest floor (3.3 $kg \cdot ha^{-1} \cdot yr^{-1}$).

Annual input of metallic cations in precipitation was only 545 eq/ha, whereas weathering input (net release of cations to solution from primary and secondary minerals) was estimated by difference at ≈9000 eq/ha. Total annual loss to groundwater was 9400 eq/ha and, because of little cation accumulation, loss almost exactly balanced input. Net transfers of P were small. Total annual input was 0.5 kg/ha, total loss was 0.7 kg/ha, and net accumulation was -0.2 kg/ha. Input of elements in precipitation and dryfall was small compared with that in the eastern United States.

Water chemistry profiles showed that N, P and K increased in concentration as water passed through the canopy and litter layer but decreased as water passed through the rooted part of the mineral soil. In contrast, Na increased by a factor of 20 as water passed through the rooted soil. Concentrations of all elements except Mg were lower in the stream water than in solution at 2.0-m depth in the subsoil.

At our site, unlike some eastern forests, Kjeldahl N (organic N plus NH_4^+) accounted for most of the measured N in solution. Nitrate levels were low, averaging ≤20 µg/L NO_3^--N at all points in the profile. Titratable alkalinity dominated anion chemistry in the mineral soil, but in the upper parts of the water chemistry profile (precipitation, throughfall and litter leachate) Cl^- and SO_4^{2-} together accounted for 30-40% of the negative charge.

Total return to the forest floor in litterfall was greater than that reported for other Douglas-fir stands mainly because of plentiful microparticulate forms and coarse woody debris. Leaf fall accounted for less than half of the total litterfall input of N to the forest floor. Element accumulations in coarse woody debris almost cancelled the negative net annual increments in the living vegetation compartments.

Overall cycling patterns show that only the biologically limiting element, N, was tightly conserved. For other elements, losses nearly equaled or even exceeded inputs. Redistribution from old to new foliage was more important for N, P and K than for Ca, Mg and Na. Solution transport processes were important for all elements and dominated the cycling patterns of biologically less important elements such as Ca and Na. Vegetation absorbed metallic cations mainly from the mineral soil. However, much N and P were absorbed by roots penetrating up to or into the litter layer.

Fluxes of hydrogen ions (H^+) resulting from water flow were negligible (≤102 $eq \cdot ha^{-1} \cdot yr^{-1}$) compared with H^+ release during carbonic acid dissociation and H^+ removal accompanying cation release in weathering (≈$10^4 eq \cdot ha^{-1} \cdot yr^{-1}$). Uptake of metallic cations by vegetation and release during decomposition exceeded uptake and release of sulfur and phosphorus anions, resulting in a net H^+ flux of ≈3×10^3 $eq \cdot ha^{-1} \cdot yr^{-1}$). An increase in acidity of the rainfall to pH 4.0 would increase H^+ input only ≈3×10^2 $eq \cdot ha^{-1} \cdot yr^{-1}$.

662. **Sollins, P.** and **F.M. McCorison.** 1981. Nitrogen and carbon solution chemistry of an old growth coniferous forest watershed before and after cutting. Water Resour. Res. 17(5):1409-1418.

Dissolved Kjeldahl N and nitrate concentrations were monitored for 1 to 2 years before and for 3 years after clearcutting of a 10.2-ha, Douglas-fir dominated watershed in the Oregon Cascade Mountains. Dissolved organic C (DOC) and ammonium concentrations were monitored after cutting. We sampled throughfall, litter leachate, and soil solutions (at four depths in and below the rooting zone) at four locations along a transect up and down the slope. We also sampled precipitation, streamwater, and seepage water. A site just off of the watershed served as the control for all positions in the water profile except for streamwater,

for which a similar, nearby watershed was the control. Objectives were (1) to document effects of clearcutting on solution chemistry and (2) to provide data from which to calculate ecosystem nutrient cycling budgets before and after cutting. Beginning 7-18 months after clearcutting, nitrate concentrations increased 3-100 times on the cut watershed but remained nearly unchanged on an adjacent, uncut, control area. Increases were greater at 2.0-m depth than at other positions along the water profile and least in seepage and streamwater. Greatest nitrate levels were detected near the bottom of the slope. At the uppermost site, about 50 m below the ridgetop, nitrate values remained the same as at the control site. Concentrations of Kjeldahl N (organic N plus ammonium) increased much less than those of nitrate (only 50-100% over precut levels) but were greater than nitrate concentrations at most profile positions both before and after cutting. Even after cutting, nitrate dominated only at 2.0-m depth and in seepage water. DOC concentrations were slightly greater on the cutover area than on the control. However, they increased as much as 3 times from year 2 to year 3 after cutting at both treated and control sites, whereas nitrate decreased from year 2 to 3, and Kjeldahl N increased little or remained the same. DOC concentrations decreased consistently with depth in the soil profile. The study showed (1) that dissolved organic N must be measured if total N transfers are to be calculated at most sites, (2) that patterns of nitrate appearance can be explained in part on the basis of decreased availability of oxidizable C, (3) that patterns of nitrate appearance after devegetation vary greatly with depth in the soil and with slope position, and (4) that loss of dissolved N after cutting was small (2.0 kg·ha·yr) compared with nearly 400 kg N/ha removed in tree boles.

663. **Solomon, A.M.** 1986. Transient response of forests to CO_2 induced climate change: simulation modeling experiments in eastern North America. Oecologia 68:567-579.

The temporal response of forests to CO_2-induced climate changes was examined for eastern North America. A forest stand simulation model was used with the assumption that climate will change at a constant rate as atmospheric CO_2 doubles, and then as CO_2 doubles again. Before being used to project future vegetation trends, the simulation model FORENA was verified by its ability to reproduce long, temporal sequences of plant community change recorded by fossil pollen and by its ability to reproduce today's vegetation. The simulated effects of changing monthly temperature and precipitation included a distinctive dieback of extant trees at most locations, with only partial recovery of biomass in areas of today's temperate deciduous forest. In the southern portion of today's deciduous-coniferous transition forests the simulated dieback was indistinct and recovery by deciduous tree species was rapid. In more northerly transition areas, the dieback not only was clearly expressed, but occurred twice, when new dominant species replaced extant conifers, then were themselves replaced, as climate change continued. Boreal conifers also underwent diebacks and were replaced by deciduous hardwoods more slowly in the north than in the south. Transient responses in species composition and carbon storage continued as much as 300 years after simulated climate changes ceased.

664. **Solomon, A.M., D.C. West, and J.A. Solomon.** 1981. Simulating the role of climate change and species immigration in forest succession. *In* Forest succession: concepts and application. D.C. West, H.H. Shugart, and D.B. Botkin (editors). Springer-Verlag, New York, NY, pp. 54-177.

Forest succession in temperate regions involves directional changes in species composition and community structure that may occur over a period of 200-1000 years, and which may end up at a "climax" end point. In this paper the authors use a forest stand simulation model (FORET) and the pollen record from middle Tennessee to evaluate the separate and combined effects of species immigration and climate on the composition of forest vegetation. Results of modeling supported the climatic climax concept: self-perpetuating forest communities developed after minor or major changes in climate. The climatic climax concept may be less valid in areas that contain few dominants, that occur far from full-glacial refugia, and that are frequently subject to environmental disturbance. **

665. **Sorg, C.F.** and **J.B. Loomis.** 1984. Empirical estimates of amenity forest values: a comparative review. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-107. 23 p.

Comparisons of empirical estimates of the values of wildlife, wilderness, and general recreation require that the values are based on comparable methodologies and comparable units of measurements. Adjustments necessary to allow such comparisons are outlined and are applied to an extensive data base of valuation studies.

666. **Sorg, C.F.** and **L.J. Nelson.** 1986. Net economic value of elk hunting in Idaho. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Resour. Bull. RM-12. 21 p.

Net willingness to pay in addition to actual expenditure for elk hunting in Idaho was estimated at $63.17 per trip and $99.82 per trip using a standard cost per mile travel cost method and a reported cost per mile travel cost method, respectively. Using the contingent value method, the values for the 1982 and 1983 elk hunting season were $51.84 per trip and $92.54 per trip, respectively. Willingness to pay was greater for double number of elk seen on a trip. Methods, results, and applications are fully described.

667. **Soulé, M.E.** 1980. Thresholds for survival: maintaining fitness and evolutionary potential. *In* Conservation biology: an evolutionary-ecological perspective. M.E. Soulé and B.A. Wilcox (editors). Sinauer Assoc., Inc., Sunderland, MA, pp. 151-169.

The major goal in conservation genetics is the development of criteria for determining the population size (or minimum area) that will provide for the maintenance of fitness and adaptive potential. Conservationists must produce sound and defensible criteria for minimal population sizes (or minimum area) to counter attacks by economic and political forces that relentlessly encroach on land and budgets given to conservation programs. This chapter proposes guidelines for the development of such criteria. Using the "time scale of survival," the author discusses two issues relevant to conservation: 1) short term fitness and survival; and 2) the continuing creation of evolutionary novelty during and by the process of speciation. The author concludes that many conservationists will have to take a second look at their conservation programs, as only a handful of programs meet the minimum critieria for short-term fitness and only a fraction of national parks and reserves are of sufficient size to sustain evolutionary viable populations of large animals. **

668. ——————. 1986. Conservation biology: the science of scarcity and diversity. Sinauer Assoc. Inc., Sunderland, MA. 584 p.

According to the author, this book has several objectives: to provide an up-to-date synthesis of conservation biology; to encourage communication among all sections of the conservation community; and to engender a sense of purpose and excitement in students and professionals. Each of the book's six sections is preceded by an introduction which describes the commonalities and differences in the papers that make up the section. These introductions were also designed to facilitate understanding and applications of the principles presented. The 25 papers which make up this volume are organized under the following sections: fitness and viability of populations, patterns of diversity and rarity (their implications for conservation), effects of fragmentation, community processes, sensitive habitats (threats and management), and interactions with the real world. **

669. ——————. 1989. Tropical rain forests: the loss of incredible riches. Trumpeter 6(2):47-48.

This is a brief overview, aimed at increasing public awareness of the problems associated with disruption of rainforest ecosystems. Incredible losses of wildlife and plant species come each day with rainforest clearing for dams, mining, agriculture, and grazing. In years to come, the loss of rainforests may lead to a shift in the world's climatic balance. As

people awaken to these problems, change is taking place at many levels by several worldwide organizations, including native people of these forests. Such organizations hold promise for slowing tropical rainforest destruction. **

670. **Soulé, M.E.** and **D. Simberloff.** 1986. What do genetics and ecology tell us about the design of nature reserves? Biol. Conserv. 35:19-40.

The SLOSS (single large or several small) debate is no longer an issue in the discussion about the optimal size of nature reserves. The best way to estimate the minimum sizes of reserves may be a three-step process: (1) identify target or keystone species whose disappearance would significantly decrease the value or species diversity of the reserve; (2) determine the minimum number of individuals in a population needed to guarantee a high probability of survival for these species; (3) using known densities, estimate the area needed to sustain the minimum number. The forces that affect population viability and determine MVPs (minimum viable populations) are extremely complex. Thoughtful estimates of MVPs for many animal species are rarely lower than an effective size of a few hundred.

Attempts to save only common or smaller species in a community will usually be ill-fated because of the web of ecological relationships between species, including the importance of predation and herbivory in the maintenance of species diversity. Other topics discussed include the complementarity of conservation goals, the problematic function of corridors and the value of buffer zones.

671. **Soulé, M.E.** and **B.A. Wilcox.** 1980. Conservation biology: an evolutionary-ecological perspective. Sinauer Assoc., Inc., Sunderland, MA. 395 p.

This book addresses current concerns for the preservation of biological diversity and its evolutionary potential. Each of the four parts of this book deals with a particular problem or theme. Part 1, entitled Ecological Principles of Conservation concerns the temporal and spatial dynamics of ecosystems, focusing particularly on the complex systems of the tropics. Part 2 discusses the consequences of insularization, the theory of insular ecology and conservation, causes of extinction, criteria for minimum population sizes, and the application of demographic theory and methodology to three conservation problems. Part 3, Captive Propagation and Conservation, provides a forum for discussing the disadvantages, advantages, theory and technology of the captive breeding of endangered species. Part 4 consists of discussions on the role of Man, both as exploiter and steward of natural systems.

672. **Sousa, W.P.** 1984. The role of disturbance in natural communities. Ann. Rev. Ecol. Syst. 15:353-391.

Disturbance is a major source of the temporal and spatial heterogeneity found in all natural communities, as well as an agent of natural selection in species evolution. In this review the author discusses the impact of disturbance on the relative abundance of species in communities and on the numerical abundance of populations. Disturbance also affects ecosystem-level processes such as nutrient cycling, primary and secondary production, energetics, and biomass accumulation. Some of the topics discussed include: factors that determine natural regimes of disturbance; response of organisms to disturbance; disturbance and evolution of organisms; and the effects of disturbance on populations and community structure and dynamics at local and regional scales. The author notes that disturbance may be as important as biological interactions in influencing community dynamics. **

673. **Speaker, R., K. Moore,** and **S. Gregory.** 1984. Analysis of the process of retention of organic matter in stream ecosystems. Verh. Inter. Verein. Limnol. 22:1835-1841.

This paper describes a method for the quantitative assessment of retention of particulate organic matter in streams, and identifies several major stream retention features that can be influenced by the structure and composition of riparian zones. Studies were conducted in or around the H.J. Andrews Experimental Ecological Reserve. The measurement of retention

was expressed as the difference between the quantity of particles in transport at a given point in a stream and the quantity of particles still in transport at some distance downstream. This experiment revealed four major results: 1) leaf retention curves conformed well to a negative exponential model; 2) though leaves were retained at fairly uniform rates at many sites, the presence of wood debris dams had a major influence on reach retention patterns; 3) retention structures differed greatly in their relative efficiency in trapping leaves; and 4) rates of leaf retention were closely related to general hydrologic and structural characteristics of the study reaches, and leaf retention rates were greater in reaches with higher ratios of wetted perimeter to channel cross-sectional area. The authors conclude that streams are very efficient at retaining particulate organic matter and debris dams enhance retention of coarse particulate matter. The significance of the relationship between riparian vegetation and stream retention in riparian ecosystems is also discussed. **

674. **Spiers, G.A., D. Gagnon, G.E. Nason, E.C. Packee,** and **J.D. Lousier.** 1986. Effects and importance of indigenous earthworms on decomposition and nutrient cycling in coastal forest ecosystems. Can. J. For. Res. 16:983-989.

The general ecology of an undescribed indigenous earthworm species in the Megascolecidae, found in the organic horizons of Podzolic soils under mixed stands of *Tsuga heterophylla, Abies amabilis, Thuja plicata*, and *Pseudotsuga menziesii*, is described. The earthworm is a member of the genus *Arctiostrotus.* Over a range of sites, population numbers of earthworms were correlated to rooting concentration in and immediately below the mor humus. By micromorphological examination, earthworm casts were found to account for up to 60% by volume of the constituent solids of the organic horizons. The abundance of both fine roots and fungal hyphae in the worm casts suggested high nutrient availability. Analysis of fresh faecal material showed a marked increase in most important nutrients (N, P, K, Mg, Fe, Na) relative to levels in noningested litter. Observations indicate that this earthworm species, whose population density may reach $200/m^2$, has a major role in the decomposer subsystem of these ecosystems.

675. **Spies, T.A.** 1990. Current knowledge of old growth in the Douglas-fir region of western North America. *In* Proc. XIX IUFRO World Congress, Div. I, Vol. I. Aug. 5-11, 1990, Montreal, QB. Can. IUFRO World Congr. Organizing Comm., Montreal, QB, pp. 116-127.

Old-growth forests in the Douglas-fir region of western North America have been the subject of considerable public debate and scientific research. Research efforts with regard to old-growth structure varies widely across the region as a consequence of variation in disturbance and stand history. Most plant and animal species occur across the full range of stand development; however, several plant and animal species find optimum habitat in old-growth Douglas-fir stands. Different strategies are available for old-growth management on public lands.

676. **Spies, T.A.** and **J.F. Franklin.** 1988. Old growth and forest dynamics in the Douglas-Fir region of western Oregon and Washington. Nat. Areas J. 8(3):190-201.

Changes in the structure and function of Douglas-fir forests as they develop from young stands to old growth are examined. Old growth Douglas-fir/western hemlock forests are a long-lived phase of a potentially very long successional sequence. After disturbance, some ecosystem attributes, such as leaf area and water quality, recover relatively quickly, while others, such as live and dead woody structures, which are important for wildlife, return to predisturbance maxima and toward a relative steady state only after four or five centuries. The gradual and variable nature of succession and stand development make the task of precisely defining old growth difficult. We propose an index of "old-growthness" or structural diversity that may be a useful tool in maintaining and managing successional diversity in forest landscapes.

677. —————. 1989. Gap characteristics and vegetation response in coniferous forests of the Pacific Northwest. Ecology 70(2):543-545.

Gaps (*sensu* Watt 1947) in forest landscapes assume a wide range of sizes from the openings created by the death of single branches or trees to areas of hundreds or thousands of hectares created by catastrophic wildfire. Most "gap" studies have focused on the death and replacement of one to several canopy trees, excluding larger sized gap processes that occur in most landscapes. However, the importance of openings created by disturbance cannot be adequately addressed without considering both fine- and coarse-scale gap processes.

Opportunities for examining gap processes at a range of spatial and temporal scales are excellent in the Pacific Northwest where extensive, uncut forests still exist and stumps on many cutover areas retain a record of previous tree ages and fire scars. Canopy disturbances are of varied types and spatial and temporal scales, and intervals between stand-replacing disturbances potentially exceed 1000 yr on many sites (Dale et al. 1986). In this essay we focus on coniferous forests dominated by Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*). Our objective is to contrast the roles and importance of fine- and coarse-scale disturbances, illustrating the importance of various disturbance characteristics and system context in controlling community dynamics. (Authors' introduction)

678. **Spies, T.A., J.F. Franklin,** and **M. Klopsch.** 1990. Canopy gaps in Douglas-fir forests of the Cascade Mountains. Can. J. For. Res. 20:649-658.

Types and rates of mortality were measured and canopy gap formation rates were estimated from 5- to 15-year records of mortality in 34 permanent plots in mature (100- to 150-year-old) and old-growth (>200-year-old) Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)/western hemlock (*Tsuga canadensis* (Raf.) Sarg.) forests in western Oregon and Washington. Gap surveys were conducted in a mature and an old-growth stand, and characteristics of 40 gaps and regeneration were measured. Most canopy trees died without disrupting the forest in both mature (87.6%) and old-growth stands (73.3%). The amount of forest area per year representing new gaps was 0.7% in mature stands and 0.2% in old-growth stands. The gap survey found a higher proportion of gaps in the mature stand than in the old-growth stand. Most regeneration (>1 m tall) in gaps was western hemlock; Douglas-fir regeneration did not occur. The ratio of seedling density in gaps to density under canopies was about 3 for the mature stand and about 9 for the old-growth stand. Seedling density was correlated with measures of gap age but not gap size. The study suggests that gap disturbances and vegetative responses are important processes in the dynamics of these forests. However, gap formation rates and vegetative responses appear to be slow relative to other forest types. In addition to gap size, canopy structure and disturbance severity are important determinants of gap response.

679. **Spies, T.A., J.F. Franklin,** and **T.B. Thomas.** 1988. Coarse woody debris in Douglas-fir forests of western Oregon and Washington. Ecology 69(6):1689-1702.

Amounts and structural characteristics of coarse woody debris (CWD) were examined in relation to stand age and site moisture condition in 196 *Pseudotsuga menziesii* stands in western Oregon and Washington. Stands ranged from 40 to 900 yr old, and most, if not all, originated after fire. In a chronosequence from the Cascade Range, the amount of CWD followed a U-shaped pattern for stands <500 yr old, with moderate levels (92 Mg/ha) in stands <80 yr old, lowest levels (<50 Mg/ha) in stands 80-120 yr old, and highest levels (173 Mg/ha) in stands 400-500 yr old. After 500 yr the amounts of CWD declined to intermediate levels. In the southern Coast Range, lowest levels (32 Mg/ha) of CWD were in the youngest stands (60-80 yr), primarily because they inherited little CWD from the preceding (prefire) stands. In the Cascade Range, levels of CWD inherited from preceding stands were highest in young stands and declined to near zero by 250 yr. The overall decay rate constant (k) for snags and logs in the Cascade Range, calculated indirectly from the

chronosequence, was 0.029/yr. Volume and biomass of CWD differed significantly in old-growth stands (>200 yr old) among site moisture classes. Dry sites averaged 72 Mg/ha, moderate sites 137 Mg/ha, and moist sites 174 Mg/ha.

The dynamics of CWD were modeled for three fire histories, each beginning with an initial fire in an old-growth stand but differing in number and severity of subsequent fires. All three models exhibited low values of CWD between 80 and 200 yr. The lowest and most prolonged minimum in CWD during succession occurred when additional fires burned early in succession, which probably happened preceding many stands in the southern Coast Range. The results of the study indicate that a steady-state condition in CWD may not be reached for >1000 yr, and that the nature and timing of disturbance play a key role in the dynamics of CWD in the region.

680. **Sprugel, D.G.** 1985a. Changes in biomass components through stand development in wave-regenerated balsam fir forests. Can. J. For. Res. 15:269-278.

Available data on the wave-regenerated *Abies balsamea* forests of the northeastern United States are synthesized into a model (BALSAM) which predicts changes in total and component biomass through the disturbance-regeneration cycle. Measured decay rates seem to imply a higher mean forest floor mass than is actually observed, so several alterations were made in the initial model to make it predict forest floor mass correctly. With or without these changes, forest floor mass decreases for about 12 years after disturbance, largely owing to low levels of litterfall in the early stages of stand development. Because changes in living biomass and dead bole mass through the disturbance cycle roughly cancel each other out, net ecosystem productivity closely parallels these litterfall-driven changes in the forest floor. Throughout the disturbance-regeneration cycle, the forest floor is derived primarily from woody tissue and its decay products, with foliage-derived material making up less than 25% of the total forest floor mass.

681. ——————. 1985b. Natural disturbance and ecosystem energetics. *In* The ecology of natural disturbance and patch dynamics. S.T.A. Pickett and P.S. White (editors). Academic Press, Inc., Toronto, ON, pp. 335-352.

1) Postdisturbance stand development in most forests and shrublands exhibits the following recognizable stages: (a) stand reinitiation; (b) stem exclusion; (c) understory reinitiation; and (d) old growth.

2) Biomass accumulation during stand development follows a sigmoid pattern, with total biomass increasing slowly at first, more rapidly after crown closure, then more slowly again in older stands. Foliage biomass initially increases rapidly, but then reaches a plateau and thereafter remains relatively constant. Bole and branch biomass continues to increase until the old-growth stage.

3) Net primary productivity is low immediately after disturbance, but then increases and reaches a peak early in the stem exclusion stage. Thereafter it remains relatively constant, at least until the beginning of the understory reinitiation stage. In most ecosystems that have been studied, NPP declines in the old-growth stage, apparently because of nutrient sequestration in the forest floor or soil organic matter.

4) Autotrophic respiration has not been well documented, but is apparently low in the stand reinitiation stage and then higher in the stem exclusion and understory reinitiation stages. Dogma holds that it continues to increase throughout the course of stand development, but this is not supported by evidence.

5) Net ecosystem productivity (NEP) is apparently negative in the stand reinitiation stage, then positive in the stem exclusion and understory reinitiation stages, possibly dropping to zero in the old-growth stage. Since NEP should average out to zero through an entire disturbance cycle, there may be measurable difference in NEP trends following fire (which consumes biomass) and windthrow (which does not).

6) Regardless of the goal toward which an ecosystem is being managed, management plans must give careful consideration to the long-term consequences of altering natural disturbance frequencies.

(Author's summary)

682. **Stace-Smith, R., L. John,** and **P. Joslin.** 1980. Threatened and endangered species and habitats in British Columbia and the Yukon: Proc. Symp. March 8-9, 1980, Richmond, BC. B.C. Min. Environ., Victoria, BC. 302 p.

The objective of this symposium was to assemble information on the current status of threatened species and habitats in British Columbia and the Yukon. The session on habitat concerns included a presentation on the role of Ecological Reserves as a conservation strategy, and brief descriptions of specific habitats; forest ecosystems, rare plant habitats, dry interior sites, ungulate winter range and threatened coastal habitats. Highlighted species were white pelicans, peregrine falcons, burrowing owl, spotted owl, Vancouver Island marmot, sea otter, sandhill cranes, gyrfalcons, grizzly bears and the Porcupine caribou. A number of presentations covered the endangered species within the following vertebrate groups, amphibians, reptiles, birds and freshwater fishes. Other considerations included discussions of peripheral species, the aspect of biological diversity, the ethics of conservation, the role of non-governmental organizations including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

683. **Stark, N.M.** 1977. Fire and nutrient cycling in a Douglas-fir/larch forest. Ecology 58:16-30.

Twenty control burns performed with a wide range of fuel loadings and moisture conditions were used to study the effectiveness of old fuel reduction under standing Douglas-fir/larch forest. This paper reports the influence of burning on nutrient retention and loss from the soil. Sixty percent of the fires were successful in reducing residual fuels with no accelerated loss of nutrients below the root zone. Net losses of Ca^{+2} and Mg^{-2} occurred below the root zone when soil surface temperatures exceeded 300°C, but were insignificant when soil surface temperatures remained below 200-300°C. No other elements were lost (net) from the soil as a result of burning. Precipitation on control soils delivers as much Ca^{+2} as is normally lost below the root zone in the absence of fire. Iron concentrations in the soil water is a good indicator of the intensity of burn. The hotter the fire, the less iron in the soil water as a result of the alkaline pH. Ash shows a definite pattern of nutrient release under the influence of precipitation. Homogeneous subsamples of litter showed predictable nutrient losses when ignited at different temperatures. Overland flow and surface erosion are of little significance on this soil type. Decomposition of Douglas-fir litter was only slightly more rapid on hot burned substrates than on control (unburned) substrates. When the biological life concept was applied to this soil, it showed that this soil is young and capable of withstanding many years of cyclic intensive burns.

684. ———————. 1979. Nutrient losses from timber harvesting in a Larch/Douglas-fir forest. U.S. Dep. Agric. For. Serv., Intermtn. For. Range Exp. Stn., Ogden, UT. Res. Pap. INT-231. 41 p.

Studies of the total amount of biologically essential nutrients removed in logs and water through clearcutting, shelterwood cutting, and group-selection cutting were conducted in the western larch (*Larix occidentalis*)/Douglas-fir (*Pseudotsuga menziesii*) forest at the Coram Experimental Forest near Glacier Park, Montana. Nutrient removal by species was investigated under three intensities of harvest. Results show that with the most intensive logging method (clearcutting) less than 0.25 percent of the total content of eight biologically essential cations in the effective root zone were removed with wood and bark. This means that intensive harvest took away an equivalent of 1.4 of 1 percent of the nutrients stored in the soil and rock of the root zone. In theory, it would require 28,000 years of clearcutting on a 70-year rotation to exhaust the total nutrients in the present root zone. Soil development will slowly extend the root zone downward. Far more important than total nutrients are those nutrients available in the soil. Harvest of wood and bark removed an equivalent of less

than 14 percent of most of the available elements in the root zone. Harvest is a one-point-in-time removal of nutrients that have been accumulated in the wood and bark of trees over 70 years' time. Removal of only 14 percent of what is at one moment available in the soil is a small loss. Unfortunately, we cannot yet measure the weathering rate so we cannot estimate how rapidly the removed nutrients will be returned through weathering. Harvest did remove from 14.8 to 91.7 percent of the available zinc in the soil (accumulated over +70 years). Although zinc is scarce in the parent material, this loss is not serious because sufficient zinc is still available for seedling growth. In most cases bulk precipitation alone will return all of the nutrients removed in harvest within 70 to 100 years. Nutrient losses from harvest on this relatively young, fertile soil is not a problem to management in the absence of erosion.

Nutrient levels in an intermittent stream were virtually unchanged by all logging treatments. The skyline system did not cause erosion. Because the area does not have a permanent stream or impermeable bedrock, it is unsuited to typical watershed study methods. Water samples taken below the root zone did show nutrient losses as a result of harvest, but these were at levels not significant to management. The most severe treatment studied, clear-cutting by skyline and light burning, did not cause serious nutrient depletion from this forest ecosystem. (Author's summary)

685. **Steele, R., R.D. Pfister, R.A. Ryker,** and **J.A. Kittams.** 1981. Forest habitat types of central Idaho. U.S. Dep. Agric. For. Serv., Intermtn. For. Range Exp. Stn., Ogden, UT. Gen. Tech. Rep. INT-114.

A land-classification system based upon potential natural vegetation is presented for the forests of central Idaho. It is based on reconnaissance sampling of about 800 stands. A hierarchical taxonomic classification of forest sites was developed using the habitat type concept. A total of eight climax series, 64 habitat types, and 55 additional phases of habitat types are defined and described. A diagnostic key is provided for field identification of the types based on indicator species used in development of the classification.

In addition to site classification, descriptions of mature forest communities are provided with tables to portray the ecological distribution of all species. Potential productivity for timber, climatic characteristics, surface soil characteristics, and distribution maps are also provided for the types. Preliminary implications for natural resource management are provided, based on field observations and current information. (Authors' summary)

686. **Steijlen, I.** and **O. Zackrisson.** 1987. Long-term regeneration dynamics and successional trends in a northern Swedish coniferous forest stand. Can. J. Bot. 65(5):839-848.

The natural age and stand structure of Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* [L.] Karst.), and birch (*Betula pubescens* Ehrh.) was studied in a virgin forest stand in northern Sweden. The stand has been unaffected by fire during the past 500 years. It is suggested that the variations in age structure and invasion pattern are the result of low-frequency climatic fluctuations influencing seed production, germination, and early survival of seedlings. The periods of climatic amelioration that occurred during the 1870s and during this century have been especially favourable to pine, resulting in a pine-dominated regeneration underneath a tree layer where spruce and birch are the most abundant species. This is contrary to generally accepted theories concerning postfire successional trends in this part of the boreal zone. It is concluded that small gap-phase replacement of trees by climatically induced regeneration and mortality events probably is the reason for the general weak correlation between age and size of trees. It is also concluded that this postfire succession will not lead to a total spruce dominance during a continuous succession under prevailing climate regimes.

687. **Stelfox, J.G., G.M. Lynch,** and **J.R. McGillis.** 1976. Effects of clearcut logging on wild ungulates in the central Albertan foothills. For. Chron. 52:65-70.

The effects on big game of clearcut logging a mature white spruce forest (*Picea glauca*) in strips 10-chains wide, with residual strips 5-chains wide to be logged 12 years later, were studied in a 6-square-mile area of the Rocky Mountain foothills near Hinton, Alberta. Use by deer, elk and moose decreased during the first 5 years following clearcut logging with the decrease most pronounced in scarified cut-overs. Five years after logging, browse production in the unscarified area exceeded the 529 lb/acre in the unlogged forest. In years 9 and 17 the logged unscarified area produced three and four times as much browse as the unlogged forest while production in the logged scarified area averaged 10% below the unscarified area. Changes in species composition and height affected both browse utilization and cover. These habitat changes were further evident in estimates of ungulate use. Observed numbers of big game 17 years after logging and scarification were much lower than expected from the forage carrying-capacity estimates. Forage carrying capacity potentials were one moose/7.7, one elk/3.6 and one deer/0.7 acres. However, in summer, observed populations were one moose/213.3, one elk/71.1 and one deer/40.0 acres respectively. Observed use of the area dropped drastically in winter, apparently due to the absence of adequate cover, to no moose or elk and only one deer/1280 acres.

688. **Stevenson, S.K.** 1979. Effects of selective logging on arboreal lichens used by Selkirk caribou. B.C. Min. For. and Min. Environ., Nelson, BC. Fish and Wildl. Rep. No. R-2. 76 p.

As the first stage in a program to evaluate the effects of selective logging on caribou (*Rangifer tarandus caribou*), the biomass of forage lichens (*Alectoria sarmentosa* and *Bryoria* spp.) below 6 m on standing trees was quantified in an Engelmann spruce - subalpine fir (*Picea engelmanni - Abies lasiocarpa*) stand in the Selkirk Mountains of southeastern British Columbia. Assessment methods were a combination of ratio estimation and variable probability sampling. Total amounts of forage lichen within reach of caribou in the three mature timber plots were estimated at 67 ± 37 kg/ha, 103 ± 21 kg/ha, and 106 ± 37 kg/ha. This forage base is relatively low, both in terms of the herd's estimated food requirements, and compared with other caribou ranges. Selective logging to a 20 in. (51 cm) diameter at stump height limit would reduce available lichen to just over one-quarter of its original amount. Within the Selkirk caribou range, selective logging should be restricted to areas used by caribou for travel. Logging of any kind should be prohibited in areas where caribou concentrate in winter. Immediate research needs include: delineating critical winter ranges, reassessing available lichen after logging, and monitoring caribou use of logged areas. Methods are recommended for inventorying lichen abundance and measuring changes in lichen biomass over time.

689. ——————. 1988. Dispersal and colonization of arboreal forage lichens in young forests. B.C. Min. Environ. and Min. For., Victoria, BC. IWIFR-38. 58 p.

Dispersal and colonization of fragments of arboreal lichens (*Alectoria* spp., *Bryoria* spp., and *Usnea* spp.) in selected second-growth stands on Vancouver Island, British Columbia, were studied. Numbers of lichens on twigs in plots adjacent to mature timber with high lichen abundance declined from high values at 100-150 m from the stand edge and levelled off at 300-400 m. Plots adjacent to mature timber with medium or low lichen levels were low in numbers of lichen fragments, regardless of distance to the mature timber. Of the genera studied, *Bryoria* appeared to be the most effective disperser. *Usnea* was rare in second growth, and can be discounted in planning for forage production.

690. **Stevenson, S.K.** and **J.A. Rochelle.** 1984. Lichen litterfall: its availability and utilization by black-tailed deer. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 391-396.

Amounts of forage available from litterfall and amounts utilized by black-tailed deer (*Odocoileus hemionus columbianus*) were measured in mature conifer forests on northern Vancouver Island. Litterfall forage, including lichens and green conifer foliage, exceeded

understory forage on three of five sites studied. The beard lichens *Alectoria sarmentosa* and *Bryoria* spp. constituted 26 percent by volume of the rumen contents of deer wintering in timber. Quantities of these lichens present in litterfall ranged from 2 to 151 kg/ha/180. Utilization of litterfall was measured by comparing accumulation inside and outside 3-m-high deer exclosures. Significantly more ($P \leq 0.05$) beard lichen litter accumulated inside than outside exclosures; utilization ranged from 37 to 53 percent of available quantities. Because beard lichens are abundant in old-growth forests but sparse in immature stands, the harvesting of mature forests reduces this source of winter forage for black-tailed deer.

691. **Stewart, G.H.** 1986a. Forest development in canopy openings in old-growth *Pseudotsuga* forests of the western Cascade Range, Oregon. Can. J. For. Res. 16:558-568.

Size and age structure, and spatial pattern analysis were used to study the population dynamics of old-growth *Pseudotsuga menziesii* forests. Tree population structures confirmed that in the absence of fire, *Pseudotsuga* was replaced by *Tsuga heterophylla* and/or *Abies amabilis*. Regeneration patterns of these species reflected establishment in canopy openings or under *Pseudotsuga*, but not under *Tsuga*. *Abies amabilis* occurred more frequently as seedlings and saplings in openings than did *Tsuga* because of favourable aspects of its life history. The composition and structure of the pioneer forest developing after fire was a determinant of subsequent regeneration. If *Pseudotsuga* dominated, *Tsuga* and *Abies* invaded the stand at an early stage. Regeneration in stands where *Tsuga* was a large component, however, was limited by dense canopies and the occurrence of canopy openings. These patterns demonstrate the importance of small-scale disturbances such as tree falls in the dynamics of Pacific Northwest conifer forests.

692. ———————. 1986b. Population dynamics of a montane conifer forest, western Cascade Range, Oregon, USA. Ecology 67(2):534-544.

Size and age structure were used to reconstruct the population dynamics of two forested stands in the western Cascade Range, Oregon, USA. Trees with different growth rates and size-age relationships occurred in the same stand. The relationships between diameter and age of 939 aged trees of four species, although statistically significant, were often weak. Data on both age and spatial dispersion added critical information on stand dynamics not available from size alone.

The population structures and regeneration patterns described were strongly influenced by natural disturbances and species' life history characteristics. Periodic fires of variable intensity and extent have produced a mosaic of relatively even-aged patches of different conifer species. The early establishment and dominance by a species on a site was a determinant of subsequent forest regeneration. If *Pseudotsuga menziesii* dominated early, regeneration of *Tsuga heterophylla*, and often *Abies amabilis*, was rapid. If, however, *Tsuga heterophylla* established first, further regeneration of other species was absent or minimal until canopy openings formed.

693. ———————. 1988. The influence of canopy cover on understorey development in forests of the Western Cascade Range, Oregon, USA. Vegetatio 76:79-88.

Natural disturbances, especialy fire and treefalls, influence tree canopy composition in the *Pseudotsuga menziesii* forests of the western Cascade Range, Oregon. The author suggests (1) the composition of understorey vegetation differs according to canopy types and (2) differences in canopy type and canopy openings correlate with degrees of understorey development in similarly aged stands. He concludes that understorey assemblages also reflect disturbance history. Before understorey assemblages can be used to relate community samples to community or habitat types, the extent to which their composition reflects long term influences of stand history vs. differences in site potential must be determined.

694. **Stewart, M.** 1956. Cost study of partial cutting treatments in interior wet belt of British Columbia. B.C. For. Serv., Dep. Lands For., Victoria, BC. Res. Notes No. 32. 22 p.

This study was initiated to compare, on an economic scale, various partial cutting methods under trial in interior British Columbia. Seven selected cutting methods were applied and the cost of each examined. Main tree species present were western white pine, Douglas-fir, western larch and some Engelmann spruce in the upper canopy. Western hemlock and red-cedar are plentiful in the understory. The most valuable products from the stand are white pine logs, cedar poles and quality Douglas-fir. The commonly used (treatment 4) method of cutting proved to give the logger maximum economic return. This cutting method included cutting of all cedar poles down to 12 inches dbh, cutting of white pine to 16 inches dbh and all other species to 14 inches dbh. **

695. **Stinson, N.J.** 1978. Habitat structure and rodent species diversity on north and south-facing slopes in the Colorado Lower Montane Zone. S.W. Nat. 23(1):77-84.

Trapping was conducted to evaluate the relationship of habitat structure to rodent species diversity on north-facing (Douglas-fir forest) and south-facing slopes (ponderosa pine forest) in the Colorado Lower Montane life zone. A total of 376 animals were captured representing five rodent species (*Peromyscus maniculatus, Eutamias minimus, Peromyscus difficilis, Microtus longicaudus*, and *Neotoma mexicana*) during the summer of 1975. The ponderosa pine woodlands showed a greater rodent species diversity (RSD = 0.855), plant species diversity (PSD = 3.11), vertical complexity of vegetation (FHD = 1.45), density of rock outcrops (RKD = 22/ha), and habitat patchiness (CV = 118.1) than the Douglas-fir forests (RSD = 0.389; PSD = 1.53; FHD = 0.81; RKD = 12/ha; CV = 56.7). Habitat patchiness or spatial heterogeneity was a significant predictor of rodent species diversity ($F = 580.4$, $p < .001$). The greater spatial heterogeneity of the ponderosa pine forests seemingly allows greater habitat division and consequently greater species packing.

696. **Stone, E.C., R.F. Grah,** and **P.J. Zinke.** 1972. Preservation of the primeval Redwoods in the Redwood National Park. Parts I and II. Am. For. 78:50-55; 48-56.

This article consists of two parts. Part I is a detailed description of the mosaic of ecosystems contained in the Redwood forest of Redwood National Park. Problems with preservation and management of continuously changing and developing ecosystems are discussed. Steps in developing a management plan for the park are presented. Part II describes the management required outside the park boundaries to protect the Redwoods inside the park. **

697. **Stordeur, L.A.** 1986. Marten in British Columbia with implications for forest management. B.C. Min. For. Lands., Res. Br., Victoria, BC. WHR-25. 57 p.

This problem analysis was initiated as a joint project between the Ministry of Environment and Parks, Wildlife Branch, and the Ministry of Forests and Lands, Research Branch, in response to concern over the potential effect of logging and silvicultural practices on marten (*Martes americana*).

Marten ranked first in revenues over all furbearers in the province for the 1984/85 trapping season. Present management policies to meet harvest demands are directed toward the manipulation of season lengths and gear restrictions, with little or no emphasis on habitat management. Based on results from a trapper questionnaire, marten density was grouped into three categories and was found to correlate roughly to biogeoclimatic units in the province. Ecosystem, stand age, and type of silvicultural practice were found to influence marten activity, prey productivity, and hence marten populations.

It is recommended that baseline studies on denning, resting, and feeding requirements be initiated. Subsequent to these studies intensive investigations on how the impact of silvicultural practices on marten can be lessened should be instituted. Logistic and monetary

constraints may limit study areas and for this reason it is suggested emphasis be placed on coastal ecosystems where data are most sparse and the dynamics of the marten-prey-ecosystem are less complex.

698. **Strand, M.A.** 1974. Canopy food chain in a coniferous forest watershed. *In* Integrated research in the coniferous forest biome. R.H. Waring and R.L. Edmonds (editors). U.S. International Biolog. Prog., Univ. Wash., Seattle, WA. Conif. For. Biome Bull. No. 5, pp. 41-47.

The internal structure and external couplings of the canopy food chain are examined to quantify the pattern of energy distribution in an old-growth Douglas-fir watershed. The food chain has been divided into nine functional groups: grazing vertebrates, grazing insects, sucking insects, seed and cone insects, predaceous birds, parasitic invertebrates, predaceous invertebrates, omnivorous birds, and nest predators. Surveys of the watershed fauna have shown that these functional groups are complex and may contain large numbers of species. For example, the five invertebrate groups may include as many as 450 species.

Modeling techniques are employed to compute total annual consumption and secondary production for two functional groups, grazing insects and omnivorous birds. The estimates are based on field density records, published data, and simplifying assumptions. The annual consumption by grazing insects on the watershed is estimated to be 42.5% kg/ha or about 1.6% of total primary production. The omnivorous bird population consumes 6.2 kg/ha while on the watershed; about 75% of their diet consists of insects. The consumption rates and mean standing crop values are similar to those reported for other forests. At current population levels, this food chain represents only a minor pathway in the total watershed energy flux.

699. **Sturtheit, J.** 1989. "Gap analysis": GIS studies wildlife, biodiversity. GIS World 2:40-42.

This article discusses how GIS technology is being used to provide an assessment of the distribution of biological diversity for conservation purposes. GIS technology is used in a process called "gap analysis" whereby gaps in existing conservation programs—essentially gaps in the system of nature reserves—are identified. Data on species distribution, areas of species richness, areas of high endemism, vegetation types and land-ownership boundaries are combined through GIS to provide an overview of how well existing nature reserves are protecting biological diversity. A gap analysis study began in 1987 in Idaho and another in 1988 in Oregon. Both studies are headed by M. Scott, a U.S. Fish and Wildlife Service employee. **

700. **Suffling, R., C. Lihou,** and **Y. Morand.** 1988. Control of landscape diversity by catastrophic disturbance: A theory and a case study of fire in a Canadian boreal forest. Environ. Manage. 12(1):73-78.

A landscape may be envisioned as a space partitioned by a number of ecosystem types, and so it conforms to a neo-Clementsian model of succession. A corollary is that intermediate disturbance rates should maximize landscape (beta) diversity. This was confirmed using eight boreal forest landscapes in northwestern Ontario, Canada, where intermediate rates of forest fire were associated with highest landscape diversity. Because current measures of evenness subsume a richness measure, it is not, as yet, feasible to assess the relative contributions of evenness and richness to biological diversity, and thus it was not possible to determine the roles of numbers of habitat types and relative amounts of habitat types in the above situation. Both theory and observations suggest that forest fire control in fire-prone landscapes increases landscape diversity, but that it is lowered by fire control in landscapes of intermediate to low diversity.

701. **Sullivan, K., T.E. Lisle, C.A. Dolloff, G.E. Grant,** and **L.M. Reid.** 1987. Stream channels: the link between forests and fishes. *In* Streamside management: forestry and fishery interactions. E.O. Salo and T.W. Cundy (editors). Univ. Wash., Seattle, WA. Contrib. No. 57, pp. 39-97.

The hydraulic characteristics of flow through channels are an important component of fish habitat. Salmonids have evolved in stream systems in which water velocity and flow depth vary spatially within the watershed and temporally on a daily, seasonal, and annual basis. Flow requirements vary during different phases of the freshwater life cycle of salmonids: free passage is necessary during migration of adults; clean and stable gravel beds ensure successful incubation of eggs; and adequate velocity and depth of flow provide space for summer rearing and overwintering. The life cycles of salmonid species have adapted to the temporal variations in flow conditions by timing the phases of the life cycle to take advantage of the seasonal discharge characteristics. Spatial variability enhances species diversity by creating a variety of habitats within stream reaches; these are partitioned among individual species and age groups having different tolerances for velocity, depth, and cover conditions.

Channel morphology is determined largely by sediment and water input to the channels, and is formed during storm events when flow is great enough to transport the coarse sediments lining the channel bed. The resulting channel shape consists of a sequence of recognizable units known as riffles, pools, and boulder cascades. Large obstructions such as woody debris, boulders, and bedrock outcrops alter channel width, increasing the variation in velocity and depth in the vicinity of the obstruction and anchoring the position of pools.

Forest management can affect channel morphology by changing the amount of sediment or water contributed to the streams, thus disrupting the balance of sediment input and removal. Strategies to minimize the effects of land management on channel morphology and fish habitat should include practices that minimize increases in coarse sediment input, and that preserve the morphologic complexity of the channel. (From authors' abstract)

702. **Sullivan, T.P.** 1979. Virgin Douglas fir forest on Saturna Island, British Columbia. Can. Field Nat. 93(2):126-131.

A survey of the Saturna Island Ecological Reserve provided a description of its virgin Douglas Fir (*Pseudotsuga menziesii*) forest. The vegetation was quantitatively analyzed with respect to structure and composition. The tree stratum dominated the structure of this reserve, followed secondarily by the low-shrub and bryophyte strata. *Pseudotsuga menziesii* was the most important tree species with *Tsuga heterophylla* (Western Hemlock) and *Thuja plicata* (Western Red Cedar) probably limited by low precipitation and soil texture. *Gaultheria shallon* (Salal) was the dominant understory species with *Eurhynchium oreganum* and *Hylocomium splendens* dominating the bryophyte stratum.

703. **Swanson, F.J., M.D. Bryant, G.W. Lienkaemper,** and **J.R. Sedell.** 1984. Organic debris in small streams, Prince of Wales Island, southeast Alaska. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep PNW-166. 12 p.

Quantities of coarse and fine organic debris in streams flowing through areas clearcut before 1975 are 3 and 6 times greater than quantities in streams sampled in old-growth stands in Tongass National Forest, central Prince of Wales Island, southeast Alaska. The concentration of debris in streams of clearcut Sitka spruce-western hemlock forests in southeast Alaska, however, is about half that in streams of clearcut Douglas-fir-western hemlock forests in western Oregon. Management guidelines for maintaining natural debris conditions include minimizing the addition of fresh material to a channel during management activities, leaving natural accumulations of debris, and managing streamside areas for production of a continuous, long-term supply of large debris for channels. Considerations in planning stream cleanup include the length of time the debris has resided in the channel and the stability of debris, which is a function of its size, orientation, and degree of burial and decay.

704. **Swanson, F.J., R.L. Fredriksen, and F.M. McCorison.** 1982. Material transfer in a western Oregon forested watershed. *In* Analysis of coniferous forest ecosystems in the western United States. R.L. Edmonds (editor). Hutchinson Ross Publishing Co., Stroudsburg, PA, pp. 233-266.

This chapter describes the nature of material transfer in a coniferous forest ecosystem in terms of: 1. characteristics of the important transfer processes; 2. relations among them; 3. transfer process/vegetation relations; 4. the relative importance of individual processes and process groupings; and 5. the effects of vegetation disturbance on material transfer in a historical context. (From authors' introduction)

705. **Swanson, F.J., R.J. Janda, T. Dunne,** and **D.N. Swanston** (technical editors). 1982. Sediment budgets and routing in forested drainage basins. Proc. Workshop. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-141. 165 p.

Sediment budgets quantify the transport and storage of soil and sediment in drainage basins or smaller landscape units. Studies of sediment routing deal with the overall movement of soil and sediment through a series of landscape units. The 14 papers and 5 summaries from discussion groups in this volume report results of sediment budget and routing studies conducted principally in forested drainage basins. Papers also deal with sediment routing studies using computer models, physical models, and field observations in nonforest environments.

This work emphasizes methods for judging the relative importance of sediment sources within a basin, the many roles of biological factors in sediment transport and storage, and the importance of recognizing changes of sediment storage within basins when interpreting sediment yield. Sediment budget and routing studies are important tools for both research scientists and land managers.

706. **Swanson, F.J.** and **G.W. Lienkaemper.** 1978. Physical consequences of large organic debris in Pacific Northwest streams. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-69. 12 p.

Large organic debris in streams controls the distribution of aquatic habitats, the routing of sediment through stream systems, and the stability of streambed and banks. Management activities directly alter debris loading by addition or removal of material and indirectly by increasing the probability of debris torrents and removing standing streamside trees. We propose that by this combination of factors the character of small and intermediate-sized streams in steep forested terrain of the Pacific Northwest is being substantially altered by forest practices.

707. ———————. 1982. Interactions among fluvial processes, forest vegetation, and aquatic ecosystems, South Fork Hoh River, Olympic National Park. *In* Ecological research in national parks of the Pacific Northwest. E.E. Starkey, J.F. Franklin, and J.W. Matthews (editors). Oreg. State Univ., For. Res. Lab., Corvallis, OR, pp. 30-34.

Interactions among fluvial processes and forest vegetation created a variety of landforms, plant communities, and aquatic habitats in the South Fork Hoh River. We distinguished six geomorphic surfaces based on differences in vegetation and elevation relative to low water level. Relations between high flows and forest vegetation vary from one surface to another. Flood effects included inundation, bank cutting, surface scour, deposition, and transport of large organic matter. Geomorphic processes have created four distinctive aquatic habitats in the valley: main river channel, off-channel areas along the main stem, and valley-wall and valley-floor tributary streams.

708. **Swanson, F.J., G.W. Lienkaemper,** and **J.R. Sedell.** 1976. History, physical effects and management implications of large organic debris in western Oregon streams. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Gen. Tech. Rep. PNW-56.

Large organic debris has historically been an important element in small mountain streams of the Pacific Northwest. The debris serves to slow the movement of water and inorganic and fine organic matter through the channel. Debris may remain in the channel for decades or longer, and tends to stabilize some sections of a streambed and streambanks while destabilizing other areas. The combination of clearcutting and the complete removal of large debris in a channel may deprive a stream of this natural feature of streams for a century or longer. The consequences are likely to be downcutting and "channelization" of the stream, accelerated transport of fine organic and inorganic sediment, and a possible decrease in biological productivity of the stream ecosystem. Therefore, stream debris management during logging operations should include leaving undisturbed the natural, stable organic debris in the channel.

The principal factors controlling the concentration, stability, and functions of stream debris are the history and condition of the surrounding timber stand, flushing history of the channel, stability and abundance of bedload material, steepness of the channel and adjacent hillslopes, and slope stability in the drainage. Because of this complexity, each stream presents a unique situation which should be inspected in the field and considered on an individual basis before a debris management decision is made.

709. **Swift, B.L., J.S. Larson,** and **R.M. DeGraaf.** 1984. Relationship of breeding bird density and diversity to habitat variables in forested wetlands. Wilson Bull. 96(1):48-59.

This study relates breeding bird density and species richness to habitat features in forested wetlands. Breeding bird populations were studied in eight deciduous forested wetlands located in the Connecticut Valley region of Massachusetts. Singing male birds were counted on 10 circular 0.25-ha plots in each study area in June 1978 and 1979. A total of 46 species were observed, with estimated densities varying among study areas from 134-720 males per 40 ha. Avian community parameters (total breeding bird density, bird species richness, and abundance of three foraging guilds) were related to 15 habitat variables by multiple regression and simple correlation. Results suggested that breeding bird communities in forested wetlands are significantly related to vegetation structure and hydrology. Generally, the most poorly drained sites appeared to have the most abundant and diverse breeding bird populations. (Authors' summary)

710. **Swindel, B.F., L.F. Conde,** and **J.E. Smith.** 1984. Species diversity: concept, measurement, and response to clearcutting and site-preparation. For. Ecol. Manage. 8:11-22.

A review of aspects of diversity recently introduced in the statistical literature by Patil and Tallie is given: species diversity as an average property of a community is defined; the property averaged is identified as species rarity; and relations between common indices of diversity and associated measures of rarity are illuminated. This paper also computes common indices of diversity from substantial empirical data collected before clearcutting and site-preparation under two management regimes and for 3 years following planting of slash pine (*Pinus elliottii*) to illustrate that the initial response to these forest operations is increased species diversity, i.e., increased species rarity. This response may be expected whenever clearcutting and site preparation reduces but does not eliminate previously abundant, late-successional species and permits the reappearance of early-successional species, including forbs and grasses.

711. **Swindel, B.F.** and **L.R. Grosenbaugh.** 1988. Species diversity in young Douglas-fir plantations compared to old growth. For. Ecol. Manage. 23:227-231.

Plant species diversity in young *Pseudotsuga menziesii* (Mirbel) Franco stands in the Western Cascades of Oregon was assessed using comparative diversity profiles. These profiles show, among other things, abundances of scarcer species only (*diversity in the tail*). Abundances of scarcer species increased steadily through age 5 years (the last year of

measurement) at which time the young plantations were more diverse than the antecedent old growth. These results are index-free (i.e., not dependent on the choice of a diversity index).

712. **Szaro, R.C., K.E. Severson,** and **D.R. Patton.** 1988. Management of amphibians, reptiles, and small mammals in North America: Proc. of the Symposium. July 19-21, 1988, Flagstaff, AZ. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO. Gen. Tech. Rep. RM-166. 458 p.

More than 50 papers were presented at this conference covering a wide range of topics related to the management of wildlife in North America. Life histories of species, specialized habitats, habitat needs and dependencies, effects of forestry practices on habitats and populations, and possible habitat guidelines for silviculture systems are discussed by various authors. Discussions of the relationship of wildlife management to biological diversity, genetics, species, and ecosystem, and the need for an environmental attitude in wildlife management, are also included. Some of the papers present techniques in sampling designs and survey methods. **

713. **Takekawa, J.Y.** and **E.O. Garton.** 1984. How much is an evening grosbeak worth? J. For. 82:426-428.

Birds consume large numbers of the western spruce budworm (*Choristoneura occidentalis*), a forest insect which defoliates economically valuable stands. We estimated the economic value of bird predation on two stands in north-central Washington by substituting the cost to spray with insecticides to produce the same mortality rate as birds cause. It would cost at least $1,820 per square km per year over a 100-year rotation. This figure may be used to appraise the value of individual predator species, such as the voracious evening grosbeak (*Hesperiphona vespertina*), to evaluate the cost-effectiveness of biological control with birds, and to assess silvicultural treatments and other practices which affect both bird and insect numbers.

714. **Tammi, N.D., S.L. Paige,** and **S.G. Boyce.** 1984. Management alternatives to meet old growth forest objectives: a North Carolina Piedmont case. *In* New Forests for a Changing World: Proc. SAF 1983 National Conven. K.A. Sabol (editor). Oct. 16-20, 1983, Portland, OR. Soc. Am. For., Bethesda, MD. SAF Publ. 84-03, pp. 56-59.

Two management strategies aimed at the integration of old growth stands for wildlife in managed forests are examined using the Uwharrie National Forest in the North Carolina Piedmont as a case study. The first alternative, the retention of existing old growth stands, results in a gradual decline of the proportion of old growth in the forest from 14.5% to 8.6% over a 200 year planning horizon. The second alternative uses area control to produce and maintain the management objective of a constant proportion of 10% old growth in the managed forest.

715. **Taylor, A.H.** and **Q. Zisheng.** 1989. Structure and composition of selectively cut and uncut *Abies-Tsuga* forest in Wolong Natural Reserve and implications for panda conservation in China. Biol. Conserv. 47:83-108.

Giant pandas *Ailuropoda melanoleuca* David inhabit cool temperate, montane, and subalpine conifer forests with a bamboo understorey in Sichuan, Gansu, and Shaanxi provinces, China. Clearcutting of subalpine conifer forest in panda habitat stimulates vegetative growth of bamboos. This impedes tree regeneration and hardwoods dominate sites after clearcutting, with conifers rarely becoming established. This study assesses the effects of selective cutting on patterns of forest regeneration through analyses of the age and size structure of tree populations in selectively cut and uncut forest. Conifer regeneration after selective cutting was adequate to produce a forest similar in structure and composition to uncut subalpine conifer forest. A selective cutting regime in production forest with

pandas would strike a balance between panda conservation and needs for wood products, and would contribute to management initiatives aimed at preserving existing panda populations outside the protection of natural reserves.

716. **Terborgh, J.** and **B. Winter.** 1980. Some causes of extinction. *In* Conservation biology: an evolutionary-ecological perspective. M.E. Soulé and B.A. Wilcox (editors). Sinauer Assoc., Inc., Sunderland, MA, pp. 119-133.

This paper attempts to identifiy some causes of extinction. The author begins by reviewing the principal generalities that have emerged from previous studies of land-bridge and habitat islands, then presents some new results which enable us to answer a number of questions about biological traits that contribute to susceptibility or resistance to extinction. Finally, some inferences are drawn as to why extinctions result from fragmentation of the natural landscape. The author concludes that comparisons of land-bridge and habitat islands with control areas indicate that the long-term survival of isolated populations is strongly area-dependent. Time and area play inverse roles in extinction. Fragmentation of habitats appears to result in a deteriorative ecological chain reaction which begins with stochastic loss of rare species, among which top predators have disproportionate importance because of their key roles in regulating prey populations. Their loss may trigger a series of secondary extinctions. To prevent such reactions, we must preserve complete ecosystems. Corrective and preventive management practices will be the key to conservation in the future. **

717. ——————. 1983. A method for siting parks and reserves with special reference to Colombia and Ecuador. Biol. Conserv. 27:45-58.

Many tropical countries contain large numbers of species with small geographical ranges, here, for convenience, termed endemics. South America, for example, harbours 440 endemic land birds having ranges of less than 50 000 km^2. These comprise about a quarter of the terrestrial avifauna of the continent. Such species are exceptionally vulnerable to deforestation and their preservation will require siting future parks or reserves in just the right places. Using Colombia and Ecuador as an illustration, we describe a simple procedure for locating areas of concentrated endemism that would be optimal for future protection. Unfortunately, there is little correspondence between the points of maximal endemism and the locations of existing and projected reserves in the two countries. The advantages and limitations of using satellite photos for habitat evaluation in centres of endemism are also discussed.

718. **Tesch, S.D.** 1981. Comparative stand development in an old-growth Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) forest in western Montana. Can. J. For. Res. 11:82-89.

The composition, structure, and reproductive dynamics of two old-growth Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) stands, located on opposing north and south aspects, were analyzed to reconstruct their past developmental patterns. Results indicate that the north aspect stand developed an even-aged structure initially and shifted to an uneven-aged structure over time. The theory of monospecific dominance by the climax species is supported on the north aspect as Douglas-fir maintains the highest importance value of all species present. The competitive exclusion principle appears inappropriate in this case as lodgepole pine (*Pinus contorta* Dougl.), an intolerant, seral dominant, is reproducing successfully under the old-growth canopy. The south aspect stand has developed an uneven-aged structure and maintains it as harsh environmental conditions limit reproductive success to favorable microsites, precluding complete canopy closure.

719. **Thomas, D.W.** 1988. The distribution of bats in different ages of Douglas-fir forests. J. Wildl. Manage. 52(4):619-626.

I examined the distribution of activity of bats in different-age Douglas-fir (*Pseudotsuga menziesii*) stands in the Pacific Northwest. Bat activity was higher (P 0.05) in old-growth forests than in mature or young tree stands. In the southern Washington Cascades,

old-growth stands had 2.65-5.67 x higher bat activity than younger stands. In the Oregon Coast Range, old-growth stands had 2.54-9.75 x higher bat activity. Feeding activity was low in all forest stands and activity by bats occurred during the first 15 minutes of the evening, indicating that bats use old-growth forests only for roosting. Reproductive females were not captured at sites 300 m elevation in the Washington Cascades, but were common at elevations 300 m in the Oregon Coast Range. Reductions in old-growth forests may have a more severe impact on populations of breeding bats in the Oregon Coast Range than in the Washington Cascades.

720. **Thomas, D.W.** and **S.D. West.** 1989. Sampling methods for bats. U.S. Dep. Agric. For. Serv., Pac. NW Res. Stn., Portland, OR. PNW-GTR-243. 20 p.

Bats represent the second most diverse group of mammals inhabiting the western slopes of the Cascade Range in southern Washington and the Oregon Coast Range. Bat populations may well be sensitive to changes in forest age, structure, or distribution, but their nocturnal habits and high mobility render the study of the habitat requirements of bats problematical. Unlike most other groups of vertebrates, bats are difficult to either observe or capture, and survey methods are poorly known. This paper reviews techniques for surveying bat populations and presents the methodology used in the Old-Growth Forest Wildlife Habitat Program in the Pacific Northwest.

721. **Thomas, J.W.** 1985. Towards the managed forest: going places that we've never been. For. Chron. 61:168-170.

This article stresses the importance of cooperation and compromise between wildlife focused biologists and wood products focused foresters. The author states that we are living in a time where we seem to be committed to the conversion of most remaining wild forests to the managed state. Often times, wildlife doesn't receive enough attention and when they do they are labelled as "constraints." When wildlife biologists and foresters become adversaries, they sometimes begin to play games to outmaneuver each other. But, warns Thomas, game playing destroys trust among professionals and between professionals and the public. He continues with a discussion of the roles that the players, including the public, must play in this process.

722. ———————— (editor). 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Agric. Handb. No. 553.

This book provides forest managers with a planning framework by describing wildlife habitats in such a way that they can be considered simultaneously with timber management. It is the work of a number of authors (wildlife biologists, plant ecologists, foresters, and soil scientists) who have incorporated comments of forest managers, planners, environmentalists, wildlife biologists and others into their final draft. They have provided the theory and biological data, with figures and numerous examples, that the forest manager needs to consider wildlife concerns in a timber management plan.

The first chapters describe the variety of habitats in the region and appendices provide quick reference tables of biological information about the wildlife species found in these habitats. A chapter on silvicultural options explains two management systems where wildlife and timber management objectives can be successfully integrated. These systems are management for species richness and management for featured species. Either system or a combination of both can be used to develop an area-specific plan suitable for an area's management goals. **

723. **Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.R. Noon,** and **J. Verner.** 1990. A conservation strategy for the Northern Spotted Owl. U.S. Dep. Agric., Int. Bur. Land Manage., Int. Fish Wildl. Serv., and Interior Nat. Park Serv., Portland, OR. 457 p.

The Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl ("the Committee") was established under the authority of an interagency agreement of August 1988 between the USDI National Park Service, USDA Forest Service, USDI Bureau of Land Management, and USDI Fish and Wildlife Service. The Committee's charter was signed by the agency heads and subsequently incorporated into Section 318 of Public Law 101-121 in October 1989. The Committee was asked to develop a scientifically credible conservation strategy for the northern spotted owl.

Since that time, the Committee has reviewed the literature on the northern spotted owl, heard presentations from most of the scientists doing research on spotted owls and from numerous interest groups, and conducted field trips in Washington, Oregon, and northern California to examine the owl's habitat. We have also interviewed dozens of biologists and land managers.

Much of the attention directed toward this bird stems from a growing debate over managing old-growth forests on Federal lands and concern about protecting biodiversity. We understand the significance of these larger issues, but we have kept to our mandate to develop a conservation strategy specifically for the northern spotted owl.

We have concluded that the owl is imperiled over significant portions of its range because of continuing losses of habitat from logging and natural disturbances. Current management strategies are inadequate to ensure its viability. Moreover, in some portions of the owl's range, few options for managing habitat are left, and options are inexorably declining across its range. Delay in implementing a conservation strategy cannot be justified on the basis of inadequate knowledge. (Authors' summary)

724. **Thomas, J.W., D.A. Leckenby, L.J. Erickson, S.R. Thomas, D.L. Isaacson,** and **R.J. Murray.** 1986. Wildlife habitat by design: national forests in the Blue Mountains of Oregon and Washington. Trans. N. Am. Wildl. Nat. Resour. Conf. 51:203-214.

This paper discusses one example of wildlife habitat by design: how foresters and wildlife biologists are affecting the appearance of the forest landscape with their considerations for wildlife habitat conservation in the national forests of the Blue and Cascade Mountains of Oregon and Washington. The authors describe the development of wildlife management practices within this area since the 1950's: establishing management objectives; developing ways to evaluate wildlife habitat; incorporating wildlife habitat criteria into silviculture practices; adapting the latest technology to allow for maximum efficiency and compatibility with evaluations conducted by other resource specialists; monitoring results to ensure that the developing landscape is meeting the objectives for wildlife habitat; and modifying models and techniques. This example illustrates the ongoing process of developing objectives, models, and techniques for wildlife habitat management. The models and techniques we use today will be considered primitive tomorrow. With the development of wildlife habitat management, the evolving landscape is being designed much differently than it would have been in the past. **

725. **Thomas, J.W., L.F. Ruggiero, R.W. Mannan, J.W. Schoen,** and **R.A. Lancia.** 1988. Management and conservation of old-growth forests in the United States. Wildl. Soc. Bull. 16(3):252-262.

Ecological characteristics, harvesting, wildlife, and management of old-growth forests are discussed, with emphasis on the Pacific Northwest. Harvesting old-growth stands truncates natural succession and only 2-15% of presettlement forests remain in the USA. It is concluded that old growth should be retained as part of managed forests so that biotic diversity and ecosystem function can be retained. **

726. **Thomas, J.W.** and **H. Salwasser.** 1989. Bringing conservation biology into a position of influence in natural resource management. Conserv. Biol. 3(2):123-127.

The maintenance of biological diversity has emerged as a primary issue in natural resource management. The best chance to establish biological diversity as a land management objective is on the public lands of the United States. Those lands are publicly owned, legislation and regulations exist that direct attention to maintaining biological diversity, and cadres of appropriately trained people exist to formulate and carry out management plans. These public lands contain 111 of the 135 Kuchler potential natural vegetation types in the United States, with "adequate" representation of 102 types. It seems unlikely that large-scale reservation of much more land will occur. Therefore, the real test for maintenance of biological diversity will occur on lands dedicated to multiple-use management. Conservation biologists are desperately needed to focus attention on biodiversity as a management goal, to provide information necessary to guide management, to train agency personnel in the philosophy and mechanisms of prescribing biodiversity, and to make sure that conservation biology goes to work on the ground. Time is short and opportunities to preserve biodiversity diminish by the day. Speed in putting conservation biology to work on the public lands is essential.

727. **Toews, D.A.** and **D.R. Gluns.** 1986. Snow accumulation and ablation on adjacent forested and clearcut sites in southeastern British Columbia. *In* Proc. of the Western Snow Conf.: 54th Ann. Meet. B. Shafer (editor). April 15-17, 1985, Phoenix, AZ. Col. State Univ., Fort Collins, CO, pp. 101-111.

This study was undertaken to determine the differences in snow accumulation and rate of ablation, and to examine any regional patterns in accumulation and ablation related to elevation and aspect on adjacent forested and clearcut sites in southeastern British Columbia. Snow accumulation was found to be 37% greater on clearcut sites than on forested sites in 60 of the sites measured over a 3-year time period; snow ablation rates were 38% faster on clearcut areas. Relationships of accumulation to elevation and aspect were, for the most part, weak. A comparison of adjacent north and south slopes indicated 16% greater snow accumulation on north slopes. Snow ablation rates, observed weekly, varied between aspects. Peak seasonal ablation occurred earlier on the south aspect than on the north. The disappearance of snow on the south forests and clearcuts occurred 7 - 14 days earlier than in north forests and clearcuts. To desynchronize water delivery to channels intentionally, these differences in snow melt rates and disappearance dates between high and low energy aspects can be used. **

728. **Toews, D.A.** and **M.K. Moore.** 1982. The effects of streamside logging on large organic debris in Carnation Creek. B.C. Min. For., Victoria, BC. Land Manage. Rep. 11. 29 p.

The stability and volume characteristics of large organic debris in undisturbed and logged reaches of Carnation Creek were studied by comparing large scale maps prepared annually for four years before logging and two years following logging. Three reaches that were logged were compared to two that remained unlogged throughout the study. The results showed that the debris is less stable, the debris volumes are similar or lower, the number of pieces is greater, and the average piece size is smaller following logging. These changes are the result of the removal and breaking up of stable instream debris and the additional unstable debris during logging. The report presents preliminary data which indicates that coho fry populations initially increase as a result of the fine debris added immediately following logging but decrease with time as a consequence of channel alternations that resulted from the removal of stable debris. Streamside logging recommendations are presented that are directed toward maintaining the prelogging distribution and stability of organic debris.

729. **Trappe, J.M.** and **R.D. Fogel.** 1977. Ecosystematic functions of mycorrhizae. *In* The belowground ecosystem: a synthesis of plant-associated processes. J.K. Marshall (editor). Col. State Univ., Fort Collins, CO. Sci. Ser. No. 26, pp. 205-214.

The great majority of vascular plants have evolved to a dependence on mycorrhizae as the most metabolically active parts of their root systems. Most woody plants require mycorrhizae to survive, and most herbaceous plants need them to thrive. Despite their relatively small biomass, the mycorrhizal fungi (mycobionts) are vital for uptake and accumulation of ions from soil and translocation to hosts because of their high metabolic rate and strategically diffuse distribution in the upper soil layers. The mycobionts produce enzymes, auxins, vitamins, cytokinins, and other compounds that increase rootlet size and longevity. They commonly protect rootlets from pathogens. They absorb and translocate water to the host.

Most mycobionts, in turn, depend on their hosts for carbon products. Except for orchid mycobionts, few are capable of decomposing organic matter, although their respiration contributes significantly to evolution of CO_2 from soil. The fungal mycelium and sporocarps are sources of accumulated nutrients and energy for decomposers and consumers. Nutrients and carbon can be translocated from one vascular plant to another by a shared mycorrhizal mycelium.

The several thousand species of fungi believed to form mycorrhizae encompass great physiological diversity. They differ in numerous ways, including degree of host specificity, resistance to environmental extremes, selectivity in ion uptake, and production of biologically active products. Net effects of one mycobiont on a host can differ from those of another, although overall functions are shared by most.

As key links in belowground nutrient and energy cycling, mycorrhizae and their mycobionts can be ignored only at substantial peril of reaching unreal conclusions about ecosystem processes.

730. **Triquet, A.M., G.A. McPeek,** and **W.C. McComb.** 1990. Songbird diversity in clearcuts with and without a riparian buffer strip. J. Soil Water Conserv. 45(4):500-503.

Equitability, richness, and diversity of breeding bird communities were monitored on four watersheds in 1983 and 1986. The community parameters were similar among all watersheds before treatment of two of them with different harvest methods in 1983. Bird abundance increased 21% and 23% on the two clearcuts during the second growing season after cutting. Bird species richness and bird diversity were highest on an uncut control area of mature forest and a best management practices harvest unit with a riparian buffer strip. Bird diversity and species equitability were lowest on a logger's choice unit without a buffer strip. Clearcutting by best management practices provided habitat for some species of mature forest birds that logger's choice clearcutting did not.

731. **Triska, F.J.** and **K. Cromack, Jr.** 1980. The role of wood debris in forests and streams. *In* Forests: fresh perspectives from ecosystem analysis. R.H. Waring (editor). Oreg. State Univ., Corvallis, OR, pp. 171-190.

In the Pacific Northwest, old-growth forests and their associated streams contain large quantities of coarse woody debris. To date, such debris has been considered an impediment to reforestation and stream quality. Consequently, it has been virtually ignored in ecological studies. In this paper, the authors attempt to correct that omission by exploring how wood debris is used in forest and stream ecosystems.

The authors describe the amounts of woody debris in various forest and stream ecosystems and the rates of accumulation in each; how debris modifies existing habitats and creates new ones; how rapidly coarse woody debris breaks down into its component elements; and how its carbon and other elements are recycled. Finally, they discuss what implications these data have for managers of forested watersheds in the Pacific Northwest. **

732. **Triska, F.J., J.R. Sedell,** and **S.V. Gregory.** 1982. Coniferous forest streams. *In* Analysis of coniferous forest ecosystems in the Western United States. R.L. Edmonds (editor). Hutchinson Ross Publishing Co., Stroudsburg, PA, pp. 292-332.

The author presents a synthesis of research into the following aspects of coniferous forest streams: stream structure and function, organic matter budget, spatial and temporal aspects of streams, and forest land-use impacts. Most of the research was conducted in or near the H.J. Andrews Environmental Forest in Oregon. Streams in this area are first- and second-order, and have high gradients and some exposed bedrock. Generally, they are heavily shaded, with wood and leaf litter forming the energy base. Input of organic matter, especially large woody debris, plays a major role in stream structure and function. Shading is important in autotroph function. Stream function, structure, and organic matter budgets are influenced by a number of factors, including the temporal and spatial aspects of streams. Human land-use practices also strongly affect stream structure and function. **

733. **Triska, F.J., J.R. Sedell, S.V. Gregory, K. Cromack, Jr.**, and **F.M. McCorison.** 1984. Nitrogen budget for a small coniferous forest stream. Ecol. Monogr. 54(1):119-140.

An annual nitrogen budget is presented for a small stream draining Watershed 10, H.J. Andrews Experimental Forest, Oregon. The role of allochthonous debris in the input, flux, and export of nitrogen is emphasized in the material balance budget. All material entering the stream channel was presumed to enter the water sometime during the year. Material estimates are based on total channel area.

The major annual nitrogen input (1974-1975) was subsurface flow (11.06 g/m^2) as dissolved organic nitrogen (10.56 g/m^2) and nitrate (0.50 g/m^2). Biological inputs of nitrogen amounted to 4.19 g/m^2 as direct terrestrial inputs of: litterfall (1.35 g/m^2), lateral movement (1.78 g/m^2), and throughfall (0.30 g/m^2). Nitrogen fixation on fine wood debris contributed an additional 0.76 g/m^2 based on rates from a nearby watershed. Total nitrogen input was 15.25 g/m^2.

The nitrogen pool was dominated by large amounts of particulate organic matter. Coarse wood constituted 32% of the nitrogen pool (3.80 g/m^2) and fine wood fractions 18% (2.18 g/m^2). The coarse wood fraction greatly influenced stream morphology. Fine organic particulates constituted an additional 40% of the nitrogen pool (4.77 g/m^2).

DON (dissolved organic nitrogen) export (8.38 g/m^2) was less than input, presumably due to biological uptake associated with litter mineralization, sorption, and chemical flocculation. Due to effective retention of particulate inputs by debris dams, biological processing in the particulate nitrogen pool, and uptake and sorption of DON, most particulate organic inputs increased in nitrogen concentration prior to export. Particulate organic nitrogen input (3.13 g/m^2) was greater than export (2.53 g/m^2). Total annual nitrogen output was 11.36 g/m^2, resulting in a gain of 3.89 g/m^2/yr to the stream. Thus, the stream was not operating on an annual steady state, but on an input-output regime related to the processing of refractory wood debris and resetting by major storms.

Although particulate and dissolved nitrogen loss per hectare was small for the 10-ha watershed, these losses passed through or were accumulated in a pool encompassing <1% of the watershed area. This concentration of N in the stream allowed establishment of a separate ecosystem whose processing efficiency and capabilities for nutrient cycling were related to the retention capacity of the channel and nutrient quality of inputs with the reach.

734. **Troendle, C.A.** 1983. The Deadhorse experiment: a field verification of the subalpine water balance model. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO, Res. Note RM-425. 17 p.

Thirty-six percent of a small, 41-ha, subalpine watershed in the Fraser Experimental Forest was harvested using a system of small 5-H circular clearcuts. Simulations, using the Subalpine Water Balance Model, indicated that a 4.3-cm increase in flow could be expected in an average year following the proposed treatment. Predictive techniques also indicated 30% more snow would be deposited in the openings. Annual water yield has increased an

average of 4.6 cm during the first 4 years after treatment with no detectable effect on peak flow rates. Significantly more snow was found in the openings than in the forest, but mean peak water equivalent for the watershed was not significantly altered.

735. ——————. 1987. The potential effect of partial cutting and thinning on streamflow from the subalpine forest. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO., Res. Pap. RM-274. 7 p.

Process studies suggest that thinning young lodgepole pine stands in Colorado and Wyoming significantly reduces winter interception loss. Soil moisture studies in lodgepole pine stands that range in basal area from 32 ft^2 to 180 ft^2 per acre, show that soil water depletion (and ET loss) is reduced and water available for streamflow is increased in direct proportion to the basal area reduced. However, because the subalpine environment is so precipitation limiting rather than energy limiting, the effect of basal area reductions on soil water depletion is eliminated in dry years.

736. **Tucker, G.F., T.M. Hinckley, J.W. Leverenz,** and **S.-M. Jiang.** 1987. Adjustments of foliar morphology in the acclimation of understory Pacific silver fir following clearcutting. For. Ecol. Manage. 21:249-268.

Growth, phenology, shoot morphology and water status of both newly exposed and unexposed understorey *Abies amabilis* trees growing at 1200 m in the Washington Cascades were examined over a 3-year period. A transect was established in June 1981 perpendicular to the East - West edge of a clearcut made in February 1981. Trees from 4 plots along the transect were studied (within the residual old-growth stand, on the inside edge, on the outside edge and well within the clearcut). The exposed plots were warmer, drier and brighter than stand plots. Significant differences in water potential and leaf conductance were not observed and there were no apparent differences in the timing of bud burst between trees from the 4 plots. However, branch growth and shoot morphology (measured by Silhouette Area Ratio) were significantly altered. Foliage damage and leaf drop were three times higher in the centre than along the edge of the clearcut. Photoinhibition, caused by sustained high light, appeared to be the major cause of this damage to the foliage. Although buds were preset under shade, shoots emerging in the sun had a sun shoot morphology. Branch growth had fully recovered in exposed trees in 1982, and in 1983 both height and branch growth were increasing. Trees released by clearcutting in 1972, which had high rates of terminal growth in 1982, showed recovery patterns similar to the newly released study trees and thus provided a longer-term examination of the transition from shade to sun foliage morphology, crown structure and growth pattern.

737. **Turner, D.P.** and **E.H. Franz.** 1985a. The influence of canopy dominants on understory vegetation patterns in an old-growth cedar-hemlock forest. Am. Midl. Nat. 116(2):387-393.

Spatial variation was examined in understory species composition and cover in an old-growth western hemlock (*Tsuga heterophylla*)-western red cedar (*Thuja plicata*) stand. Total understory cover increased with distances from the stem to the canopy perimeter of both cedar and hemlock individuals but was consistently higher under cedar. Species number was also higher under cedar (28/80 m^2) than hemlock (22/80 m^2), and of the 21 species found under both trees, 13 had significantly higher frequencies under cedar. In a polar ordination, understory plots clustered in relation to overstory species. These observations suggest that microsite heterogeneity associated with large individual trees provides a basis for niche differentiation among understory species in this stand type.

738. ——————. 1985b. The influence of western hemlock and western redcedar on microbial numbers, nitrogen mineralization, and nitrification. Plant and Soil 88:259-267.

Microbial numbers in the forest floor and mineral soil (Al horizon) under large individual western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*) trees were compared. The lower pH and base saturation of hemlock samples was associated with

higher fungal spore counts while cedar samples had higher total microbial counts and populations of ammonium oxidizing bacteria. Nitrogen mineralization rates were greater in laboratory incubations of hemlock soil but nitrification was only observed in incubations of cedar soil. These differences in nitrogen mineralization and nitrification are aspects of species-specific nutrient cycling regimes.

739. ———————. 1985c. Size class structure and tree dispersion patterns in old-growth cedar-hemlock forests of the northern Rocky Mountains (USA). Oecologia 68:52-56.

Tree population size structures and dispersion patterns were studied using stem maps in three old-growth western hemlock (*Tsuga heterophylla* Sarg.) - western redcedar (*Thuja plicata* Donn.) stands in the Rocky Mountains of northern Idaho and adjacent Washington. The two species were codominant in one stand, hemlock dominated the second and cedar the third. Shade intolerant species such as western white pine (*Pinus monticola* Dougl.) were present only as canopy individuals. Hemlock, but not cedar, was well represented in size classes with dbh less than 20 cm. Although large individuals of both species have substantial influences on soil properties beneath them, forming distinct cedar or hemlock patches, nearest neighbour analyses did not indicate that these patches influence tree recruitment patterns. Juvenile trees were generally found in monospecific groups, and their location was most dependent on rotting wood and other safe sites. Aggregation decreased as size class increased for both species in all cases except for cedar in the mixed stand, where the largest size class was aggregated. Aggregation of large cedars suggests that proximity to conspecifics increases survivorship among cedar in mixed stands. This may be due to the formation and maintenance of soil patches favoring a cedar cycling regime.

740. **Turner, J.** and **J.N. Long.** 1975. Accumulation of organic matter in a series of Douglas-fir stands. Can. J. For. Res. 5:681-690.

The total aboveground biomass of a series of Douglas-fir stands which are located in western Washington increased with age while the foliar biomass and total crown biomass reached a steady state of about 11,000 kg/ha at between 40 and 50 years, depending upon stand density. Maximum wood productivity occurred near the time of crown closure, but the age of crown closure varied, with denser stands reaching crown closure at a younger age. Understory aboveground biomass and returns represented a significant portion of stand organic matter before crown closure but decreased in importance as the stand increased in age. In terms of relative contribution to stand organic matter, the vascular species of the understory were supplanted by mosses during the later stages of stand development. While the understory represented a small proportion of organic matter distribution, that is, less than 5% of standing plant biomass, it was a significant proportion of total productivity (up to 17%) and an even higher proportion of organic matter that was returned to the forest floor (up to 43% of total return). The forest floor in this series of stands did not reach a steady state but continued to increase in weight. The decomposition rate appeared to decrease with age.

741. **Turner, J.** and **M.J. Singer.** 1976. Nutrient distribution and cycling in a sub-alpine coniferous forest ecosystem. J. Appl. Ecol. 13:295-301.

In this paper the authors characterize nutrient pools and the magnitude of nutrient transfers in an old-growth (175-year-old) forest of Pacific silver fir (*Abies amabilis*). The study was conducted at 1200 m elevation in the Findley Lake basin in the city of Seattle's Cedar River watershed, in Washington. The distribution of N, P, K, Ca, Mg, and Mn in the ecosystem was described and estimations of nutrient transfer were made. Tree growth was judged to be slow and accumulation of nutrients in trees was equally low. Uptake was noted to be about 12, 1, 25, 23, 5, and 2 kg/ha per year for N, P, K, Ca, Mg, and Mn, respectively. Requirements for growth were estimated at 23, 2, 22, 20, 2, and 1 kg/ha per year for the same nutrients. Biomass and nutrient content of understory lichens were found to be similar at approximately 3% that of the trees. Nutrient returns to the forest floor were found to be

18, 2, 23, 45, 4, and 5 kg/ha per year for N, P, K, Ca, Mg, and Mn, respectively, mostly in the form of litter, except for the importance of throughfall for K and Mg. Losses from the rooting zone at approximately 3, 0.5, 2, 7, 1, and 0.1 kg/ha per year slightly exceeded inputs from rainfall. **

742. **Urban, D.L., R.V. O'Neill,** and **H.H. Shugart, Jr.** 1987. Landscape ecology: a hierarchical perspective can help scientists understand spatial patterns. BioScience 37(2):119-127.

Landscape ecology is an emerging discipline, state the authors of this paper, which seeks to understand the development and dynamics of pattern in ecological phenomena, the role of disturbance in ecosystems, and characteristic spatial and temporal scales of ecological events. The authors outline a hierarchical paradigm of pattern and behaviour to aid in the understanding of spatial patterns. The events and patches that compose a complex landscape occur at scales that are positively correlated in time and space. Hierarchy theory explains how, for example, a forested landscape is a mosaic of patches, and patches are the component of pattern. Hierarchy theory can serve as a unifying conceptual and analytical framework for landscape ecology, explaining how patches relate to landscape pattern and process. **

743. **Ure, D.C.** and **C. Maser.** 1982. Mycophagy of red-backed voles in Oregon and Washington. Can. J. Zool. 60:3307-3315.

We analyzed stomach contents from two subspecies of *Clethrionomys californicus* and three subspecies of *C. gapperi* from coniferous forests of Oregon and western Washington. Seasonal diets were determined for each subspecies of *C. californicus.* Major foods eaten were the fruiting bodies of hypogeous ectomycorrhizal fungi, predominantly Gasteromycetes, and fruticose lichens, regardless of season. Fungus consumption partially depended on availability. When fungi became scarce, lichens were substituted. Other foods were important only during winter in Cascade Range. *Clethrionomys gapperi* from Washington consumed large quantities of conifer seed and green plant parts in midautumn. These materials were a small part of the diets of Oregon red-backed voles in midautumn, but this may relate to localized small seed crops. Dependence on ectomycorrhizal fungi by western red-backed voles probably accounts for the latter's disappearance from deforested sites.

744. **Usher, M.B.** 1985. Implications of species-area relationships for wildlife conservation. J. Environ. Manage. 21:181-191.

The two criteria, diversity and area, have frequently been used in the assessment of conservation value or conservation potential. In a review of the relationship between these criteria, it is concluded that an equation of the form $S=CA^z$, where S is the number of species (a crude measure of diversity), A is area and C and z are constants, provides a generally satisfactory description. This relationship is used to investigate two conservation strategies: (1) which site should be selected as a reserve and (2) would it be better to allocate resources to a few large reserves or to many more smaller reserves? The discussion draws attention to the complexity of conservation strategies, showing that many factors are interrelated and that functions more complex than simple species-area models may be necessary.

745. **Van Ballenberghe, V.** and **T.A. Hanley.** 1984. Predation on deer in relation to old-growth forest management in southeastern Alaska. *In* Proc. Symp. on Fish and Wildlife Relationships in Old-Growth Forests. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors). April 12-15, 1982, Juneau, AK. Am. Inst. Fish. Res. Biol., Morehead City, NC, pp. 291-296.

Populations of Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) that occupy old-growth forest in southeastern Alaska are hypothesized as existing at equilibrium in naturally regulated systems that include the gray wolf (*Canis lupus*). Wolf densities are adjusted to prey biomass density, and predation acts to reduce deer fawn survival and increase mortality of adults compared to areas where wolves are absent. Recruitment to such

deer populations is low, and deer densities tend to be lower than the available vegetation could support. A simple model of predation that links several important variables is developed, based on the ratio of deer per wolf at equilibrium. This ratio is determined by the kill rate of wolves, the potential rate of increase of deer, and the mortality of deer due to causes that are additive to predation. The model suggests a negative exponential relationship between deer:wolf ratios and the rate of increase of deer. If the fecundity of a deer population declines so as to cause a corresponding decline in rate of increase below certain thresholds, the number of deer per wolf required to maintain equilibrium increases exponentially. This results in a rapid decline in deer density, with predation as the proximate cause. Logging of old-growth forest stands can initiate such declines by lowering the carrying capacity of the environment for deer. Deer populations subject to such scenarios may fail to increase from extremely low densities unless wolf numbers are reduced and hunting is curtailed. The management implications of wolf control are discussed.

746. **Van der Kamp, B.J.** 1975. The distribution of microorganisms associated with decay of western red cedar. Can. J. For. Res. 5:61-67.

The heartwood of old growth western red cedar (*Thuja plicata* Donn.) on the British Columbia coast exhibits a rather consistent color pattern surrounding columns of decay. Surrounding the column of laminar decay lies a zone of brown stained wood; to the outside of this one finds a narrower layer of red stained wood, and the outer heartwood is straw-colored. Isolation of microorganisms demonstrated that whereas the outer heartwood was essentially sterile, the red and brown stained sound wood was inhabited by three fungi, two of which were restricted to the inner portion of the brown zone. The typical laminar decay apeared to be caused by *Poria albipellucida* Baxter which was isolated only from a narrow zone at the edge of the sound wood. The central decay column was inhabited by a large number of filamentous fungi, yeasts, bacteria, insects, and plant roots. These results support the hypothesis that decay of western red cedar involves a succession of organisms. Presumably the early invaders destroy the toxic natural extractives present in the heartwood.

747. **Van Pelt, N.S.** 1980. Dendrochronological sites: associated values and issues. J. Ariz.-Nev. Acad. Sci. 15:26.

Dendrochronologists have long used, and continue to seek, old forest and woodland stands of suitable species for the derivation of tree-ring chronologies. Beginning in the southwest and intermountain regions of the U.S., the discipline has the objective of completing a grid of sampling stations in North America and abroad for paleoclimatological reconstruction, teaching, and correlative studies. Old trees showing a common response to environmental factors are preferred. The purpose of this investigation was to describe tree-ring sites as superlative or critical environments, as sources of benefits and values in addition to tree-ring series, and as living resources possibly influenced by three current forest management issues: liquidation of old-growth forests, exploitation of forests on stress sites, and completion of systems of ecological reserves in North America. Several conservation solutions, such as the Natural Heritage Program concept, are tentatively presented.

748. **Van Pelt, N.S.** and **T.W. Swetnam.** 1990. Conservation and stewardship of tree-ring resources: living trees and subfossil wood. Nat. Areas. J. 10(1):19-27.

Sources of wood used in dendrochronology (analysis of dated tree rings) are essential to long-term understanding of climatic and ecological changes. Tree-ring resources also constitute valuable and often poorly understood forms of biodiversity. However, living and remnant resources and sample collection sites are frequently unprotected, although they deserve consideration in natural heritage programs and in the selection of new natural areas. This paper describes living and subfossil resources, presents rationales for their protection, and suggests ancillary conservation and research values. Existing and potential natural areas

can perpetuate important occurrences while benefitting from chronology-based stewardship information. Sample-collection impacts and their mitigation are discussed and recommendations are made for heritage programs, conservationists, and North American dendrochronologists.

749. **Veblen, T.T.** 1986a. Age and size structure of subalpine forests in the Colorado Front Range. Bull. Torrey Bot. Club 113(3):225-240.

Age and size data on over 2200 trees were used to reconstruct developmental patterns and regeneration dynamics of four successional and two climax stands of subalpine forests in the Colorado Front Range. The dominant tree species of these forests are Engelmann spruce (*Picea engelmannii*), *subalpine fir* (*Abies lasiocarpa*), limber pine (*Pinus flexilis*), and lodgepole pine (*Pinus controta*). Due to relatively weak relationships between age and size for all four species, patterns of stand development could not have been reliably inferred from size data alone. Following wildlife on the most xeric sites, limber pine is the principal pioneer species and dominates seedling establishment for 50 to 100 or more years. At most sites, however, Engelmann spruce and subalpine fir eventually establish and gradually replace limber pine. On less xeric sites, depending on availability of seed, either Engelmann spruce or lodgepole pine, alone or together, may act as pioneer species. Establishment of subalpine fir may be coincident or may be several decades later. Eventually the stands investigated are consistent with the view that variation in establishment is at least as important as mortality in shaping age frequency distributions in successional stands. In climax Engelmann spruce-subalpine fir stands both species have all-aged populations; the typically greater abundance of young subalpine fir appears to be compensated by the much greater longevity of Engelmann spruce.

750. ———————. 1986b. Treefalls and the coexistence of conifers in subalpine forests of the central Rockies. Ecology 67(3):644-649.

Differences in replacement patterns and frequencies of treefalls were investigated for subalpine fir (*Abies lasiocarpa*) and Englemann spruce (*Picea engelmannii*) in the Colorado Front Range. In seven old-growth unlogged stands, data were collected on age and size of trees, frequencies of fallen trees, growth rates of trees, and sizes and abundances of occupants of treefall gaps. Subalpine fir accounted for 74.5% of the potential successors in the 125 treefall gaps sampled. The much greater abundance of subcanopy trees of subalpine fir implies more frequent recruitment into the canopy. However, its greater recruitment rate into the canopy is approximately balanced by its greater loss from the canopy; even through subalpine fir accounted for only 37% of the canopy trees it accounted for 76% of the fallen trees. The consistently lower frequency of Engelmann spruce as treefalls and its greater longevity compared to subalpine fir imply a lower adult mortality rate for the spruce. Consequently, the greater proportion of young subalpine fir does not imply that it will gradually replace Engelmann spruce in old-growth stands unaffected by large-scale exogenous disturbance. The results of this study provide empirical support for the coexistence of ecologically similar species by means of different life history strategies.

751. **Verner, J.** 1980. Bird communities of mixed-conifer forests of the Sierra Nevada. *In* Proc. Workshop on Management of Western Forests and Grasslands for Nongame Birds, Feb. 11-14, 1980, Salt Lake City, UT. U.S. Dep. Agric. For. Serv., Intermtn. For. Range Exp. Stn., Ogden, UT. Gen. Tech. Rep. INT-86. 25 p.

Avian community composition in the various seral stages and canopy closure classes of mixed-conifer forests of the Sierra Nevada of California is examined from the standpoint of forest management. Comparison of field studies with predictions of a bird species-habitat association matrix suggests that managers can rely on information in the matrix when assessing responses of bird communities to changes in vegetation structure in the forest. Modern forest management practices have altered the structure and species composition of mixed-conifer forests in relation to pristine conditions. The most important change from the

standpoint of bird communities is a substantial reduction in the amount of forest in mature to old-growth conditions. Several recommendations are made, some directly related to assurance of adequate acreages of mature and old-growth forest stands.

752. **Verner, J.** and **A.S. Boss** (technical editors). 1980. California wildlife and their habitats: western Sierra Nevada. U.S. Dep. Agric. For. Serv., Pac. SW For. Range Exp. Stn., Berkeley, CA. Gen. Tech. Rep. PSW-37. 439 p.

This is a report on wildlife and their habitats in the western Sierra Nevada zone of California. The report provides a species list, a species habitat matrix, and species notes and distribution maps for the various amphibians, reptiles, birds, and mammals in the zone. Where applicable, notes are also presented on rare species. **

753. **Verner, J.** and **T.A. Larson.** 1989. Richness of breeding bird species in mixed-conifer forests of the Sierra Nevada, California. Auk 106:447-463.

We report relationships between bird species richness (BSR) and physical and biotic attributes of 51 sites in mixed-conifer forests of the Sierra Nevada of California. Three sites were in uncut forest and one was in a permanent shrubfield. The remaining 47 had been logged one to several times in the previous 10 years. Mean BSR in "unforested" sites (n = 20) was 7.6 for 1978 and 1979, combined; that in "forested" sites (n = 31) was 20.1. On 6-ha subplots in the forested sites, BSR averaged 16.7 breeding species in 1978 and 16.5 in 1979. Total crown volume was the best single predictor of BSR in each year separately and in the pooled data set for both years. Total crown volume accounted for 76% of the variance in BSR in the pooled data. Total crown volume and site size made up the best 2-variable subset for predicting BSR in each year separately and in both years combined. Addition of 3 and 4 variables to the predictor subsets accounted for little additional variance in all cases. The simple correlation between foliage height diversity (FHD) and BSR was significant, but when the covariance of FHD with other independent variables, especially total crown volume, was controlled through partial correlation, FHD was among the least useful variables for predicting BSR. BSR was less well predicted on forested and unforested sites separately, with 2-, 3-, and 4-variable subsets accounting for only 38-61% of the variation, compared with 76-84% for all sites combined.

754. **Verner, J., M.L. Morrison,** and **J.C. Ralph.** 1986. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Oct. 7-11, 1984, Fallen Leaf Lake, CA. Univ. Wis. Press, Madison, WI. 470 p.

This volume is based on the international symposium, "Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates," held in October 1984 in California. The objective of the symposium was to provide a forum for communication between researchers and land managers on the use of wildlife-habitat modeling. This volume provides examples of models in use to predict how terrestrial vertebrates will respond to habitat change. The volume contains 60 papers divided into six topic areas: Part I—Development, testing and application of wildlife-habitat models; Part II—Biometric approaches to modeling; Part III—When habitats fail as predictors; Part IV—Predicting effects of habitat patchiness and fragmentation; Part V—Linking wildlife models with models of vegetation succession; and Part VI—Synopsis. A section on references is also provided. **

755. **Vitousek, P.M.** 1985. Community turnover and ecosystem nutrient dynamics. *In* The ecology of natural disturbance and patch dynamics. S.T.A. Pickett and P.S. White (editors). Academic Press, Inc., Toronto, ON, pp. 325-333.

In this chapter the author explores the relationships among disturbance, patch development, and nutrient availability. Nutrient availability is reviewed in terms of both nutrient pools and nutrient turnover. Nitrogen and phophorus are emphasized as they most often limit plant growth. To examine how nutrient cycling changes over time, the characteristics of a patch created by clearcutting are described. The effects of clearcutting on nutrient cycling is also

compared to that of natural disturbances including fire and wave-form dieback. Little information, however, is available to discuss the relationship of nutrient dynamics to smaller patches such as single tree gaps. The importance of understanding patch dynamics and patterns of vegetation turnover to interpret watershed-level nutrient budgets is outlined. **

756. **Voegtlin, D.J.** 1982. Invertebrates of the H.J. Andrews Experimental Forest, Western Cascade Mountains, Oregon: a survey of arthropods associated with the canopy of old-growth *Pseudotsuga menziesii*. Oreg. State Univ., For. Res. Lab., Corvallis, OR., Special Publ. 4. 30 p.

For forest entomologists. Techniques are described for collecting arthropods in major habitats of the canopy of old-growth Douglas-fir trees. Species commonly collected in three such trees in the H.J. Andrews Experimental Forest are identified with their relative abundance, within-tree habitat, and yearly quarter of collection.

757. **Vogl, R.J.** 1973. Ecology of knobcone pine in the Santa Ana Mountains, California. Ecol. Monogr. 43:125-143.

Knobcone pine (*Pinus attenuata*) is restricted in the Santa Ana Mountains to hydrothermally modified serpentinite which supports only limited shrub growth as opposed to the surrounding dense chaparral on nonspecialized substrates. *Ceanothus papillosus* var. *rowaenus* and *Ribes malvaceum* var. *viridifolium* are also restricted locally. The pines survive on the serpentinite by tolerating the existing edaphic conditions, including nitrogen and phosphate deficiencies and low pH, and because otherwise dense competitive growth has been minimized. The water-retaining capacity of the serpentinite is nearly double that of the chaparral soils. This soil characteristic, the frequent fogs, the location of the pines in fog gaps, the scattered growth, multiple-trunked trees, spreading crowns, and medium-length needles all contribute to the persistence of the pines by enhancing their ability to intercept marine air and produce considerable fog drip which is readily held by the soils.

The controlling influences of the serpentinite diminish as soil genesis advances. This is countered by the dynamic expansion and uplifting of the serpentine body and by continuous erosion which is linked to the friable geology, typically steep slopes, thin soils, sparse cover, and repeated disturbance by fire. The life cycle of these knobcone pines is related to fire, and its periodic occurrence is a necessity for survival. The pines posses a strict closed-cone habit, with firmly attached cones accumulating throughout the life of each tree. The seed remains until heat generated by a fire opens the cones. Cones are seldom burned, and the seed is not shed until well after the fire, remaining viable for at least 3 years in open cones. Fire creates pioneer conditions necessary for seedling establishment. Trees have a short lifespan and occur in even-aged groves that date back to known fires.

758. **Vogt, K.A., R. Dahlgren, F.C. Ugolini, D. Zabowski, E.E. Moore,** and **R. Zasoski.** 1987. Aluminum, Fe, Ca, Mg, K, Mn, Cu, Zn and P in above- and belowground biomass. II. Pools and circulation in a subalpine *Abies amabilis* stand. Biogeochemistry 4:295-311.

Elemental concentration of above- and belowground tissues were determined in an *Abies amabilis* stand in the Cascade Mountains, Washington, USA. These data were used to calculate the pools and circulation of trace elements and micronutrients on a stand level. For all elements except Al, a greater proportion (from 62 to 87%) was distributed in above- rather than belowground tissues. This contrasted sharply with the biocirculation of elements where 97% of the Al and Fe, 88% of the Cu and 67-84% of the Ca, P, and Mg of total detrital cycling was from the belowground components. Aboveground tissues, however, contributed 69% of the Zn, 65% of the K and 68% of the Mn found in annual detritus production. The proportion of total element pool circulated annually was the highest for Al (82%) and Fe (32%) followed by 13% and less for the remaining elements. Copper, Fe and Al were accumulated in root tissues, while Mn and Zn accumulated in foliage.

We hypothesize that roots are an effective mechanism for avoiding Al toxicity in these subalpine ecosystems. The large root biomasses of these stands allow for high Al levels to be taken up and immobilized in roots; this is observed in the significantly higher Al

accumulations in below- than aboveground tissues. The high root turnover in these stands is hypothesized to be a result of root senescence occurring in response to high Al accumulation. Furthermore, Al inputs into detritus production occur by soil horizon so that roots with high Al concentrations located in the Bhs horizon turnover and are retained within that horizon. These roots also decompose very slowly (99% decay = 456 years) due to the high Al and low Ca, Mn and Mg present in these tissues and therefore have very little impact on short-term cycling.

759. **Vogt, K.A., R.L. Edmonds,** and **C.C. Grier.** 1981. Seasonal changes in biomass and vertical distribution of mycorrhizal and fibrous-textured conifer fine roots in 23- and 180-year-old subalpine *Abies amabilis* stands. Can. J. For. Res. 11:223-229.

Seasonal changes in biomass and vertical distribution of fibrous, mycorrhizal, and total conifer fine roots (≤2 mm) were examined in 23- and 180-year-old Pacific silver fir [*Abies amabilis* (Dougl.) Forbes] ecosystems. In both stands, 80% of fine roots was located in the upper 15 cm of the soil profile, in the forest floor (O_1 and O_2) and A horizon. During periods of active root growth in the young stand, significantly higher conifer root biomass occurred in the A horizon (370 to 690 g/m) than the forest floor (200 to 350 g/m). At all sampling times, a significantly higher biomass of conifer fine roots was located in the forest floor (550 to 1090 g/m) than the A horizon (290 to 640 g/m) in the old stand. In both stands, mycorrhizal roots comprised 10 to 15% of the total weight of conifer fine roots during peak root growth, 2 to 69% when roots were not growing, and 21 to 29% during the winter and early spring when roots were growing. Up to 69% of the biomass of fibrous and mycorrhizal roots was located in the forest floor in both stands.

760. **Vogt, K.A., C.C. Grier,** and **C.E. Meier.** 1983. Organic matter and nutrient dynamics in forest floors of young and mature *Abies amabilis* stands in western Washington, as affected by fine-root input. Ecol. Monogr. 53(2):139-157.

Seasonal patterns of decomposition and nutrient release from the major litterfall components were determined using litterbags in young (23-yr-old) and mature (180-yr-old) *Abies amabilis* stands in western Washington, U.S.A. The time required for each litterfall component to decompose completely was estimated in both stands. Long-term organic matter and nutrient residence times in the forest floor were estimated using forest floor and aboveground literfall masses. In addition, the effect of root turnover in the forest floor on estimates of organic matter and nutrient residence time was determined.

Similar litter substrates lost mass at a significantly faster rate in the young than in the mature stand. An initial rapid mass loss (9-67%) for litter substrates during the winter months coincided with increased immobilization of nitrogen and calcium and mineralization of phosphorus, potassium, and magnesium. However, herb species and epiphytic lichen decomposing in both stands showed no immobilization of N, P, K, Ca, or Mg or increased mass in litterbags at all sampling dates. The remaining litter substrates showed no loss or gain in mass during summer and autumn, with continued immobilization of N and P, while K, Ca, and Mg levels remained the same or decreased. From 36 to 77% of the total 2-yr mass loss of all litter substrates occurred during the initial 4 mo. The various litter components required approx.=6-15 and 2-24 yr for 99% decomposition to occur in the young and mature stands, respectively.

The addition of roots into the estimation of organic matter residence time (MRT) in the forest floor reduced the estimate by approx.=75% in both stands. The predicted turnover time of 1 yr's litterfall (11-12 yr) was very similar to the estimated residence time of total forest floor when roots were included in the calculations. The inclusion of roots in the estimation of forest floor MRT decreased the nutrient residence time for N by 74%, for P by 75-86%, for K by 81-90%, for Ca by 52-55%, and for Mg by 66-85% in both stands. Addition of root nutrient input into estimates of forest floor nutrient MRT increased the annual turnover of forest floor nutrients from 1-2% to 4-16% in the young stand and from

1-4% to 4-8% in the mature stand. The element mobility series resulting from litterbag studies did not give the same pattern of mobility as obtained from the total forest floor with or without root input.

761. **Vogt, K.A., C.C. Grier,** and **D.J. Vogt.** 1986. Production, turnover, and nutrient dynamics of above- and belowground detritus of world forests. Adv. Ecol. Res. 15:303-377.

Data currently available on carbon and nutrient cycling in forest ecosystems was synthesized and analyzed. Generalities were developed from this data on factors affecting nutrient cycling and forest productivity in different climate regimes, and on the importance of above- and below-ground litter in the life form of trees and tree behavior. The authors summarize eight conclusions: 1) in similar climatic regimes, coniferous forests accumulated greater forest floor mass than the deciduous forest; 2) contrary to broad-leaved forests, climatic factors or latitude did not explain variation in litterfall N input or aboveground litterfall mass in needle-leaved forests; 3) N accumulating and circulating in the forest floor was found to be at greater concentrations than that returned to aboveground litterfall in warm temperate, boreal, and cold temperate forests; 4) in evergreen forests of warm temperate zones, broad-leaved and narrow-leaved trees showed little difference in mean total root mass; deciduous forests, however, showed less total root mass than evergreens; 5) climatic factors were, generally, positively correlated with root turnover and there was a positive correlation between root mass and altitude in needle-leaved evergreen forests; 6) live root mass was positively correlated with content of N in forest floor but no significant correlation with content of N in litterfall was found in needle-leaved forests; 7) with the exception of broad-leaved deciduous forests, a greater amount of N was added to the soil by root turnover than by litterfall; and 8) the proportion of total detrital input to the forest floor (litterfall + root turnover) occurring as aboveground litterfall in cold temperate forests varied from 23 to 80%. **

762. **Vogt, K.A., D.J. Vogt, E.E. Moore, B.A. Fatuga, M.R. Redlin,** and **R.L. Edmonds.** 1987. Conifer and angiosperm fine-root biomass in relation to stand age and site productivity in Douglas-fir forests. J. Ecol. 75:857-870.

(1) Conifer and angiosperm fine-root biomass were determined in an age sequence (range 13-160 years) of eight high-productivity and seven low-productivity Douglas-fir stands in western Washington, U.S.A.

(2) No significant changes in total (conifer plus angiosperm) root biomass occurred among the different stand ages within each productivity class. Of the total fine-root biomass, however, the proportion of angiosperm to conifer roots varied significantly when stands were in the "tree initiation" and "competitive tree-stem exclusion" stages of stand development.

(3) Conifer fine-root biomass reached a peak at canopy closure in both low- and high-productivity stands. After canopy closure, conifer fine-root and foliage biomass levelled off as basal area continued to increase in the low-productivity stands; however, conifer fine-root biomass decreased as basal area increased and foliage biomass levelled off in the high-productivity stands.

(4) At all stand ages, the low-productivity stands had significantly more total (conifer plus angiosperm) fine-root biomass than those of high-productivity. At canopy closure and later stages of stand development, a significantly higher conifer fine-root biomass was maintained in low-productivity compared to high-productivity stands.

(5) Conifer fine-root biomass was positively related to litterfall lignin content, litterfall lignin:nitrogen ratio and forest-floor nitrogen content in low-, but not in high-productivity stands; these patterns followed an asymptotic exponential curve.

763. **Wallmo, O.C.** 1982. Managing forests to retain the wildlife habitat characteristics of old growth. *In* Proc. Conf. on Old Growth Forests: A Balanced Perspective, Feb. 12-14, 1982, Eugene, OR. U.S. Bur. Gov. Res. Serv., Univ. Oreg., Eugene, OR, pp. 29-33.

The author discusses several management options made by ecologists to retain the attributes of old-growth forests required to support a variety of wildlife species and their habitats. Silviculture and ecological objectives, logging methods, transportation and marketing problems, and social and economic benefits and losses should be considered in the planning of management schemes. The author concludes by saying that any effort to exploit and then recreate old-growth forest ecosystems will fail to restore their original ecological identity within the foreseeable future. He maintains we should preserve the small amount of old-growth forest we have remaining now. **

764. **Waring, R.H.** 1987. Characteristics of trees predisposed to die. BioScience 37(8):569-574.

Trees experiencing stress exhibit a variety of responses that may help us diagnose the source and degree of stress and the probability of survival. Nearly any stress, if sustained, reduces the canopy, photosynthetic activity, and storage reserves throughout the tree. Shade, drought, mechanical abrasion, and nutrient imbalance cause distinctive alterations in how photosynthate is allocated along the bole and to the roots. Successful attempts to ameliorate stresses should reestablish a more normal photosynthate distribution and lower the probability of death due to a variety of factors. (Author's conclusions)

765. **Waring, R.H., W.H. Emmingham, H.L. Gholz,** and **C.C. Grier.** 1987. Variation in maximum leaf area of coniferous forests in Oregon and its ecological significance. For. Sci. 24(1):131-140.

Maximum leaf areas (calculated for all surfaces) accumulated by 40 mature forest stands in western Oregon ranged from 5 to 53 m^2m^{-2}. Forests of the west-central Cascade Mountains had much more leaf area than forests in the eastern Siskiyou Mountains along the California border.

In both regions, environmental analyses correlated high maximum leaf areas with moderate air and soil temperature and with adequate soil moisture. The Siskiyou Mountains, with a more continental climate than the Cascades, had generally lower leaf areas. There the greater evaporation in the summer and colder winter temperatures apparently restrict leaf area development more than in the Cascades. In both regions, nutritional limitations may restrict the leaf areas to considerably less than the potential afforded by local climatic conditions.

766. **Waring, R.H.** and **J.F. Franklin.** 1979. Evergreen coniferous forests of the Pacific northwest. Science 204:1380-1386.

The massive, evergreen coniferous forests in the Pacific Northwest are unique among temperate forest regions of the world. The region's forests escaped decimation during Pleistocene glaciation; they are now dominated by a few broadly distributed and well-adapted conifers that grow to large size and great age. Large trees with evergreen needle- or scale-like leaves have distinct advantages under the current climatic regime. Photosynthesis and nutrient uptake and storage are possible during the relatively warm, wet fall and winter months. High evaporative demand during the warm, dry summer reduces photosynthesis. Deciduous hardwoods are repeatedly at a disadvantage in competing with conifers in the regional climate. Their photosynthesis is predominantly limited to the growing season when evaporative demand is high and water is often limiting. Most nutrients needed are also less available at this time. The large size attained by conifers provides a buffer against environmental stress (especially for nutrients and moisture). The long duration between destructive fires and storms permits conifers to outgrow hardwoods with more limited stature and life spans.

767. **Waring, R.H.** and **S.W. Running.** 1978. Sapwood water storage: its contribution to transpiration and effect upon water conductance through the stems of old-growth Douglas-fir. Plant, Cell and Environment 1:131-140.

Enough water is stored in the sapwood of large Douglas-fir to significantly contribute to transpiration. Sapwood water content falls through the season, causing the wood's conductivity to fall. This leads to low leaf-water potentials, stomatal closure, and reduced photosynthesis by the trees.

The amount of water stored in the sapwood of Douglas-fir 50-60 m tall, growing in the Cascade Mountains of Oregon, was estimated periodically over two seasons from measurements of sapwood relative water content (R_s). The relationship between R_s and volume of water contained in the sapwood was determined in the laboratory, and an equation describing the variation of relative conductivity (K) with R_s was derived from the literature. Stomatal conductance (k_s) and leaf water potentials were measured in the field.

The relative conductivity of the sapwood was calculated from estimates of the flow rate through the tree and differences in water potential between dawn and the time of comparison. Flow rate was assumed to equal transpiration rate, calculated from the Penman-Monteith equation using measured k_s values. A sixfold decrease in K during the summer was attributed to changes in R_s. The maximum observed diurnal variation in K would require a change in R_s estimated at 25%.

About 270 m^3/ha (27 mm) of water were stored in sapwood, and 75% of that was in the stemwood. Withdrawal from this store reached 1.7 mm/day on clear days after cloudy or rainy weather. Recharge could be almost as fast (up to 1.6 mm/day) after rain, but was very slow if the foliage remained wet.

768. **Welsh, D.A.** 1988. Meeting the habitat needs of non-game forest wildlife. For. Chron. 64:262-266.

The author provides arguments in favor of ecosystem-based wildlife management systems as opposed to featured-species management. **

769. **West, D.C., H.H. Shugart,** and **D.B. Botkin.** 1981. Forest succession: concepts and application. Springer-Verlag, New York, NY.

The chapters included in this text represent the papers presented at the conference held in June 1980, at Mountain Lake, Virginia. The objective of the conference was to provide a forum through which vegetation succession ecologists could present current research. Topics included the concepts, theories and models of succession, causality and the role of disturbance patterns, the dynamics of succession in various types of forests, and the relationship of nutrient cycling to succession. Some specific descriptions of forest succession are given for forests of Alaska and the Pacific Northwest. **

770. **West, N.E.** 1969. Tree patterns in central Oregon ponderosa pine forests. Am. Midl. Nat. 81(2):584-590.

Four types of pattern in the structure of ponderosa pine forests of central Oregon can be recognized: (1) differences in relative density, dominance, and regeneration of ponderosa pine when competing with other species along a moisture gradient; (2) a mosaic pattern of relatively even-aged reproduction clusters averaging about 2/3 acre in size, produced by periodic fire in the past; (3) variations in stand density within an even-aged group primarily due to chance factors during establishment; and (4) a tendency toward regular dispersion of individual trees in a reproduction cluster produced by competition. The same types of patterns and their causes have been described for the ponderosa pine forests of Arizona. However, the Oregon forests exhibit a much larger scale of pattern in the reproduction clusters.

771. **Wetmore, S.P.** and **B. Booth.** 1986. A reconnaissance of bird communities in old-growth coastal hemlock forests, British Columbia. Environ. Can., Can. Wildl. Serv., Pac. and Yukon Reg., Delta, BC. Tech. Rep. Ser. No. 14. 16 p.

A reconnaissance survey of bird populations in coastal hemlock old-growth forests was conducted in 1983. The main objectives were to assess the similarities between bird populations in undisturbed old-growth western hemlock (*Tsuga heterophylla*) forests and those found in: (1) western hemlock residuals and (2) mountain hemlock (*Tsuga mertensiana*) forests at higher elevation. We found that populations in undisturbed western hemlock forests and western hemlock residuals were similar. Populations in higher elevation mountain hemlock forests were different. We conclude that future work should focus on the capacity of managed second-growth western hemlock forests to support old-growth bird communities and on the status of cavity nesters in managed second-growth and high elevation mountain hemlock forests.

772. **Wetmore, S.P., R.A. Keller, and G.E.J. Smith.** 1985. Effects of logging on bird populations in British Columbia as determined by a modified point-count method. Can. Field Nat. 99(2):224-233.

Breeding bird populations in mature Mountain Hemlock (*Tsuga mertensiana*) and in Engelmann Spruce (*Picea engelmannii*)-Subalpine Fir (*Abies lasiocarpa*) forests and clearcuts were surveyed in 1982. In steep, valley-oriented Mountain Hemlock forests the uncut strip of timber up-slope of the clearcuts supported the same bird communities as did continuous forest extending from below alpine to the valley bottom. In Engelmann Spruce-Subalpine Fir forests, bird communities in unlogged stands between clearcuts were similar to those in large uncut areas. In forests where clearcut logging occurs there is a net loss to mature forest bird populations; however, in residual stands the bird communities continue to exist at similar densities. Also, logging results in a different bird community which occupies the clearcuts. A single-visit modified point-count method was developed for censusing the rugged, heavily forested terrain. The method combines features of the Finnish line transect and point-count methods. Densities estimated were similar to those obtained in other studies conducted in the northwestern United States and southern British Columbia.

773. **Whipple, S.A.** 1978. The relationship of buried, germinating seeds to vegetation in an old-growth Colorado subalpine forest. Can. J. Bot. Vol. 56:1505-1509.

Species of buried, germinating seeds and species occurring in the vegetation are compared for two Colorado subalpine forest stands, one dry and one mesic, both over 325 years old. The total numbers of seeds found were small and the correspondence with species in the vegetation was poor. This is consistent with reports from other old-growth forests and may be accounted for by a combination of low seed input and rapid loss of viable seeds from the soil reservoir for old-growth forest species.

774. **White, A.S.** 1985. Presettlement regeneration patterns in a southwestern ponderosa pine stand. Ecology 66(2):589-594.

Tree stems ≥106 yr old (i.e., established before significant European influence in this area) in a 7.3-ha old-growth ponderosa pine (*Pinus ponderosa*) forest in northern Arizona were aged and mapped. Age structure analysis showed that successful establishment of ponderosa pine was infrequent. The periods without successful establishment could be quite long, as suggested by four consecutive decades in which only two surviving trees were established.

The stems were strongly aggregated, as measured with nearest neighbor analysis, and groups were visually distinct in the field. Most of the stems occurred in groups of three of more, with group size ranging from 3 to 44 stems and area occupied by a group ranging from 0.02 to 0.29 ha. Ages of stems within groups were variable, the most homogeneous group having a range of 33 yr and the least having a range of 268 yr.

The data are not consistent with the commonly held view that southwestern ponderosa pine occurs in even-aged groups and that each group became established following the demise of the group previously occupying the site. Instead, it seems more likely that seedlings became established when one or two trees within the group died, the additional fuel surrounding the dead trees causing an intensely burned spot in the otherwise low-intensity fires that were

frequent in the area. The hot spot would create a potential seedbed for pine by eliminating, at least temporarily, the competing grasses on that small area. This decreased competition, in conjunction with adequate seed production and favorable moisture conditions in the spring and early summer, may well have been critical for ponderosa pine establishment. The relative infrequency of all these events occurring in the necessary sequence could explain the erratic age structure data from this area.

775. **White, P.S.** 1979. Pattern, process, and natural disturbance in vegetation. The Bot. Rev. 45(3):229-299.

In this paper the author presents a review and evolutionary framework of the major forms of natural disturbance which influence North American vegetation patterns and processes. The role of endogenous and exogenous effects on the temporal variation in vegetation patterns is discussed. The author notes that there is a gradient from those community dynamics that are caused by endogenous factors to those caused by exogenous factors. The major types of natural disturbance in North America are: fire, windstorm, ice storm, ice push on shores, cryogenic soil movement, temperature fluctuation, precipitation variability, alluvial processes, landslides, lava flows, dune movement, saltwater inundation, coastal processes, karst processes, and biotic disturbances. A discussion of allogenic (driven by environmental change) and autogenic (driven by properties of species) models of vegetation community change is provided. The author points out the weakness of the climax concept in describing vegetation community dynamics. In discussing vegetation and landscape the coenocline concept is discussed and accepted with some modifications. **

776. **White, P.S.** and **S.P. Bratton.** 1980. After preservation: philosophical and practical problems of change. Biol. Conserv. 18:241-255.

Even after land is legally protected, ecological change continues to affect species and ecosystems. Changes vary from natural to human-caused, from beneficial to detrimental, and from manageable to impossible to manage. Management can be approached on two levels: (1) an ecosystem-community ("process-oriented") level and (2) a species-population ("species-oriented") level. Management on these two levels sometimes conflicts. Key changes in reserves include: natural and human disturbance, manipulation of fire regimes, succession, imbalance of animal populations (e.g., elimination of large predators and population fluctuation of grazers), population and genetic change of rare species, introduction of exotics, pollution of air and water, interference with hydrologic regimes, and increased visitor pressure. Man-caused changes and poor management are still the greatest threats to nature reserve systems.

A preservationist "hands-off" legacy, while idealistic and philosophically attractive, may contribute to lack of firm leadership in reserves by biologists and managers. Because the effects of humans are now omnipresent, some form of management (if only to regulate visitor impact) usually is necessary. Dealing with ecological change requires statement of preservation goals, priorities, and clear policy on key issues; in addition, resource inventory, monitoring, and management-oriented research are required.

777. **White, P.S., M.D. MacKenzie,** and **R.T. Busing.** 1985. Natural disturbance and gap phase dynamics in southern Appalachian spruce-fir forests. Can. J. For. Res. 15:233-240.

Spatially small canopy gaps dominated the natural disturbance regime of old-growth spruce-fir forests in the Great Smoky Mountains, North Carolina and Tennessee. New gaps $\leq 200m^2$ in size were formed with a frequency of 0.006 to 0.009/year and the 1- to 10-year age class of these gaps covered an estimated 6 to 17% of the study area (depending on calculation method). Sixty canopy gaps sampled on a 7-ha intensive study site ranged in size from 15 to 150 m^2. Although tree replacement patterns in these gaps were unpredictable from gap size and age, the gap event was important in species interactions. The three canopy dominants, *Abies fraseri* (Pursh) Poir., *Picea rubens* Sarg., and *Betula lutea* Michx.f., had unique suites of life history traits. *Abies* reached high understory densities, but

had the highest canopy turnover rate of the three species. *Betula* was scarce in the understory, but had a crown expansion rate in gaps eight times that of the two conifers. *Picea* was the longest lived species and appeared to have the best survivorship. Tree replacement models based on advanced regeneration led to the prediction that *Abies* canopy density would increase and *Betula* canopy density would decrease, while models based on gap inventories led to opposite conclusions. Data from direct observation of the gap capture process supported the hypothesis that this old-growth stand was near compositional equilibrium and underscored the importance of disturbance effects in community organization.

778. **Whitmore, T.C.** 1982. On pattern and process in forests. *In* The plant community as a working mechanism. E.I. Newman (editor). Comm. For. Inst., Oxford Univ., Oxford, UK, pp. 45-59.

The author suggests that, throughout the world, forests are similar in pattern despite differences in structural complexity or floristic richness because the same processes of maintenance and succession operate. This article focuses on the dynamic structure of the forest canopy. The growth cycle, distinguished in three phases—gap, building, and mature—can illustrate the pattern and process of changing forests. Gap dynamics in temperate and tropical forests and Chilean forests is illustrated with examples. The occurrence of different ecological groups of tree species in all forests was recognized by foresters long ago. The primary characteristic of these groups was the amount of light required by seedlings. Other characters of each group concern tree architecture, seed biology, and aspects of ecophysiology. During the process of secondary succession, dominance is attained by progressively more shade-tolerant species. The stage of succession containing greatest species richness depends on the number of species belonging to different tolerant classes. For example, in species-rich tropical rain forests, many species may adapt to a gap of any given size; that is, they have overlapping niches. Ecosystems at different stages of the growth cycle have many values to mankind. An example can be found in the forest industry where high quality timber occurs in forests just past the mature stage. Conservation values necessitate the maintenance of full species richness (i.e., species in all stages of the growth cycle), which depend on continuous occurrence of gaps of all sizes. **

779. **Whitney, G.G.** 1987. Some reflections on the value of old-growth forests, scientific and otherwise. Nat. Areas J. 7(3):92-99.

Old-growth forests have played a prominent role in the development of ecological thought and theory. The unique characteristics of old-growth forests are reviewed as well as the ecologist's rationale for conserving them. The information accumulated in old-growth forest community and ecosystem studies has been substantial. Scientists should not, however, overlook the less scientific and more ethically oriented arguments for the conservation of old-growth forests.

780. **Wiens, J.A.** 1976. Population responses to patchy environments. Ann. Rev. Ecol. Syst. 7:81-120.

The author presents a broad treatment of how populations respond to patchy environments. Special emphasis is placed on the effects of patchiness in horizontal space on terrestrial consumers (primarily vertebrates). Specific topics addressed include: the definition of patchy environments, dimensions of patchiness, the spatial heterogeneity of vegetation, and consumer population attributes in patchy environments. The latter topic makes up the bulk of the paper and contains sections on optimization and group selection, habitat selection, dispersal and homing, social organization, predator-prey relationships, population stability, and genetic structure. As an example, an examination is provided of how harvester ants (genus *Pogonomyrmex*) play a role in creating habitat patchiness, and how this affects other populations and ecological factors. The heterogeneity of ecosystems poses problems for modeling the dynamics of such ecosystems. In summary, the author notes that there is a paucity of good information about how patchiness influences populations, communities, or ecosystems. Questions and directions for further research are presented. **

781. **Wigg, M.** and **A. Boulton.** 1988. Quality wood, sustainable forests. For. Watch 9:7-12.

The authors argue against the U.S. Forest Service's emphasis on producing high volumes of fiber in the Pacific Northwest. Such an approach is replacing high quality, high volume wood from old-growth forests with low quality wood. The authors predict that this approach will result in the loss of industries that rely on clear lumber, promote the encroachment of roads into isolated areas, hinder the sustainability of forests, and harm soils, water quality, and wildlife. A different approach is suggested, emphasizing the production of high quality wood. Longer rotations, commercial thinning, pruning, the use of diverse tree species, and imitation of natural forest succession are recommended as management techniques. This approach, the authors believe, will result in the production of good quality wood over long rotations while preserving existing jobs, creating new high-paying jobs, generating revenue, and protecting the forests. **

782. **Wilcove, D.S.** 1987. From fragmentation to extinction. Nat. Areas J. 7(1):23-29.

Restricted in size and surrounded by a modified, even alien environment, fragmented ecosystems can suffer a loss of biological diversity, most noticeably through the extinction of species. The extinction process that occurs as a result of fragmentation can be divided into four categories: (1) the loss of species that initially were excluded from the protected fragments; (2) the loss of species that no longer find certain fragments to be acceptable habitat; (3) the loss of species that can reproduce successfully within the fragments but that occur as small populations; and (4) the loss of species due to ecological imbalances within the fragments. I discuss these categories in the context of designing and managing nature reserves.

783. **Wilcove, D.S., C.H. McLellan,** and **A.P. Dobson.** 1986. Habitat fragmentation in the temperate zone. *In* Conservation biology: the science of scarcity and diversity. M.E. Soulé (editor). Sinauer Assoc., Inc., Sunderland, MA, pp. 239-256.

In this chapter we examine three questions relating to habitat fragmentation in the temperate zone: (1) What is the effect of fragmentation on the species originally present in the intact habitat? (2) How does fragmentation lead to the loss of species? (3) For an already fragmented landscape, are there any guidelines for the selection and management of nature reserves? Here we shall set as our goal the long-term preservation of those species whose continued existence is jeopardized by habitat destruction. At the outset we note that this chapter is slanted towards vertebrate communities (especially birds) and forested habitats. Our bias reflects, in part, a bias in the existing literature. On the other hand, by virtue of their low population densities, birds and mammals are among the taxa most likely to disappear from isolated fragments. (From authors' introduction)

784. **Wilcox, B.A.** 1984. Concepts in conservation biology: applications to the management of biological diversity. *In* Proc. Workshop on Natural Diversity in Forest Ecosystems. J.L. Cooley and J.H. Cooley (editors). Nov. 29-Dec. 1, 1982, Athens, GA. Inst. Ecol., Univ. Georgia, Athens, GA, pp. 155-172.

Like many other national and international agencies responsible for conserving natural diversity, the USDA Forest Service faces the difficult technical challenge of both fulfilling growing demands for resources and, at the same time, protecting diversity. This problem results from the inevitable conflict between increasing the rate and scope of exploitation of natural resources and the consequential threat of decreasing the diversity inherent in natural ecosystems. Diversity is the key to maintaining the functional integrity of natural ecosystems, thus their capacity to provide resources on a sustainable basis. Preserving biological diversity poses three basic problems: (1) to establish an operational definition of diversity, (2) to understand the natural processes involved in maintaining diversity and how those processes are threatened, and (3) to develop management programs that mitigate these threats. Biological diversity can be defined as the diversity of life forms, the different ecological functions they represent, and the genetic diversity they contain. Components of biological diversity at different levels of biological organization (i.e., ecosystem, species,

populational, and molecular) and different elements constituting those components can be recognized. Individual elements (i.e., community types, species, populations, and genes) serve as the focus of conservation strategies. However, functional interrelationships between (and among) all levels determine the survival or extinction of any element. Thus, diversity at all levels of biological organization must be considered in management planning. The greatest threat to biological diversity, habitat conversion, can be mitigated only by first understanding how the loss and insularization of habitat affect the viability of wildlife populations, and thus the communities and ecosystems they constitute. A general protocol· for determining minimum area requirements for maintaining biological diversity can be described. It involves selecting target species in a community and determining their minimum viable populations and their habitat requirements.

785. **Wilcox, B.A.** and **D.D. Murphy.** 1985. Conservation strategy: the effects of fragmentation on extinction. Am. Nat. 125:879-887.

The authors briefly review the SLOSS (single large or several small) reserve issue. The discussion then focuses on the apparent contradiction between the assertion that habitat fragmentation should be innocuous to most species and the prevailing view that habitat fragmentation negatively affects population survival and, thus, biological diversity. **

786. **Wilkinson, M.** 1989. Wildwood tree farm. Trumpeter 6(2):65-66.

The author describes the system of selective harvesting and natural regeneration which has been operating on his tree farm since 1945. **

787. **Williams, J.T.** 1990. Vavilov's centres of diversity and the conservation of genetic resources. Biol. J. Linnean Soc. 39:89-93.

Attention is drawn to Vavilov's agro-ecotype concept of cultivated plant adaptation, and genotype/environment interactions in crops. Vavilov developed an ecological classification of cultivated plants and stressed the need for national and international evaluation of collections and breeding lines, based on materials collected in areas of great genetic diversity. A discussion of Vavilov's centres of diversity highlights the importance of land races and wild crop relatives to breeders in Vavilov's day, and even more so at present.

This is followed by a brief description of the work of the International Board of Plant Genetic Resources (IBPGR) in relation to Vavilov's philosophy, in its efforts to conserve the genetic diversity of crops and especially old land races, which have developed resistances to diseases and pests, and adaptation to a wide range of environmental conditions. Related wild species are also of great importance here, and one of IBPGR's tasks is to see that all these materials are evaluated with a view to building useful characters into new and better crop varieties.

788. **Wilson, B.C.** 1990. Gene-pool reserves of Douglas-fir. For. Ecol. Manage. 35:121-130.

The Washington State Department of Natural Resources (DNR) is concerned about the long-term effects of forest management practices on the western Washington Douglas-fir native gene pool. As a gene conservation measure, the DNR is establishing a Douglas-fir gene-pool-reserve system on DNR land. Reserves are designated in each 500-ft (152-m) elevation band within every seed zone in which the DNR has over 1000 acres (405 ha). The aim is to select natural stands of about 25 acres (10.1 ha) which contain at least 400 dominant or co-dominant trees. Over 100 gene-pool reserves have been established, ranging from sea level to 4500 ft (1372 m) elevation. Stand ages range from 40 years to old-growth. Stands will be withdrawn from the timber-harvest land base and will be managed strictly for gene-conservation purposes.

789. **Wilson, E.O.** 1985. The biological diversity crisis. BioScience 35(11):700-706.

The number of described species has reached 1.7 million since Linnaeus inaugurated the binomial system in 1753. The great majority of kinds of organisms everywhere in the world are not only tropical, but also inconspicuous invertebrates such as insects, crustaceans, mites, and nematodes. Despite unprecedented extinction rates, the extent of biological diversity remains unmeasured. Environmental destruction, a worldwide phenomenon, is reducing the numbers of species and the amount of genetic variation within individual species. When the area of a habitat is reduced to one-tenth, the number of species that can persist in it indefinitely will eventually decline to one-half. **

790. ——————. 1988. Biodiversity. National Academy Press, Washington, DC. 521 p.

This book addresses biological diversity in 12 parts: 1) challenges to the preservation of biodiversity; 2) human dependence on biological diversity; 3) diversity at risk: tropical forests; 4) diversity at risk: the global perspective; 5) the value of biodiversity; 6) how biodiversity is monitored and protected; 7) science and technology: how they can help conserve biological diversity; 8) restoration ecology; 9) alternatives to destruction; 10) policies to protect biological diversity; 11) present problems and future prospects; and 12) ways of seeing the biosphere. Each part consists of several articles. **

791. ——————. 1989. Threats to biodiversity. Sci. Am. 261(3):108-116.

The loss of biodiversity is the most important process of environmental change because it is irreversible. Habitat destruction, mostly in the tropics, is resulting in the extinction of thousands of species each year. This article cites a brief history of biological diversity and offers lessons that can be drawn from it. Although the impact of habitat destruction is felt most severely in the tropical rain forests, it is also felt in other areas of the planet, particularly where large areas of old-growth forest are being cut every year. Implications of loss of biodiversity are discussed and many examples are given. It is concluded that countries must expand their taxonomic inventories of species to identify "hot spots" of priority for conservation. At the same time, conservation must be closely coupled with economic development. Biological research should be closely tied to zoning and regional land use development, not only to conserve species, but also to make more efficient use of land previously converted to agriculture and monoculture timber. **

792. **Wilson, M.V.** and **A. Shmida.** 1984. Measuring beta diversity with presence-absence data. J. Ecol. 72:1055-1064.

(1) Six measures of beta diversity (five from the literature, one proposed here) were compared and evaluated. Application was limited to measures suited for species presence-absence data along environmental gradients.

(2) Four ecological criteria of "good" performance of beta diversity measures were developed: (i) conformity with the notion of community turnover ensures that the magnitude of a measure is meaningful; (ii) additivity is the property that the sum of beta diversities between contiguous segments equals the beta diversity of the entire gradient; (iii) independence from alpha diversity ensures useful application of a measure to systems with different alpha diversities; (iv) independence from excessive sample size obviates any spurious effects of oversampling.

(3) Two measures of beta diversity (one proposed by Whittaker [1960] and one proposed in the present paper) came closest to fulfilling all four criteria and should be of most use in ecological applications.

(4) Field data from Mt. Hermon in Israel were used to compare the usefulness of the six measures.

(5) Current problems and issues, including the relationship between species-area curves and beta diversity, and future applications in measuring beta diversity are discussed.

793. **Wolf, E.C.** 1985. Conserving biological diversity. *In* State of the world 1985: a Worldwatch Institute report on progress toward a sustainable society. L. Starke (editor). W.W. Norton & Company, New York & London, pp. 124-146.

The author presents a thorough discussion of the planet's biological diversity crisis. After noting the many values of biological diversity, the author points out the seriousness of the present crisis. It is not only the fact that 15-20% of existing species could be pushed to extinction by the year 2000, notes the author, but also other losses of diversity, such as the loss of unique races of populations. The author stresses the importance of genetic diversity for improving agricultural performance and in biotechnological uses. Finally, conservation strategies and priorities which can be followed to stem the decline of biological diversity are discussed. **

794. **Wolff, J.O.** and **J.C. Zasada.** 1975. Red squirrel response to clearcut and shelterwood systems in interior Alaska. U.S. Dep. Agric. For. Serv., Pac. NW For. Range Exp. Stn., Portland, OR. Res. Note PNW-255. 7 p.

Population response of red squirrels to clearcut and shelterwood silvicultural systems in interior Alaska was determined by counting the population before and after cutting. Following harvest, all territories from the clearcuts were vacated and the number of squirrels in the shelterwood decreased from 1 per 0.69 ha to 1 per 2.0 ha. The squirrel population in the adjacent control area and along the cutting area boundary remained stable.

795. **Wood, G.W.** 1990. The art and science of wildlife (land) management: frustrations with old science drive new forestry. J. For. 20:8-12.

This article discusses past and present problems and controversies in the attempts of forest management to maintain "land health." Within the definition of "land health" lies an undeniably subjective perspective. This perspective is most deeply divided between those who perceive resource management to be total control of the land and those who perceive conservation to be total restraint. The division between those who view their primary duty as short-term service to the people, and those who believe their primary duty lies with the land which may then serve the people, is less clear, notes the author.

Two main issues are then discussed: 1) the declining capacity of land to support both wildlife and existing forests, and 2) the approaches and direction of current research in wildlife and land management. Using Leopold's essay on the role of universities in natural resource education as a base, the author explores the division between our current high-tech era of science and the intimate personal experience of the land which fosters a land ethic incorporating both use and protection. **

796. **World Wildlife Fund Canada.** 1987. Annual report. Toronto, ON. 32 p.

This is a report on the following 1987 conservation programs: 1) Wildlife Toxicology Fund; 2) Partners in Conservation; 3) Carolinian Canada; 4) Wild West; 5) Canadian Endangered Species Program; 6) Wildlands, Wildwaters; 7) International Program; 8) Education Program; and 9) Communication Program. Also included is a list of all conservation projects for 1987, and financial statements. **

797. **Worrall, J.** 1990. Subalpine larch: oldest trees in Canada? For. Chron. (Oct.):478-479.

The growth and development of Subalpine Larch (*Larix lyallii*) was examined in Manning Park, British Columbia. The study found that about 40 years was required for the trees to reach breast height and 90 years to reach 3 m in height. Increment in radius was slow, ranging from 1/6 to 1/2 mm, with many annual rings having only 5-10 cells. Increment borings of 25 trees showed that the oldest tree with a solid core was 470 years old; all older trees had extensive heart rot. Fifty-year average radial increments for individual trees were reasonably consistent. Differences between trees were marked, presumably due to

micro-environmental and genetic factors. Age, however, correlated very well with diameter. The author speculated that some of the trees with rotten cores may be over 2000 years old and thus the oldest trees in Canada. **

798. **Wright, H.E.** 1974. Landscape development, forest fires, and wilderness management. Science 186:487-494.

The author evaluates and reconciles certain concepts of landscape development by clarifying the time scales for which the various concepts are applicable. Research on long-term landscape development can only be successfully carried out on landscapes that have been developing naturally over very long periods of time. Virgin forests are required to provide the controlling factors for this research. Discussion then focuses on vegetational succession and climax in the cutover forest of the Appalachian Mountains and the fire-dependent virgin forest of the Boundary Waters Canoe areas in Minnesota. The author concludes that fire may provide the long-term stability needed to preserve certain conifer forest ecosystems. Amenity values and management of wilderness areas are discussed. **

799. **Wright, H.E.** and **M.L. Heinselman** (editors). 1973. The ecological role of fire in natural conifer forests of western and northern America. Quat. Res. 3(3):317-513.

This issue includes an editor's introduction and the following papers from the symposium held at the annual meeting of the Ecolog. Soc. Am. and the Am. Insti. Biolog. Sci., Univ. of Minn., Aug., 1972: 1) M.L. Heinselman, Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota; 2) A.M. Swain, A history of fire and vegetation in Northeastern Minnesota as recorded in lake sediments; 3) S.S. Frissell, The importance of fire as a natural ecological factor in Itasca State Park, Minnesota; 4) J.R. Habeck and R.W. Mutch, Fire-dependent forests in the Northern Rocky Mountains; 5) L.L. Loope and G.E. Gruell, The ecological role of fire in the Jackson Hole Areas, Northwestern Wyoming; J.S. Rowe and G.W. Scotter, Fire in the boreal forest; 6) L.A. Viereck, Wildfire in the Taiga of Alaska; 7) B.M. Kilgore, The ecological role of fire in Sierran conifer forests. **

800. **Yanishevsky, R.M.** 1987. The rise of plans and the fall of old growth: a comparative analysis of old growth in region one. Forest Watch (June):23-27.

Analysis of old-growth and snag management in the 13 Region One forest plans shows that, in general, the plans fail to meet both legal and biological requirements of the National Forest Management Act (NFMA) passed in 1976. Although the words "old growth" do not appear in the NFMA regulations, protection of old growth is crucial to the preservation of diversity in plant and animal communities. Issues addressed are old-growth management, snag management, indicator species and monitoring, and habitat effectiveness. **

801. **Yarie, J.** 1986. A preliminary comparison of two ecosystem models, FORCYTE-10 and LINKAGES for interior Alaska white spruce. *In* Proc. Symp. on Predicting Consequences of Intensive Forest Harvesting on Long-Term Productivity. G.I. Agren (editor). May 24-31, 1986, Jadraas, Sweden. Swed. Univ. Agric. Sci., Dep. Ecol. Environ. Res., Uppsala. Rep. No. 26, pp. 95-103.

The simulated development of an old growth white spruce stand was compared between two ecosystem models, FORCYTE-10 and LINKAGES. Both models adequately depicted the development of aboveground standing crop and the biomass dynamics of the forest floor and humus layers. Only FORCYTE-10 satisfactorily portrayed stand density dynamics and nitrogen mineralization when compared to existing data. Further calibration work with LINKAGES was suggested to remedy the discrepancies.

802. **Young, J.S., D.M. Donnelly, C.F. Sorg, J.B. Loomis,** and **L.J. Nelson.** 1987. Net economic value of upland game hunting in Idaho. U.S. Dep. Agric. For. Serv., Rocky Mtn. For. Range Exp. Stn., Fort Collins, CO, Resour. Bull. RM-15. 23 p.

Net willingness to pay in addition to actual expenditure for upland game hunting in Idaho was estimated with the Travel Cost Method (TCM) at $34.77 per trip and with the Contingent Value Method (CVM) at $25.82. For pheasant hunting, a major component of all upland game hunting, net willingness to pay was estimated with TCM at $28.84 and with CVM at $24.86. Net benefit differences between methods result in part from their long-run and short-run orientations in this study.

803. **Zarnowitz, J.E.** and **D.A. Manuwal.** 1985. The effects of forest management on cavity-nesting birds in northwestern Washington. J. Wildl. Manage. 49(1):255-263.

Population characteristics and nest-site preferences of 11 species of cavity-nesting birds were studied in the Olympic National Forest (ONF) of northwestern Washington in the spring and summer of 1979-80. We characterized breeding populations in four different forest successional stages where either high or low densities of snags occurred. Species richness (N = 13 vs. N = 9), densities (P<0.01), and diversities (P<0.01) of cavity-nesting birds increased with increasing snag densities. Active cavity-nests were five times more numerous on the 1980 plots (Snag Plots) than the 1979 plots (Clean Plots). Snag densities on the Snag Plots varied from 13.8/ha in a clear-cut to 97.1/ha in 25-50-year-old second-growth stand. Clean Plots contained from 0.5 snags/ha in a clear-cut to 37.3/ha in old-growth. Hairy woodpeckers (*Picoides villosus*), a primary cavity-nester, selected western hemlock (*Tsuga heterophylla*) snags for nest sites. In contrast, broken-topped Douglas-fir (*Pseudotsuga menziesii*) snags were preferred by secondary cavity-nesters. The average diameter at breast height (DBH) for active nest trees was substantially greater than the mean DBH for sampled snags in the ONF. Snags appear to be a limiting factor for breeding cavity-nesting bird populations. We discuss management recommendations for cavity-nesting birds in the ONF.

804. **Zinke, P.J.** 1967. Forest interception studies in the United States. *In* International Symp. on Forest Hydrology. W.E. Soper and H.W. Lull (editor). Pergamon Press, Oxford, UK, pp. 137-161.

In this article the author reviews several American studies on forest interception within the context of water balance in a watershed. This review presents several relevant hydrological definitions, relationships between interception quantities and various elements, and methods used in measuring them. Results from studies on interception storage, stem flow, and interception losses are presented, grouped by major vegetation types and by vegetation species. The effects that foliage interception has on aerial sprays (insecticides) and the dropping of fire retardants, as well as its effects on drop size beneath the canopy, are discussed. Currently, the major problem with research on interception processes is the determination of whether the interception process is representative of a true evaporative loss in the water balance of the forest. **

805. **Zobel, D.B., A. McKee, G.M. Hawk,** and **C.T. Dyrness.** 1976. Relationships of environment to composition, structure, and diversity of forest communities of the Central Western Cascades of Oregon. Ecol. Monogr. 46:135-156.

Temperature and moisture stress of conifer saplings and needle nitrogen content of conifer saplings were measured at reference stands representing 16 forest communities in the central portion of the western Cascades province of Oregon.

Most species occur over a wide range of temperature and moisture stress; many occupy a wider range of environments in the western Cascades than they do in the eastern Siskiyou Mountains of southwest Oregon. Differences between vegetation zones are reflected in a temperature index; within zones, communities are distinguished by moisture stress and, to a lesser extent, by temperature. In two cases vegetation differences appear to be related to low needle nitrogen contents. Use of complex gradients for vegetation ordination suggests certain environmental differences between communities which are contrary to the differences measured; therefore, we prefer the measured gradients over the complex gradients defined.

Species diversity (the total number of vascular species) increases, and dominance (Simpson's index) decreases away from moderate environmental conditions to warmer-drier and colder communities. Diversities of different strata are unrelated. Dominance is concentrated in fewer strata of the vegetation on the colder sites. However, discontinuities in the pattern of diversity with environment occur which are not related to major differences in our measured environmental indexes. Evergreenness of shrubs is highest in stands with the lowest foliar nitrogen levels.

Dissertations

806. **Annas, R.M.** 1974. Boreal ecosystems of the Fort Nelson area of north-eastern British Columbia. Ph.D. thesis. Univ. B.C., Vancouver, BC.

807. **Baker, C.O.** 1979. The impacts of log jam removal on fish populations and stream habitat in Western Oregon. M.Sc. thesis. Oreg. State Univ., Corvallis, OR. 81 p.

808. **Beaudry, P.G.** 1984. Effects of forest harvesting on snowmelt during rainfall in coastal British Columbia. M. For. thesis. Univ. B.C., Vancouver, BC. 185 p.

809. **Beese, W.J.** 1981. Vegetation - environment relationships of forest communities on Central Eastern Vancouver Island. M. For. thesis. Univ. B.C., Vancouver, BC. 239 p.

810. **Beil, C.E.** 1969. The plant associations of the Cariboo — Aspen — Lodgepole Pine — Douglas-fir Parkland zone. Ph.D. thesis. Univ. B.C., Vancouver, BC.

811. **Bell, M.A.M.** 1964. Phytocoenoses in the dry subzone of the Interior Western Hemlock zone of British Columbia. Ph.D. thesis. Univ. B.C., Vancouver, BC.

812. **Cordes, L.D.** 1972. An ecological study in the Sitka spruce forest of the West Coast of Vancouver Island. Ph.D. thesis. Univ. B.C., Vancouver, BC. 452 p.

813. **Dorey, R.J.** 1979. A fire history investigation and the effects of fire exclusion on a ponderosa pine forest in southeastern British Columbia. B.Sc. thesis. Univ. B.C., Vancouver, BC. 56 p.

814. **Fitzharris, B.B.** 1975. Snow accumulation and deposition on a west coast mid-latitude mountain. Ph.D. thesis. Univ. B.C., Vancouver, BC. 367 p.

815. **Franklin, J.F.** 1966. Vegetation and soils in the subalpine forests of the southern Washington Cascade Range. Ph.D. thesis. Wash. State Univ., Pullman, WA. 132 p.

816. **Graham, R.L.** 1981. Biomass dynamics of dead Douglas-fir and western hemlock boles in mid-elevation forests of the Cascade Range. Ph.D. thesis. Oreg. State Univ., Corvallis, OR. 152 p.

817. **Heimann, D.C.** 1989. Recruitment trends and physical characteristics of coarse woody debris in Oregon Coast Range streams. M.Sc. thesis. Oreg. State Univ., Corvallis, OR. 121 p.

818. **Hines, W.W.** 1971. Plant communities in the old-growth forests of north coastal Oregon. M.Sc. thesis. Oreg. State Univ., Corvallis, OR. 146 p.

819. **Ingram, G.B.** 1989. Planning district networks of protected habitat for conservation of biological diversity: a manual with applications for marine islands with primary rainforest. Ph.D. thesis. Univ. Cal., Ann Arbor, MI.

820. **Kaufmann, P.R.** 1987. Channel morphology and hydraulic characteristics of torrent-impacted forest streams in the Oregon Coast Range, U.S.A. Ph.D. thesis. Oreg. State Univ., Corvallis, OR. 235 p.

821. **Klinka, K.** 1976. Ecosystem units, their classification, interpretation, and mapping in the University of British Columbia Research Forest. Ph.D. thesis. Univ. B.C., Vancouver, BC. 622 p.

822. **Kojima, S.** 1971. Phytogeocoenosis of the Coastal Western Hemlock Zone in Strathcona Provincial Park, B.C., Canada. Ph.D. thesis. Univ. B.C., Vancouver, BC. 321 p.

823. **Korol, R.L.** 1985. The soil water regime and growth of uneven-age interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) stands. M.Sc. thesis. Univ. B.C., Vancouver, BC. 164 p.

824. **Krumlik, G.J.** 1979. Comparative study of nutrient cycling in the subalpine Mountain Hemlock zone of British Columbia. Ph.D. thesis. Univ. B.C., Vancouver, BC.

825. **Long, B.A.** 1987. Recruitment and abundance of large woody debris in an Oregon coastal stream system. M.Sc. thesis. Oreg. State Univ., Corvallis, OR.

826. **McMinn, R.G.** 1957. Water relations in the Douglas-fir region on Vancouver Island. Ph.D. thesis. Univ. B.C., Vancouver, BC.

827. **Ogilvie, R.T.** 1962. Ecology of spruce forests on the east slope of the Rocky Mountains in Alberta. Ph.D. thesis. Univ. Wash., Pullman, WA.

828. **Orloci, L.** 1961. Forest types of the Coastal Western Hemlock zone. M.Sc. thesis. Univ. B.C., Vancouver, BC. 206 p.

829. ————————. 1964. Vegetation and environmental variation in the ecosystems of the Coastal Western Hemlock zone. Ph.D. thesis. Univ. B.C., Vancouver, BC. 199 p.

830. **Revel, R.D.** 1972. Phytogeocoenoses of the Sub-Boreal Spruce biogeoclimatic zone in north central British Columbia. Ph.D. thesis. Univ. B.C., Vancouver, BC.

831. **Rochelle, J.A.** 1980. Mature forests, litterfall and patterns of forage quality as factors in the nutrition of black-tailed deer on northern Vancouver Island. Ph.D. thesis. Univ. B.C., Vancouver, BC.

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