United States Department of Agriculture

Forest Service

Pacific Northwest Research Station

General Technical Report
PNW-GTR-494
August 2000

Alternatives to Clearcutting in the Old-Growth Forests of Southeast Alaska: Study Plan and Establishment Report

Michael H. McClellan, Douglas N. Swanston, Paul E. Hennon, Robert L. Deal, Toni L. De Santo, and Mark S. Wipfli

Authors

Michael H. McClellan is a research forest ecologist, **Douglas N. Swanston** is a research geologist (retired), **Paul E. Hennon** is a research forest pathologist, **Robert L. Deal** is a forester, **Toni L. De Santo** is an ecologist, and **Mark S. Wipfli** is a research aquatic ecologist, Forestry Sciences Laboratory, 2770 Sherwood Lane, Suite 2A, Juneau, AK 99801-8545.

Abstract

McClellan, Michael H.; Swanston, Douglas N.; Hennon, Paul E.; Deal, Robert L.; De Santo, Toni L.; Wipfli, Mark S. 2000. Alternatives to clearcutting in the old-growth forests of southeast Alaska: study plan and establishment report. Gen. Tech. Rep. PNW-GTR-494. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 40 p.

Much is known about the ecological effects, economics, and social impacts of clear-cutting, but little documented experience with other silvicultural systems exists in south-east Alaska. The Pacific Northwest Research Station and the Alaska Region of the USDA Forest Service have cooperatively established an interdisciplinary study of ecosystem and social responses to alternative silvicultural systems to evaluate their ability to provide for sustainable wood production and protection of other forest values. This information is needed to select appropriate systems for managing old-growth stands on timber-producing lands in southeast Alaska. We present the study plan and establishment report because of the large-scale and long-term nature of this study, and in response to significant interest from resource managers, researchers, and the public.

A short-term retrospective study and a longer term, operational-scale, experimental study are planned. Ecosystem and social responses to be evaluated include tree regen-eration, growth, and mortality; plant diversity and abundance; tree damage agents, deer habitat quality; bird diversity and abundance; headwater stream ecology; ground-water changes; slope stability; visual quality; and social acceptability. The extensive pretreat-ment site assessments will add significant new knowledge of old-growth forests and associated aquatic ecosystems.

Keywords: Ecosystem management, clearcutting, alternative silviculture, silvicultural systems, wildlife habitat, fish habitat, visual quality, slope stability, forest ecology.

Introduction

In the native forests of southeast Alaska, large tracts of even-aged, mature stands are uncommon. About 87 percent of the productive forest lands bear old-growth western hemlock-Sitka spruce (*Tsuga heterophylla* (Raf.) Sarg.-*Picea sitchensis* (Bong.) Carr.) stands (Hutchison and LaBau 1975), most of which are uneven aged.[1] Most of these stands are in a natural condition, but many stands close to salt water have been selectively harvested in the past for high-quality logs. Before pulp factories had been established in southeast Alaska, most timber harvesting was done with partial cutting because there was no economic incentive to harvest pulp-quality trees (Harris and Farr 1974).

Since the early 1950s, even-age management with clearcutting has been the dominant silvicultural system used in southeast Alaska because it is widely accepted as an economical and efficient method for timber production. From a timber-production perspective, it was considered undesirable to manage the existing uneven-aged, defective, late-successional stands (Harris and Farr 1974); rather, it was preferable to clearcut and regenerate young, rapidly growing, even-aged stands. The dominance of clearcutting was apparent from timber harvest reports at the onset of this study in 1994. For example, during fiscal year 1994, 3683 hectares were harvested on the Tongass National Forest; of this total, 3675 hectares were clearcut.[2] Some timber sales on which alternative silvicultural systems were used were planned but had not yet reached the harvest stage because of the lengthy planning lead time.

Even-age management with clearcutting has been criticized because of effects on other forest values. Critics of conventional harvest practices assert that clearcutting of old-growth forests in southeast Alaska creates young-growth forests that are poor habitat for many important wildlife and understory plant species; reduces biodiversity by eliminating understory plants after crown closure; and diminishes important structural components found in old-growth stands, such as logs on the forest floor and in streams, snags, large green trees, and multilayered canopies. Others hold that clearcutting reduces slope stability, increases landslide activity, and accelerates erosion and sediment production, all of which lead to degraded fish habitat. Perhaps the greatest fault many critics find is that conventional practices create landscapes that are aesthetically displeasing to both residents and visitors.

Responding to these concerns and others, the USDA Forest Service has committed to the concept of ecosystem management and to reducing the use of clearcutting.[3] This new management philosophy has engendered the following key objectives for ecological management of land for wood production in southeast Alaska:

- Maintain ecosystem health, resilience, and productivity
- Maintain compositional, structural, and functional diversity
- Produce a sustainable supply of timber

---

[1] Farr, Wilbur A.; McClellan, Michael H. Size and age structure of trees in the old-growth forests of southeast Alaska. Manuscript in preparation.

[2] U.S. Department of Agriculture, Forest Service. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Alaska Region, 709 W. 9th St., Juneau, AK 99802-1628.

[3] Robertson, F.D. 1992. Letter dated June 4 to Regional Foresters and Station Directors. Ecosystem management of National Forests and Grasslands. On file with: Forestry Sciences Laboratory, 2770 Sherwood Lane, Suite 2A, Juneau, AK 99801.

- Reduce the reliance on clearcutting
- Protect wildlife and fish habitat essential for nonconsumptive, subsistence, sport, and commercial uses
- Protect slope stability and prevent soil erosion
- Maintain an aesthetically pleasing landscape for local residents and an economically important tourist industry
- Maintain water quality
- Provide high-quality recreation settings

The movement to reduce clearcutting, however, has revealed a knowledge gap. Much is known about the ecological effects, economics, and social impacts of even-age management and clearcutting, but little scientifically documented experience with other silvicultural systems exists in southeast Alaska, despite widespread partial cutting before 1950. Several silvicultural systems have been promoted as alternatives to the controversial practice of clearcutting, but these systems must be evaluated for their ability to provide for sustainable wood production and protection of other forest values. To be useful, silvicultural options must be biologically and socially acceptable and meet a complex and evolving set of management objectives. Several alternatives to conventional clearcutting seem feasible and merit further evaluation.

Even-age management with clearcutting could be modified to retain more biological legacies—structures and components from the preharvest stand. Green trees, snags, stilt-rooted trees, and coarse woody debris are examples of potentially valuable legacies that might be retained or created during harvesting. This system is known as clearcutting with reserves.

Selection harvest systems ranging from single-tree selection to group selection could be used in southeast Alaska to mimic natural disturbance regimes and to match retention levels to site-specific requirements. Depending on multiresource objectives, selection harvesting could be used to create two-aged stands or multistoried, uneven-aged stands that retain many of the desired features of unmanaged old-growth stands.

Shelterwood systems and seed-tree cutting are used in some forest types to promote regeneration in adverse conditions. These techniques are unlikely to be applied widely in southeast Alaska, however, because regeneration after timber harvest is usually prolific. Seed-tree cutting may have value in special cases—to promote regeneration of western redcedar (*Thuja plicata* Donn ex D. Don) or yellow-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach), for example.

Literature Review

Silviculture

Foresters have been reluctant to try various forms of partial cutting in southeast Alaska because of potential damage from wind or logging operations, lack of suitable logging systems, and excessive costs. One of the most serious problems in using partial cutting is the fact that 87 percent of the sawtimber volume in southeast Alaska is in late-successional stands (Hutchison and LaBau 1975). Limited study has shown that the tree ages (see footnote 1) and amount of decay (Farr and others 1976) of late-successional stands are highly variable. Stands in the 150- to 200-year age class are generally sound and even aged in structure. Most of these stands are dense and have a limited tree-diameter range.

As stands age, overstory trees fall victim to insects, disease, or wind. As the canopies begin to open, more light reaches the forest floor, and tree regeneration becomes established along with other plants (Alaback 1989, Deal and others 1991). Because western hemlock is more tolerant of shade than is Sitka spruce or cedar, stands gradually convert to hemlock. Depending on how stands are disturbed, old-growth stands tend to have predominantly two, three, or more age classes. Site productivity of old-growth stands is gradually reduced as raw, undecomposed humus builds in the forest floor (Taylor 1933). Trees that develop in the shaded understory tend to grow slowly because of insufficient light. Understory trees are more defective because falling limbs and trees easily damage them, or they may be infected by hemlock dwarf mistletoe (*Arceuthobium tsugense* Rosendahl). Total stand volume diminishes over time because of decay in standing trees, inefficient use of growing space, and reduced soil productivity. Loss from decay eventually offsets growth, and in advanced successional stages, net stand growth may be negative.

The structure of late-successional stands is variable because of species composition, soil drainage, and the effect of chance damage from wind, insects, or other factors. Most trees in a typical old-growth stand are western hemlock. Relatively few Sitka spruce exist in these stands, especially in the smaller diameter classes. Cedars are rare on the better sites and more common on the less productive timber sites. For trees of equal diameter, hemlock are generally older than spruce. Advanced regeneration also tends to be old. Hemlock with diameters of 13 to 15 centimeters average about 120 years old and spruce about 70 years old; small sawtimber hemlock, 28 centimeters in diameter, average 180 years old, and similar sized spruce are about 110 years old. On average, most spruce over 28 centimeters in diameter and hemlock over 13 centimeters are at least 100 years old (Harris and Farr 1979).

Hemlock is generally more defective than spruce. About 35 percent of the sawtimber-sized hemlock and 20 percent of the spruce have some external indicators of decay, such as basal scars, trunk scars, frost cracks, broken tops, or conks (Farr and others 1976). On average, total defect accounts for about 31 percent of the gross board-foot volume of old-growth stands. For hemlock especially, there is considerable volume loss in the older age classes.

There has been little experience with various forms of partial cutting of old-growth stands in Alaska, except for selective logging of high-quality spruce along much of the accessible shoreline. Consequently, many shoreline stands have a low percentage of spruce and contain many suppressed hemlocks that have developed in an understory position. A comprehensive evaluation of these residual stands has not been made. It is encouraging to note, however, that although blowdown is common in stands that were selectively logged 40 to 100 years ago, severe wind damage does not necessarily follow. Partial cutting was done in a streamside stand of spruce and hemlock at Pavlof River (Chichagof Island) in 1978. Although insufficient time has elapsed to evaluate long-term wind damage, little has occurred to date.

Some experience has been gained with various forms of partial cutting in conifer stands in the Pacific Northwest. Selective cutting based on economic value was attempted during the 1930s (Kirkland and Brandstrom 1936). Experience showed that selective logging damaged the residual stand, windthrow proved excessive, and growth of the residual stand was poor (Issac 1956, Wright and Isaac 1956).

Two studies of partial cutting in even-aged hemlock-spruce stands, one in Alaska (Farr and Harris 1971) and one in Oregon (Williamson and Ruth 1976), provide some insight into regeneration response that might apply to old growth but little indication of probable wind damage. In southeast Alaska, a study of partial cutting show that a 96-year-old stand responded well to thinning (Farr and Harris 1971). Blowdown was not a serious problem on one test area thinned to 297 trees per hectare and to two-thirds of the original basal area. Dense hemlock regeneration became established, but growth rate was slow. Seventeen years after the initial cut, there were 61,900 seedlings per hectare, averaging 2.1 meters in height. An adjacent test of thinning suffered severe wind damage and had to be abandoned.

In western Washington, partial cutting in a 60-year-old stand resulted in dense regeneration, with up to 45,700 postlogging seedlings per hectare (Williamson and Ruth 1976). Overstory ranged from 9 square meters to nearly 54 square meters of basal area per hectare. Greatest number of seedlings became established under moderate overstories of 9 to 18 square meters of basal area. Some blowdown occurred during a severe gale 2 years after the initial cut, and because of this, the second cut was advanced 1 year. Extent of damage was generally heavier in the more open stands and was noticeably affected by topography.

In Montana, Alexander (1963) found in old-growth Engelmann spruce-subalpine fir (*Picea engelmannii* Parry ex Engelm.-*Abies lasiocarpa* (Hook.) Nutt.) stands that 11 years after removal of 60 percent of the volume by single-tree selection cutting, ample regeneration exists beneath the residual stand. Some slash disposal and exposure of mineral soil seedbeds was recommended. Mean annual net increment on all plots was related to reserve volume, and the rate of growth in residual stand was not stimulated by cutting. Net increment was only about one-third that in uncut stands. Mortality was not reduced by cutting because of heavy windfall losses in the residual stand. The 60-percent stand removal was later conceded to have been too drastic (Alexander 1973), and recommendations were made to make a light cut, removing 20 to 30 percent of basal area on an individual tree basis or in small groups. The objective would be to initially open up the stand enough to develop windfirmness and salvage low-vigor and poor-risk trees.

A study in an Englemann spruce-subalpine fir stand in northern Idaho where 67 percent of the original volume was cut showed that damage from blowdown was not excessive (Roe and DeJarnette 1965). Annual mortality from wind in the residual stand was 41 board feet per acre per year, mostly spruce. Most fir mortality was due to sunscald and other causes. Seed source and environmental conditions favored establishment of regeneration in the partial cut, but the best environmental conditions for later growth were in clearcut areas.

In Oregon, an administrative study of partial cutting of mature even-aged Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stands in the Pansy Basin area of the Mount Hood National Forest was done between 1973 and 1977 (Tokarczyk and others 1979). Seven units were partial cut. In a light partial cut, little effect occurred on the stand because the cut was so light. Skyline yarding along narrow corridors did little damage to residual trees. This unit was judged to have met visual quality objectives. In most cases, however, blowdown was a serious problem in residual stands. Although unmerchantable material on the units was removed and some units received additional slash disposal treatment, considerable logging slash remained on site. The Pansy Basin report concluded that windthrow of leave trees destroyed much of the effectiveness of the partial cutting efforts. Partial cuts suffered much windthrow in exposed locations or where there was shallow soil and a high level of soil moisture. Investigators cautioned that subsequent overstory removal likely would damage reproduction.

Diseases

Disease plays a vital role in the normal functioning of unmanaged forests in southeast Alaska. Because fire and some other forms of disturbance are uncommon, disease-causing organisms have a more significant effect on stand structure, development, and succession than in many other forest ecosystems. The action of disease is slow and chronic, and the effects are sometimes overlooked or underestimated. Heart rot and hemlock dwarf mistletoe are the two diseases that seem to have the greatest effect on timber values and the most influence over ecological conditions. Both are abundant in old hemlock-spruce forests. For example, heart rot causes most of the estimated one-third cull of live trees on the Tongass National Forest. Both, for different periods of time, are largely eliminated from sites through clearcutting and the resulting early-successional stages of hemlock and spruce. The reduction of these diseases may be beneficial for timber production, but their absence seems to result in a loss of diversity of structure and diminished wildlife habitat.

Because of their dispersal and infection mechanisms, heart rot and dwarf mistletoe are well adapted to small-scale disturbances and will be favored by alternative harvesting techniques, in comparison to clearcutting. Dwarf mistletoe thrives where stand openings seem to trigger its reproductive cycle. More importantly, its short-range seed dispersal allows it to spread over limited distances from large, infected residual hemlocks. Most of the heart rot in southeast Alaska is associated with bole wounding, an event that is certain to occur in varying amounts with any form of selection harvest because of the thin bark of all coastal tree species.

Thus, the spread of decay fungi into bole wounds and dwarf mistletoe from residual trees are two major concerns among many forest managers about alternative harvesting in southeast Alaska. An ecosystem management perspective of these diseases, however, would evaluate their functional roles in unmanaged forests (which seem to be significant) and consider managing for levels of disease that are beneficial for various resource objectives. The health and productivity of the forest that remains after alternative harvesting must be an important consideration in any ecosystem management approach. Thus, some of the goals of our proposed research are to determine the ecosystem roles of disease, evaluate the health of the residual forest after alternative harvesting, and develop silvicultural tools to manage for low to moderate levels of disease with predictable impacts so that many resources are benefited, but undue timber losses are avoided.

Deer Habitat

Much of the debate over forest management in southeast Alaska has centered on the effects of clearcutting on the habitat of the Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) (Hanley and others 1989, Meehan and others 1984). Hanley and others (1989) review and synthesize recent research on this species, and Hanley (1984) reviews research conducted before 1980. With the widespread interest in the Sitka black-tailed deer and the relative wealth of information available on its biology, Hanley (1993) proposes the Sitka black-tailed deer as an ecological indicator species, one that integrates biological, cultural, and economic values and their responses to resource management. The viability of deer populations is not currently endangered by timber harvesting, but large, productive deer populations are required to meet subsistence and recreational hunting demands, and this potential harvest is what is affected by logging (Hanley and others 1989). In addition, deer are an important part of the prey base of the Alexander Archipelago populations of the gray wolf (*Canis lupus ligoni*), recently proposed for listing as a threatened species.

Late-successional forests provide high-quality habitat for deer, especially during winter (Wallmo and Schoen 1980). Frequent, low-intensity disturbances in these stands produce small canopy openings that allow the development of a diverse and productive understory (Alaback 1982, 1984). Evergreen forbs such as five-leaved bramble (*Rubus pedatus* Sm.) and bunchberry (*Cornus canadensis* L.) do well under these conditions and provide high-quality forage for deer in winter (Hanley and McKendrick 1983). In contrast, the even-aged stands that develop after clearcutting have low understory productivity for 100 to 150 years after canopy closure (Alaback 1982). Before canopy closure (typically at 25 to 35 years), understory productivity is high but is dominated by conifer seedlings and shrubs (Alaback 1982). In the ample light of young clearcuts, these plants produce abundant forage, but it is of lower quality because of its high carbon-nutrient ratio and high concentration of tannins, which limit protein digestibility (Hanley and others 1989).

Snow accumulation and persistence affect deer habitat quality by lowering the quantity and quality of food available and by increasing the effort required to move about. Snow packs can bury the low-statured evergreen forbs, leaving only the less digestible twigs, lichens, and conifer foliage available. Thus, snow pack not only affects overall forage availability but also lowers the average diet digestibility (Hanley and others 1989). The energy expended by mule deer (*Odocoileus hemionus*) and elk (*Cervus elephus*) traveling through snow increases with snow depth and density (Parker and others 1984). In a study of the relation between forest structure and snow pack, Hanley and Rose (1987) found that snow depths generally are negatively related to overstory canopy cover and gross stand volume, although the precise relations varied between sampling periods. By removing canopy cover, timber harvesting alters the accumulation and persistence of snow packs that, in turn, affect deer food resources and movement.

The preceding discussion is not meant to imply that other wildlife species are unimportant or unaffected by forest management. Taylor (1979) lists 231 bird species, 54 mammal species, and 5 species of reptiles and amphibians present on the Tongass National Forest; many are associated with forested ecosystems. An interdisciplinary team of Forest Service and cooperating biologists selected 13 of these species to be management indicator species for the purposes of land use planning (USDA Forest Service 1991): red squirrel (*Tamiasciurus hudsonicus*), black bear (*Ursus americanus*), brown bear (*Ursus arctos*), American marten (*Martes americana*), river otter (*Lutra canadensis*), Sitka black-tailed deer, mountain goat (*Oreamnos americanus*), gray wolf, Vancouver Canada goose (*Branta canadensis fulva*), bald eagle (*Haliaeetus leucocephalus*), red-breasted sapsucker (*Sphyrapicus ruber*), hairy woodpecker (*Picoides villosus*), and the brown creeper (*Certhia americana*). Recently, concern has increased over the status of the marbled murrelet (*Brachyramphus marmoratus*) and the Queen Charlotte goshawk (*Accipiter gentilis laingi*). All these species are at least seasonally associated with high-volume old-growth conifer stands and presumably derive some benefit from the structure, composition, or function of these environments.

Avian Diversity and Abundance

Birds traditionally have been used as important indicators of ecosystem condition. Furthermore, several avian species that occur in southeast Alaska forests are of special interest, as part of the nationwide concern for the population viability of Neotropical migrants or because their regional status may be in jeopardy. Birds are an important component of biodiversity from two points of view: (1) **Ecosystem function**. Birds are critical agents of pollination and especially seed dispersal for several understory plants in southeast Alaska, and thus are part of the reproductive cycle of those plants; they are also notable consumers of many insect species. (2) **Public attention**. Birds are conspicuous and popular animals that attract public interest and concern. For these reasons, an understanding of the avian response to alternative silvicultural practices is essential to assessing the impact of different practices.

Conventional timber harvesting in southeast Alaska involves clearcutting of sizeable areas, a practice that has major effects, not only on mammals and aquatic organisms, but also on birds. Removal of trees from large areas of land eliminates all the birds that require relatively large trees (e.g., woodpeckers, brown creepers, and kinglets [*Regulus* spp.], red-breasted nuthatches [*Sitta canadensis*], goshawks, murrelets, etc.) for nesting; it also destroys habitat for birds that normally nest in forest understory (e.g., the varied thrush [*Ixoreus naevius*] and hermit thrush [*Catharus guttatus*]). Rather than typical conifer-forest birds, clearcuts commonly host species that customarily inhabit forest edges and deciduous stands (e.g., orange-crowned warbler [*Vermivora celata*], yellow warbler [*Dendroica petechia*], Wilson's warbler [*Wilsonia pusialla*], Swainson's thrush [*Catharus ustulatus*], juncos [*Junco hyemalis*], and fox sparrows [*Passerella iliaca*]). Changes in southeast Alaska avian communities in relation to habitat and clearcutting are described by Willson and Comet (1996a, 1996b), DelaSalla and others (1996), and Kessler and Kogut (1985). In short, the avian community changes radically. Less drastic habitat modification is imposed by patch cuts and thinning, but the quantitative impact of alternative timber-harvesting practices on the avian community has not been assessed previously.

A major factor determining the distribution, abundance, and nesting success of breeding birds in many forests, including those of southeast Alaska, is predation on nest contents (eggs and chicks, reviewed in Sieving and Willson 1998 and De Santo and Willson, in press). Nest predation is thought to be responsible, not only for the evolution of many avian life-history characteristics, but also for local and regional patterns of population viability. For example, "edge effects" (at the borders of woodlots, for example) resulting from nest predation (and brood parasitism) are common and important in many other forests. Much of our study, therefore, focuses on patterns of nest predation and nest-predator distribution.

Fish Habitat and Aquatic Productivity

Knowledge of the influences of forest management on salmonid fish habitats in the Western United States is compiled and reviewed by Meehan (1991a). As the effects of forest management on fish habitat became better known over the past two decades, increased concern for habitat quality led to the establishment of protective measures, including no-cut buffers along anadromous fish-bearing streams (Meehan 1991b). Recently proposed management strategies would extend buffers to all headwater streams on commercial forest lands, but little is known of how headwater streams affect downstream anadromous fish habitat and food web productivity in southeast Alaska or how those effects might differ between undisturbed and disturbed forest cover. Chamberlin and others (1991) emphasize the importance of small streams and their sensitivity to forest management activities. Headwater streams may export sediment, particulate organic detritus, dissolved nutrients, and invertebrates to downstream fish-bearing lakes and streams (Murphy and Meehan 1991). Conditions in headwater streams also might affect important water quality parameters such as pH, temperature, and dissolved oxygen. Disturbances that alter these export functions could be natural (such as windthrow) or human-caused (such as clearcutting or alternative timber harvest regimes). Clearly, important questions remain about the functions of headwater streams and their response to disturbance.

Ground-Water and Soil Mass Movement

In southeast Alaska, soil mass movements are among the principal processes of slope erosion and sediment transport to stream channels. As well as removing or reducing the productivity of timber area, these mass movements are prodigious producers of sediment and large woody debris in class I and class II streams (anadromous and resident fish streams) that may directly or indirectly affect populations and habitat (Meehan 1974, Phillips 1971).

High soil moisture levels and oversteepened slopes are characteristics common to sites of mass wasting activity in the region. Because of the high infiltration rates and hydraulic conductivities of the forest soils, water moves almost exclusively by subsurface flow with almost no overland flow occurring except in defined channels. During intense rainfall periods, high soil moisture levels and localized areas of saturation are produced, greatly enhancing the probability of slope failure.

Fluctuations of the moisture regime in hillslope soils affect their stability in three ways: (1) The rise of a natural or perched ground-water table above a potential failure plane in the soil mantle creates positive pore water pressures, which decrease the soil shear strength. The extent to which shear strength is reduced is proportional to the water table rise and can be easily calculated (Torheim 1977). (2) Changes in soil moisture content above the water table also impact cohesive forces operating within the soil. In fine-grained soils, true cohesion is produced primarily by weak electric bonding of contained clay minerals. In such materials, true cohesion generally increases with increasing moisture content to a maximum slightly above the plastic limit of the soils, and then decreases rapidly as the moisture content is further increased (Baver and others 1972). This relation is less quantifiable than the influence of a rising water table, although some earlier research (Nichols 1931) shows that the product of soil moisture component and cohesion should be a constant for a fine-grained soil at moisture conditions greater than the plastic limit, but less than saturation. Steep-slope soils in southeast Alaska are almost universally coarse grained and possess only a small amount of true cohesion. These soils characteristically possess an “apparent” cohesion produced by capillary tension between mineral grains and rock particles when the soils are in a relatively dry state. Increasing moisture content destroys this “apparent” cohesion. (3) Finally, water content within the soil mantle directly influences slope stability because of changes in gravitational stress (both normal and downslope components) as the weight of the soil mass increases. By knowing these changing moisture conditions along with slope angle and soil depth, we can more accurately define and calculate their impacts on the driving and resisting forces of slope mechanics.

Research in southeast Alaska (Bishop and Stevens 1964, Swanston 1969, Vandre and Swanston 1977), Oregon (Dyrness 1967, Fredricksen 1963, Swanson and Swanston 1977), California (Cleveland 1973, Rice and Fogging 1971), Alberta (Beaty 1972), and Great Britain (Hutchinson and Bhandari 1971) has shown that increasing soil moisture and piezometric head through precipitation inputs and water diversions have greatly accelerated the frequency of planar and rotational mass failures. Although it is generally conceded that increased water levels within the failure zones initiated these mass movements, the extent to which increasing soil moisture increases shear stresses and shallow ground-water levels is unknown.

Swanston (1967) developed a nomograph to predict piezometric head based on accumulated rainfall for linear depressions in the Maybeso Creek Valley of Prince of Wales Island. Pierson (1977) found that maximum 24-hour rainfall is highly correlated with piezometric response for shallow Coast Range soils of Oregon. The predictive capabilities of both of these studies were highly site specific. The ability to predict maximum piezometric rise and soil moisture levels (in the range in which they would decrease cohesion) on an areal basis would be a major advance in slope stability hazard rating.

In addition to defining response of soil moisture levels to hydrometeorological and geomorphological variables, monitoring the effects of various timber harvesting systems on subsurface hydrology also should be done. Presently, slope stability mapping of watershed-sized areas is based primarily on measurements of slope steepness with assumptions made for internal angle of friction of the soil, apparent cohesion, and ground-water location (Burroughs and others 1976, Nichols 1931, Quigley 1975). The need for developing reliable techniques and models to predict ground-water levels and soil moisture changes for potentially unstable hillslopes was outlined at the USDA Forest Service interstation slope stability workshop in November 1978.

Detailed models have been developed (Ward and others 1979) that incorporate the influence of ground water on shear strength for areal slope hazard mapping. The reliability of this type of model, however, is only as good as the ability to predict strength characteristics and hydrologic responses. Thus it is proposed that a more generalized predictive model (on an areal basis) be developed by carefully selecting geomorphological and soils properties of individual drainages. This would initially involve predicting maximum piezometric rise based on rainfall inputs for given areas of similar soils and geologic conditions. Ultimately, more theoretical models will be developed or existing models (Stephenson and Freeze 1974) modified to predict subsurface hydrologic response on relatively uniform slopes. This type of approach will require verification with field data as outlined in this plan.

In some cases, clearcutting may be unacceptable on steep slopes because the loss of a living root system may contribute to slope instability (Swanston 1973). With the use of clearcutting with reserves or two-stage cutting, part of the forest root system would be retained to maintain soil stability while a replacement root system developed from the regenerating stand. This would allow an effective root system and forested cover to be maintained under even-age or two-age management. Similar results could be produced with single-tree or group-selection harvesting under an uneven-age management scheme.

Research Study Overview

Research Objectives

Our general objective is to provide information that will guide sustainable timber production, in an ecosystem management context, by evaluating several silvicultural systems that may be practical alternatives to even-age management with clearcutting in southeast Alaska. The specific study objectives follow.

Stand dynamics, understory response, and forest health—

1. Increase our understanding of old-growth stand structure and dynamics in southeast Alaska—including physical structure, age distribution, disturbance history, plant communities, and natural levels of tree damage and mortality—and how these factors influence responses to selected silvicultural systems.

2. Determine how selected even- and uneven-age silvicultural systems affect important stand features and processes, including:

- Survival and growth of residual overstory trees; survival and growth of advance regeneration; and new tree germination, establishment, and growth
- Habitat features such as canopy structure and the longevity and recruitment of standing snags, logs, root wads, and others
- Understory plant diversity and abundance, understory plant productivity, and the nutritive quality of important wildlife forage species
- Tree damage that occurs during timber harvesting and subsequent postharvest tree damage due to wind, dwarf mistletoe, fungi, insects, and other agents.

Avian ecology—

1. Characterize the preharvest and postharvest composition and density of forest birds.

2. Determine habitat use and quality via measures of fitness; i.e., the breeding success of forest birds among the experimental treatments after tree harvest.

Aquatic ecology—

1. Measure transport of aquatic and terrestrial invertebrates (prey for juvenile salmonids) and particulate organic matter from headwater to downstream fish-bearing streams.

2. Measure changes in (1) the structure of the aquatic invertebrate community and the composition of functional feeding groups, and (2) the transport of invertebrates and organic matter in response to silvicultural treatments.

3. Determine how silvicultural treatments affect aquatic invertebrate biodiversity in headwater areas.

4. Measure how silvicultural treatments affect sediment transport, determine the role of large wood in maintaining aquatic productivity in headwater areas, and determine how silvicultural treatments affect this productivity through large wood dynamics.

Hydrology and slope stability—

1. Evaluate the effects of clearcutting and alternative silvicultural systems on ground-water accumulation and movement in response to seasonal and individual storm rainfall.

2. Evaluate the impacts of clearcutting and alternative silvicultural systems on soil mass movement and slope stability.

Socioeconomic—

1. Evaluate the visual effects of selected silvicultural systems by comparing perceptions before and after treatment, both within and across treatments. Determine how perceptions differ among different populations such as local residents, nonresidents in the lower 48 States, visiting nonresidents, and other user groups.

2. Evaluate alternatives to clearcutting (ATC) treatments for their social acceptability, a broader issue that encompasses visual, economic, and environmental concerns. Determine how social acceptability differs among various geographic and stakeholder groups.

3. Identify and document technical and operational problems encountered while implementing alternative silvicultural systems and develop management guidelines based on successful problem resolution or prevention.

Benefits and Applications

Alternative silvicultural systems have many potential benefits, including sustainable timber harvests, protection of fish and wildlife habitat, maintenance of biological diversity, maintenance of slope stability, reduction of visual impacts, reduced conflict over land management options, and greater social acceptance of commodity production. This study is intended to assist natural resource managers in choosing among management options by providing essential information on the costs and benefits of adopting alternative silvicultural systems. Such research will fill gaps in our knowledge about the application and effects of alternatives to clearcutting.

The principal users of this information will be USDA Forest Service personnel managing the hemlock-spruce forests of southeast Alaska. Other users, however, will include natural resource scientists studying the biology and management of forests and associated ecosystems; forest policymakers in the executive, legislative, and judicial branches of the Federal Government; and members of the public interested in the biology and management of forests and associated ecosystems. The major non-Federal forest landowners in southeast Alaska—the Alaska Native Corporations and the State of Alaska—also may find uses for the results of this study.

A central tenet of ecosystem management is the importance of partnerships between science, management, and the public; this research presents new opportunities for creating such partnerships. We have established experimental study installations on the Chatham, Stikine, and Ketchikan Areas of the Tongass National Forest. Not only will this test the treatments over a representative range of biogeoclimatic conditions, but it also will facilitate cooperation and sharing of knowledge between researchers, land managers, and the public throughout southeast Alaska. The retrospective study sites are also well distributed throughout southeast Alaska.

Research Strategy

The ATC study is an integrated group of studies designed to supply information needed for choosing among silvicultural options for managing late-successional stands on timber-production lands in southeast Alaska. We are examining biological, physical, and socioeconomic effects within an integrative research framework. Because the need for this information is urgent, we will use a combination of long-term experimental and short-term retrospective studies.

We propose to establish a well-designed, controlled, and replicated experimental study with installations at three sites on the Tongass National Forest. The study will be established over a span of 5 to 10 years, with followup monitoring after that. Results from this study will be defensible and reliable, but we recognize that it will not yield quick answers to all of our questions. To provide interim guidance to land managers, we will augment the experimental study with retrospective studies of forest ecosystem responses to natural or human-caused disturbances. The retrospective approach will be most useful for quickly (within 5 years) answering questions about changing ecological conditions and resources, stand dynamics, understory vegetation response, and pest and pathogen dynamics.

Experimental Study Design

In this experimental study, we will test silvicultural systems that are practical and likely to be applied, that are under consideration by practicing silviculturists in the Alaska Region, and that retain or create forest structures similar to those created by natural disturbances in old-growth forests.

Our original study proposal called for testing skyline cable yarding systems as well as helicopter yarding, but the level of funding received allows testing of only one harvest system if a full range of silvicultural treatments is to be implemented. To avoid confounding treatment effects with yarding systems, a single yarding system must be used in all treatments. Because helicopter yarding is the only method suitable for all the planned treatments, we will limit testing of yarding systems to helicopter only. The effects of cable yarding systems can be assessed through adaptive management studies coordinated with this study. In addition, we recognize the importance of landscape-level issues associated with timber harvest, but limited resources constrain the scale of the proposed experimental study to the stand level or below. Some opportunities exist to address landscape-level questions through retrospective studies, but again our primary focus will be on responses at the stand level or below.

Treatments will include clearcutting with and without reserved trees (single tree and groups), single-tree selection at various levels of retention, group-selection cuts of various sizes, and an uncut control. The experimental design that follows is complex, but it offers a rich set of practical and interesting treatments designed to answer important silvicultural and ecological questions.

Three factors and their interactions will be tested: (1) the amount of trees retained after timber harvest, (2) the spatial pattern of the retained trees (i.e., uniform vs. patchy), (3) and the size of patches (gaps or uncut clumps). Treatments will be arranged in a randomized complete block factorial split-plot design. Retained stand density and spatial pattern will be the factorial, whole-plot treatments; patch size will be the subplot treatment.

Total basal area per unit area will be the measure of stand density, and treatment levels will be defined by the percentage of the initial stand density retained after timber harvest. Posttreatment densities will range from 0 to 100 percent of the initial stand density (clearcut and uncut control, respectively), with three intermediate densities. Because the density treatment is defined in terms of the initial stand density on the treatment unit, it is essential that the treatment units within a block have initial stand densities that are as similar as possible. Variation of initial stand density between units will add to the experimental error, but random assignment of treatments will eliminate this as a potential source of bias.

We will test three spatial patterns of the retained trees, holding the stand-level density constant. In one pattern, retained trees will be uniformly dispersed throughout the stand, another pattern will have uncut patches or clumps within a uniform matrix, and the final pattern will have patches or gaps cut into the uniform matrix. The matrix density will differ according to the desired stand-level density, but the number, size distribution, and total area of patches will be the same across all patch treatments. Three size classes of patches will be created with diameters equal to one, two, and three times the average regional overstory tree height (32 meters, see footnote 1 for source). As far as possible, equal numbers of small, medium, and large patches will be within each treatment unit. Figure 1 is a schematic illustration of the proposed treatments. Assuming a mean overstory height of 32 meters and a treated area of 18 hectares, there will be four clumps or gaps of each size in each treatment unit. Descriptions of the treatments follow, and a summary of the treatments can be found in table 1.

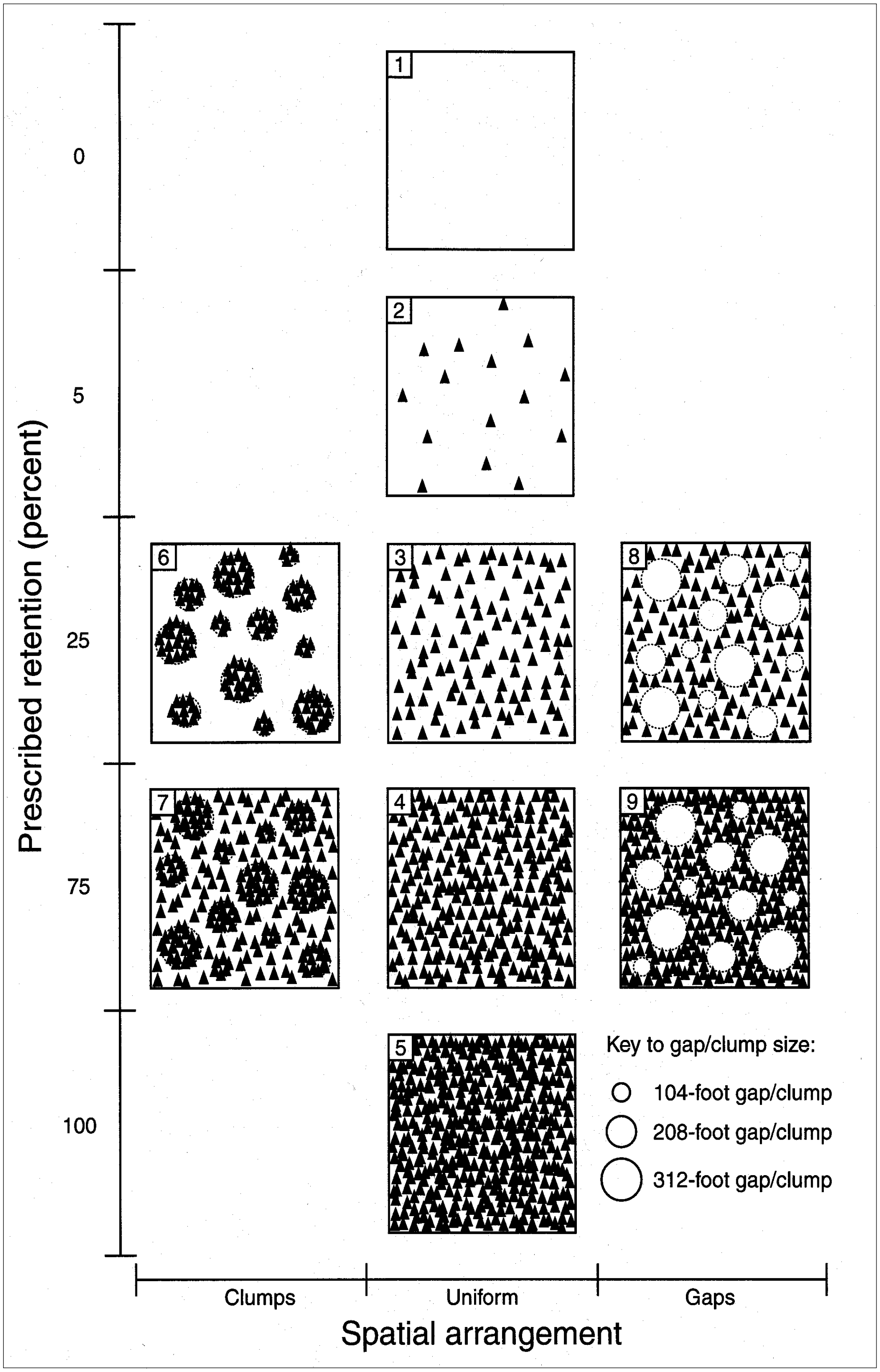

Figure 1—Schematic representation of experimental treatments.

Table 1—Summary of planned treatments

Treatment number	Stand-wide residual basal area	Spatial arrangement of retained trees	Matrix residual basal area
	Percent		*Percent*
1	0	Uniform	NA
2	5	Uniform	NA
3	25	Uniform	NA
4	75	Uniform	NA
5	100	Uniform	NA
6	25	Patchy (clumps)	0
7	75	Patchy (clumps)	66.6
8	25	Patchy (gaps)	33.3
9	75	Patchy (gaps)	100

NA = not applicable.

Treatment 1. This is an even-age silvicultural system using clearcutting and natural regeneration. No trees above merchantable size, 23 centimeters in diameter at breast height (d.b.h.), will be retained. In practice, many of the submerchantable trees are cut or destroyed by logging activities. This has been the dominant silvicultural prescription in southeast Alaska until recently, and this treatment allows us to compare the effects of alternative treatments to the status quo. No further regeneration cuts are planned for the current rotation.

Treatment 2. This is an even-age silvicultural system using clearcutting and natural regeneration. Five percent of the basal area will be retained as green trees with d.b.h. greater than 23 centimeters, spaced evenly across the unit. This “wildlife tree” silvicultural prescription is commonly applied in southeast Alaska. No further regeneration cuts are planned for the current rotation.

Treatment 3. This is an uneven-age silvicultural system using single-tree selection cutting. Twenty-five percent of the basal area will be retained, and the residual trees will be evenly spaced across the unit. The treatment is not a shelterwood cut, as the purpose is not to moderate site conditions for regeneration, and no further regeneration cuts are planned for this rotation.

Treatment 4. This is an uneven-age silvicultural system using single-tree selection cutting. Seventy-five percent of the basal area will be retained, and the residual trees will be evenly spaced across the unit. An additional single-tree selection cut is planned for this rotation to remove another 25 percent of the basal area 30 to 40 years after the initial treatment.

Treatment 5. This is an uncut control.

Treatment 6. This is an uneven-age silvicultural system using group retention cutting. Twenty-five percent of the basal area will be retained, the residual trees will be aggregated into clumps, and the matrix surrounding the clumps will be clearcut. The clumps will be one, two, and three tree heights in diameter. In this treatment, about 25 percent of the treated area is in clumps, the clump diameters are 31.7, 63.4, and 95.1 meters, respectively, and the individual clump areas are 0.08, 0.32, and 0.71 hectare, respectively. No further regeneration cuts are planned for this rotation.

Treatment 7. This is an uneven-age silvicultural system using single-tree selection cutting. Over the entire stand, 75 percent of the basal area will be retained. To achieve this, 25 percent of the area will be left uncut in clumps (same size and number as in treatment 6), and the matrix surrounding the clumps will be cut by single-tree selection, with two-thirds of the original basal area being retained. An additional single-tree selection cut is planned for this rotation to remove another 25 percent of the basal area 30 to 40 years after the initial treatment.

Treatment 8. This is an uneven-age silvicultural system using both single-tree and group selection cutting. Over the entire stand, 25 percent of the basal area will be retained. To achieve this, 25 percent of the area will be cut by group selection (gaps of the same size and number as the clumps in treatment 6), and the matrix surrounding the gaps will be cut by single-tree selection, with one-third of the original basal area being retained. No further regeneration cuts are planned for this rotation.

Treatment 9. This is an uneven-age silvicultural system using group selection cutting. Over the entire stand, 75 percent of the basal area will be retained. To achieve this, 25 percent of the area will be cut by group selection (gaps of the same size and number as the clumps in treatment 6), and the matrix surrounding the gaps will be left uncut. An additional group selection cut is planned for this rotation to remove another 25 percent of the basal area 30 to 40 years after the initial treatment.

We originally planned to establish six blocks (replicates) of the nine-treatment set, distributing the blocks over the three administrative areas of the Tongass National Forest. Limited funding led to reducing the experiment to three blocks—one on each area. Plot establishment and pretreatment measurements began on block 1 at Hanus Bay (57°23’32” N. latitude, 134°58’22” W. longitude) in the Sitka Ranger District, Chatham Area, late in 1994; on block 2 at Portage Bay (56°56’16” N. latitude, 133°10’23” W. longitude) in the Petersburg Ranger District, Stikine Area, in 1996; and block 3 at Lancaster Cove (55°11’03” N. latitude, 132°06’01” W. longitude) in the Craig Ranger District, Ketchikan Area, in 1997 (see fig. 2 for locations). All treatment units within a particular block must be cut and yarded within one field season. The Hanus Bay block was harvested in 1997, Portage Bay was harvested in 1999, and Lancaster Cove is slated for harvesting in 2000 or 2001. Within-block conditions (soils, stand conditions, and topography) should be relatively uniform, but greater between-block heterogeneity is tolerable. Variation due to the time of establishment—if present—will be included within the blocking effect. Two constraints were met to protect the scientific validity of this study: first, all treatments, including the clearcut and no-cut control, were randomly assigned to treatment units; second, all harvesting uses the same logging system (helicopter) to ensure that disturbance effects are comparable. The first constraint required sale planners to make available a pool of units equal to the number of treatments, reccognizing that one will be clearcut, another will remain uncut, and that the prescription for a particular unit would be chosen by a random process. Because the single-tree-selection treatments require yarding by helicopter, the second constraint requires that all treatment units be yarded by helicopter, even if a cable system would be more appropriate.

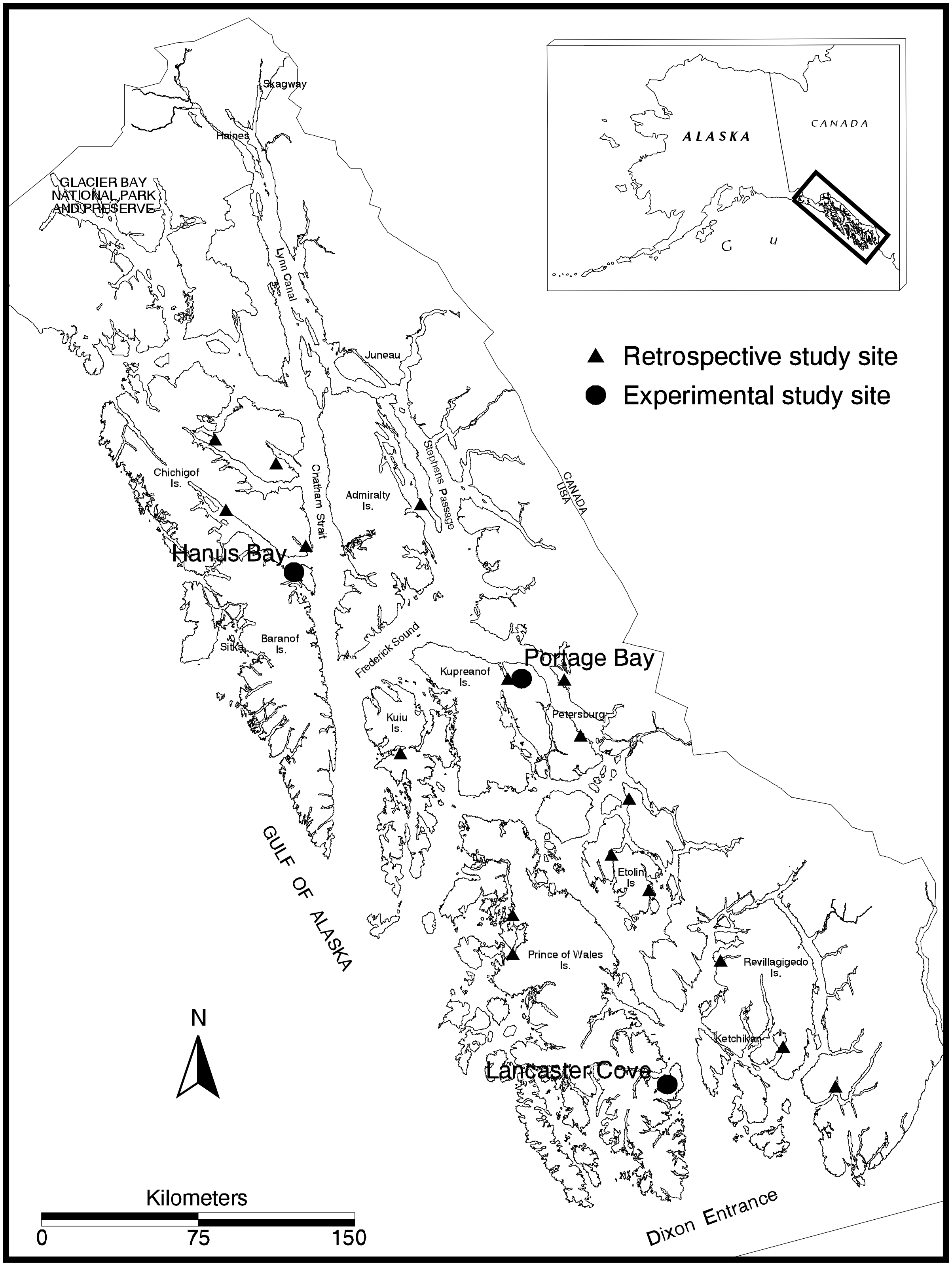

Figure 2—Distribution of experimental and retrospective study sites.

Site selection was done in consultation with Area and Ranger District staff after considering the study objectives, research plan and schedule, and site-selection criteria. After compiling information on available sites, we reviewed, evaluated, and selected potential sites through office reviews and site visits. Environmental analysis requirements differed among sites. The Hanus Bay block comprised National Environmental Policy Act-cleared sale units (part of a larger environmental impact statement [EIS] and conventional sale program) that were slightly modified for this study. The Portage Bay block was selected through an environmental analysis process that considered only experimental units. The experimental units for the Lancaster block were covered by an EIS that included additional conventional harvest units. On completion of the environmental analyses, Ranger District staff were responsible for the timber-sale preparation, including marking of unit boundaries specified jointly by the PNW Research Station and Ranger District staff. Tasks performed by the PNW Research Station during this phase were generally limited to review and resolution of questions or problems.

An interdisciplinary team made up of PNW Research Station silviculturists and other resource specialists from the National Forest System (NFS) developed tree-marking guides based on the general treatment prescriptions. Ranger District staff were primarily responsible for pretreatment marking of trees to be retained or harvested, and PNW Research Station scientists assisted in training marking crews. To assure that the treatments are applied as intended, the Station consulted with contracting officers, sale administrators, and operators before harvest to ensure they understood and assented to the aims, objectives, and methods of this study. In addition, a Station field representative is onsite during harvest to monitor operations, answer questions, and resolve questions about implementation.

Components of the Experimental Study

The study described in this document is a set of integrated studies of biological, physical, and social responses to alternative silvicultural treatments. We refer to these mutually supporting studies as component studies; and although they are described separately in the sections that follow, they share common sites, experimental design, and often, field data-collection tasks. The goal is not simply to share study sites, but to build on each other's work to create a unified whole. Accordingly, the successful analysis and interpretation of each component study will require the integration of results from its companion studies. We present plans for the component studies, which include research on:

- Effects of alternative silvicultural treatments on the structure and dynamics of late-successional hemlock-spruce stands and associated vegetation
- Retrospective studies of disturbance effects on the structure and dynamics of late-successional hemlock-spruce stands and associated vegetation
- Influence of alternative silvicultural treatments on the dynamics of hemlock dwarf mistletoe infection
- Harvest-related and postharvest wounding, windthrow, and stress of residual trees after alternative silvicultural treatments
- Avian diversity and abundance in managed forest stands
- Hydrologic factors influencing slope stability
- Sediment transport as affected by alternative silvicultural treatments
- Effects of alternative silvicultural treatments on the productivity of headwater streams.

Effects of Alternative Silvicultural and Harvest Systems on the Structure and Dynamics of Old-Growth Hemlock-Spruce Stands and Associated Vegetation[4]

Introduction and objectives—This study will examine responses of overstory and understory vegetation to the experimental silvicultural treatments outlined previously. We will determine the effects of initial stand structure, residual stand density, and the spatial arrangement of residual trees on components of stand change: accretion (growth of residual trees), ingrowth, mortality, removals (both actual and potential for future), net growth (ingrowth + accretion - mortality), and net change (net growth - removals). Also, we will determine how initial stand and understory structure, harvest-related disturbance of soil and understory, residual stand density, and the spatial arrangement of residual trees affect tree regeneration, particularly the balance between spruce and hemlock regeneration.

The effects of thinning and clearcutting on understory vegetation are well known from ongoing studies by the PNW Research Station. In general, aggressive woody shrubs dominate the understory until they are shaded out by the overstory, and a substantially less diverse understory develops in these second-growth stands. After natural disturbances such as windthrow, however, plant diversity often increases. As in other rain forest types, frequent small-scale disturbances play a key role in maintaining ecosystem diversity. The central question is whether small openings created by partial cutting can emulate natural disturbance and, if so, how large a canopy opening can be created before the understory degrades into a shrub-dominated monolayer. In this study, we will use single-tree and group selection systems to create a wide range of canopy openings and establish where this threshold lies. We will determine how initial stand and understory structure, harvest-related disturbance of soil and understory, residual stand density, and the spatial arrangement of residual trees affect understory plant diversity and abundance, competitive relations, and the nutritive quality of important forage species.

With this study, we will test the following hypotheses:

- If the density and spatial arrangement of trees in late-successional stands control understory plant diversity and abundance, and if stands are manipulated by silvicultural systems to create conditions similar to those that occur after natural disturbances, then the resulting understory plant diversity and abundance will be similar to that found in naturally disturbed, unmanaged stands.
- If stand density is significantly reduced, postharvest wind damage will (1) be greater than in uncut or lightly cut stands, (2) be greatest in patch treatments with the greatest contrast between patch and matrix densities, and (3) increase with gap diameter.
- The inclusion of no-cut clumps within cutting units will (1) encourage continued occupancy or use of the stand by old-growth-dependent species; (2) hasten the reestablishment of late-successional structures and functions in the surrounding harvested matrix; and (3) provide greater structural, compositional, and functional diversity in all plant strata, compared to uniform spatial arrangements of residual trees.
- The inclusion of gaps will (1) encourage the development of nonwoody understory plants; (2) favor regeneration of less-tolerant tree species such as Sitka spruce; and (3) provide greater structural, compositional, and functional diversity in all plant strata, compared to uniform spatial arrangements of residual trees.

---

[4] McClellan, Michael H.; Hennon, Paul E. 1994. Study plan. Unpublished document. On file with: Forestry Sciences Laboratory, 2770 Sherwood Lane, Suite 2A, Juneau, AK 99801.

Methods—To determine the response of the stand to treatment, we will measure or estimate stand attributes (trees per unit area, basal area per unit area, or volume per unit area) and components of change: accretion (growth of residuals), ingrowth, mortality, removals (harvest), net growth (ingrowth + accretion - mortality), and net change (net growth - removals). Also, we will collect extensive data on stand structure and will measure harvest-related and subsequent damage. To determine the understory response to treatment, we will measure the diversity and abundance of understory plants. For selected species (e.g., important deer-forage plants), we will gather additional information on biomass and nutritional quality.

Once unit boundaries are marked on the ground, we will establish a systematic set of 20 permanent vegetation inventory plots in each treatment unit. Plot establishment and maintenance will follow guidelines presented by Curtis (1983). To reduce edge effects, permanent plots will be located at least 30 meters from unit boundaries. Plot centers will be located and mapped with a combined global positioning system (GPS)-laser surveying system, and plot centers and corners will be marked with durable surface and subsurface markers to ease relocation. Nested, square, fixed-area plots will be used to sample living vegetation, snags, and down logs. Multiple plot sizes will be used to ensure that an adequate number of stems are measured throughout the experiment, as shown in the following tabulation:

Plot area	**Side length**	**Items inventoried**
Square meters	*Meters*	
800	28.3	Living and dead trees with d.b.h. ≥ 25 cm
400	20.0	Living and dead trees with d.b.h. ≥ 15 cm
16	4.0	Living and dead trees with d.b.h. ≥ 2.5 cm, shrubs
1	1.0	Tree seedlings (d.b.h. < 2.5 cm), herbaceous plants

Plot dimensions will be corrected to horizontal distance units. Trees will be permanently tagged—and the following tree characteristics will be measured or estimated: species, diameter, crown class, 10-year radial increment, crown geometry, rooting habit, height, height to the base of the live crown, and the presence of damage, defects, or mistletoe. To determine stand age structure, we will collect increment cores from a subsample of trees, stratified by crown class and species. If necessary, additional tree ages will be obtained from cut stumps after harvest. All dead trees (standing or down) in decay classes 1 to 3 (Hennon and McClellan 1999) with d.b.h. greater than 25 centimeters will be tagged and measured. Highly decayed and small-diameter dead trees will be counted but not tagged. Tree seedling counts and herbaceous plant cover will be estimated on eight 1-square meter plots located adjacent to each permanent plot. After cover estimation, alternating plots will be destructively sampled to determine understory biomass.

Pretreatment vegetation data will be collected concurrently with permanent plot establishment. After timber harvesting, trees on the permanent plots will be examined for logging-related damage. This will be done before winter in order to distinguish logging-related damage from subsequent natural events. If there is a significant delay between the pretreatment damage survey and logging, a new damage survey will be conducted just before harvest. At 5-year intervals after treatment, the permanent plots will be re-examined to determine the stand and understory response to treatments.

Integration and applications—This study will provide pretreatment and posttreatment vegetation data required by all the other component studies. Information from studies of damage agent dynamics will be required for full understanding of the stand and understory responses. This study is linked with other studies described later in the text and shares these objectives with them:

- For a given silvicultural system, determine how harvest-related damage to trees and understory is related to initial stand structure, residual stand density, and the spatial arrangement of residual trees.
- Determine how postharvest susceptibility to wind and other damage agents is related to initial stand structure, harvest-related damage, residual stand density, and the spatial arrangement of residual trees.
- Identify and document technical and operational problems encountered while implementing alternative silvicultural systems, and help develop interim management guidelines based on successful problem resolution or prevention.

Information on the response of overstory and understory vegetation will be presented in scientific journal articles and other technology transfer media as appropriate. To assist the application of study results to management decisions, we will produce reports that integrate the results of this study with those of the companion studies and provide recommendations for management. In addition, we will present our results and recommendations to appropriate Alaska Region workshops and training sessions, such as the annual joint workshop for silviculturists, ecologists, and biologists. Because the results of this study will become available over a long time, multiple interim reports will be produced at suitable intervals.

Harvest-Related and Postharvest Wounding, Windthrow, and Stress of Residual Trees Under Alternative Silvicultural Systems[5]

Introduction and objectives—The principles of ecosystem management ensure that the health of the residual forest must be an important consideration of any silvicultural treatment. High among the concerns of forest managers regarding selection harvesting are damage to residual trees (wounding and invasion by decay fungi) and windthrow. Western hemlock and Sitka spruce have thin bark and are easily wounded during selection harvesting. In an experimental treatment of even-aged forests on Prince of Wales, for example, 33 percent of hemlocks and 63 percent of spruce received one or more wounds. Wounds, particularly larger ones, provide infection courts for the entry of heart rot fungi, which cause a slow, persistent decay of internal wood over time. Combining the results of this study with a previous study on decay development in wounded trees (Hennon and DeMars 1997) would result in predictive models and guidelines, which would enable forest managers to control heart rot at desired levels by managing the size and incidence of bole wounds during stand entries.

Windthrow (tree uprooting and bole breakage), a common natural event in the forests of southeast Alaska, is thought to occur generally during fall and early winter storms that bring strong winds, heavy precipitation, and water-saturated soils (Harris 1989). Managers are concerned that opening the canopy of a forest through selection harvest will cause substantial windthrow of the residual stand. Topographic features, soil properties, and the degree to which a stand is opened (e.g., harvest intensities), and existing heart rot levels are thought to influence the windfirmness of the residual stand, but this topic has not been thoroughly investigated in southeast Alaska.

---

[5] Hennon, Paul E.; McClellan, Michael H. 1994. Study plan. Unpublished document. On file with: Forestry Sciences Laboratory, 2770 Sherwood Lane, Suite 2A, Juneau, AK 99801.

Stand openings cause various forms of stress to remaining trees in some forest ecosystems, but such a response in western hemlock-Sitka spruce forests is unknown. Conceivably, stand openings might reduce growth, increase insect attack, trigger bole fluting on hemlock, or cause mortality of residual trees.

We hypothesize that the amount of wounding, windthrow, and tree stress will be variously affected by the amount of the stand removed, topographic setting, soil properties, tree characteristics (e.g., diameter, height:diameter ratio, crown position, rooting habit, or existing heart rot), and the logging-yarding system used.

Methods—The permanent vegetation plots described in the previous section will be used for this study. All trees will be examined before treatment and annually for 5 years after harvesting. Subsequent examinations will be at longer intervals. Broken tops, uprooting, crown health, stilted roots, bole fluting, bole seams, lean, fungal fruiting bodies, or any indicator of internal decay will be noted. Wounds larger than 100 square centimeters on the exposed roots or bole of each tree will be recorded for length, width, depth, and height aboveground, along with the presence of any fungal fruiting bodies. For any tree whose bole breaks, the height aboveground of the break, percentage of the cross-sectional area decayed at the break, azimuth of fall, type of decay, and causal fungus (if known) will be recorded. For any tree completely uprooted, the presence of root disease will be determined and the direction of fall recorded.

Tree stress or attack by insects will be evaluated by recording defoliation (percentage of crown thinning) and evidence of attack by both bark beetles and defoliating insects. The degree of hemlock bole fluting will be recorded. All trees will be examined for these characteristics before stand treatment and until completion of the study. Tree stress also can be interpreted by measuring reduced radial growth. Data on radial growth before and subsequent to stand treatment will be compared.

We will compare the incidence of wounding, windthrow, and stress responses by stand treatment. The experimental design will permit separation of the effects of harvest intensity, spatial distribution of leave trees, and patch size on the dynamics of damage agents. More detailed analyses will probe relations of tree damage with tree size (i.e., diameter and height), crown position (i.e., suppressed through dominant), and proximity to stand openings or retained groups of trees. Differences in the frequency of windthrow and bole breakage within and among treatments will be compared to soil characteristics and plant association classes to develop new hypotheses. Orientation of treefall will be compared to local topography and patterns of prevailing winds.

Integration and applications—Results on size and incidence of wounding are highly compatible with a recent study on the rate of decay in wounded trees (Hennon and DeMars 1997). In that study, the authors dissected more than 100 western hemlock and Sitka spruce that had a single wound ranging from 1 to 80 years old, quantified internal decay, and developed equations to estimate decay rates. Information on both amount of wounding and decay rates will equip forest managers with the ability to predict heart rot decay over time on a stand-wide basis. Such information could be used to assess the volume of timber loss or the development of wildlife habitat. The incidence of wounding probably can be used to manipulate the amount of decay to desirable levels.

Results from the proposed study should be applicable throughout the Tongass National Forest in hemlock-spruce communities. We will develop technology transfer documents that integrate results from the previous study with those of the proposed study. New information on relations of windthrow with topographic and other site features, stand characteristics, and intensity of harvesting will stimulate new research and be developed into technology transfer. Results on the orientation of windthrow will be compared to data that suggest that windthrow occurs during maritime (southeasterly) storms (Harris 1989). Stress responses, fluting, and insect activity that differ by silvicultural treatments will lead to new hypotheses and be described in technology transfer documents.

The proposed study will be conducted on the experimental silvicultural treatment sites, and much sharing of plot data and field personnel will occur during the pretreatment and posttreatment inventories. Information developed through the pretreatment vegetation analysis will be required for interpreting the results of this study and for the constructing predictive models. Results of this study will be essential to understanding the vegetation structure and dynamics evolving after treatment. As described previously, the proposed study is a logical extension of a previous study on decay rates in wounded trees.

Hemlock Dwarf Mistletoe Response to Alternatives to Clearcutting[6]

Introduction and objectives—Intensification of hemlock dwarf mistletoe has been a major concern with alternatives to clearcutting. The disease is abundant in the old-growth forests of southeast Alaska, where it causes substantial growth loss and mortality. It appears to thrive in canopy-gap disturbance regimes of old stands because its short-range seed-dispersal mechanism maintains its abundance in the forest canopy. Limited sampling that we have conducted in stands partially disturbed by wind 60 to 100 years ago suggests that the intensification of dwarf mistletoe is a slow, predictable process. The disease does not aggressively spread throughout the regenerating component of hemlock. Most spread, even for decades after disturbance, is limited to within 10 meters of residual trees—the known distance of dwarf mistletoe seed dispersal.

Clearcutting largely eliminates dwarf mistletoe from early successional stands. Reestablishment of the disease through long-range seed dispersal is slow—probably vectored by birds in rare events. Selection harvesting probably will increase the abundance of the disease over that of clearcutting, but this has not yet been quantified. Evidence from British Columbia suggests that heavily infected trees experience a 40-percent growth loss over time; growth loss in lightly infected trees, however, is negligible (Smith 1969, Thompson and others 1985).

The large, dense brooms that result from mistletoe infection contribute to the diversity of canopy structure and may provide wildlife habitat, but this latter attribute has not been investigated in southeast Alaska. An ecosystem management perspective might acknowledge a habitat role for dwarf mistletoe and use selection harvesting as a tool for maintaining desired levels of these structures.

We predict that the spread of dwarf mistletoe and its effects on tree growth will be correlated with the number per unit area, size, spatial distribution, and degree of infection of hemlocks that remain after selection harvesting. The objective of this experimental study is to quantify this relation with detailed pretreatment stand information and close monitoring of the short-term response to harvesting for dwarf mistletoe and for trees.

[6] Hennon, Paul E.; McClellan, Michael H.1994. Study plan. Unpublished document. On file with: Forestry Sciences Laboratory, 2770 Sherwood Lane, Suite 2A, Juneau, AK 99801.

Methods—We will use the six-point Hawksworth dwarf mistletoe rating (DMR) system (Hawksworth 1977) to quantify the levels of mistletoe infection before harvesting and as the stand develops. This technique requires viewing the entire crown, visually breaking the crown into three equal vertical intervals, and assigning a value of zero (none), one (dwarf mistletoe present, less than half of the branches infected), or two (more than half of the branches infected). Thus, a value zero to six may be assigned to each tree. The mean six-point DMR score for understory trees will be used as the basic measure of dwarf mistletoe response—to be correlated with characteristics of residual trees (number per unit area, size, spatial distribution, and degree of infection). Distances from dwarf mistletoe-infected understory trees to the nearest infected residual tree will provide information on spread rates over time.

The experimental approach will use the stand silvicultural treatments and vegetation permanent plots described elsewhere in this plan. All plot trees, including those in both the overstory and understory, will be evaluated for dwarf mistletoe by using DMR before stand treatment and annually for 5 years. Intensification (increase in DMR) in both the overstory and understory components of the stand will be correlated by using regression procedures with silvicultural treatment (i.e., proportion of original basal area removed). These plots probably will be maintained and remeasured long after the 5-year duration of this study. This will provide an invaluable opportunity to assess growth loss by different intensities of dwarf mistletoe infection.

Integration and applications—This study will be conducted in the same stands where other scientists are investigating ecological responses to stand-level experimental treatments, and it will use stand information produced by those studies. This study will contribute information essential for the interpretation of long-term growth and yield results. It will be necessary, however, to select stands with an adequate level of dwarf mistletoe. Locating suitable stands should not be a problem because hemlock dwarf mistletoe is abundant throughout southeast Alaska.

This study will provide information on the short-term dynamics of dwarf mistletoe infection after disturbance, which complements the mid-term (20 to 90 years) effects to be documented by the retrospective study described later in this document, and the long-term (110 years) effects reported by Trummer and others (1998). Results from our experimental treatments can be used to verify interpretations made from these retrospective works.

Information on the dynamics of dwarf mistletoe gained from these studies will be the basis for predicting the incidence and impact of hemlock dwarf mistletoe resulting from different stand management options. Guidelines will be developed for managing dwarf mistletoe at desired infection levels to meet resource objectives. The guidelines likely will involve the silvicultural manipulation of the number, spatial distribution, size, and infection levels of residual trees. This will provide an opportunity to manage for potentially beneficial levels of the disease where wildlife habitat and structural diversity are enhanced, but avoid unnecessary losses to the timber resource. Thorough technology transfer of these new applications will be made to forest managers.

Avian Diversity and Abundance in Managed Forest Stands[7]

Introduction and objectives—Understanding the avian response to alternative silvicultural practices is essential to assessing the impact of different practices. Because of great variance in space and time, it is not currently possible to predict the diversity and abundance of birds from vegetation measurements; to know the effect of forest management practices on avian populations, one must count the birds at each site. Although it is also fundamentally necessary to assess reproductive success in order to understand the prospects for population viability in modified habitats, funding is not adequate to execute fully a study of reproductive success; we have therefore selected only certain central components of such a study.

The following objectives and selected predictions have been established:

1. Measure community composition, diversity, and abundance of breeding birds before and after various silvicultural treatments.
   a. The more trees are removed, the greater the loss of conifer forest birds and the greater the representation of birds that are characteristic of edges and deciduous stands (but the rates of decline and gain need to be determined).
   b. When cutting is patchy, the rate of increase of edge/deciduous-stand birds will be greater than the rate of loss of conifer-forest birds because the former tend to be more opportunistic in habitat use.
   c. When cutting is uniform throughout a stand, the rate of increase of edge/deciduous-stand birds will be lower than the rate of loss of conifer-forest birds because the latter can use thinned forest better than the former.
2. Identify one bird species that potentially occupies all the habitats resulting from the proposed timber-cutting treatments and whose reproductive success may be used as an indicator of potential treatment effects.
3. Determine the magnitude and distribution of "edge effects" on avian nest distribution and success.
   a. Edge effects will be less in spruce-hemlock forest, compared to eastern forests, because major nest predators do not concentrate on conifer-forest edges in southeast Alaska (except near human settlements).
4. Determine the distribution of nests and the distribution and abundance of major nest predators in relation to vegetation structure.
   a. Nest predation increases in stepped fashion as the abundance of mature (cone-producing) spruces and red squirrels increases.
   b. Forest birds distribute their nests in patterns that reduce the risk of predation by major predators, such as red squirrels and northwestern crows.

Methods—We will use standard avian censuses of study sites (pretreatment and post-treatment) using timed point counts, as in Willson and Comet (1996a, 1996b). From this, we will identify the bird species whose reproductive success is to be measured and document changes in conifer- and deciduous-forest birds along the harvesting gradient. Changes can be assessed both in terms of extent of modification from pretreatment status and of differences among segments of the harvesting gradient.

---

[7] Willson, Mary F.; De Santo, Toni. 1994. Study plan. Unpublished document. On file with: Forestry Sciences Laboratory, 2770 Sherwood Lane, Suite 2A, Juneau, AK 99801.

We will record distribution of natural nests and nesting success of natural and experimental nests on forest edges. Experimental nests are baited with Japanese quail eggs and exposed to natural predators (Sieving and Willson 1998) along transects in edges and away from edges. Predators are censused by standard methods.

We will document nesting success and distribution of natural nests and success of experimental nests, and census nest predators, along a gradient of mature spruce density. Nest predators are censused by standard methods. The distribution of natural nests can be mapped in relation to distribution of nest-predator den sites; preliminary data indicate a strong effect of proximity to predator residences. Experimental nests are arrayed along transects near and far from squirrel middens and crow colonies.

Integration and applications—This study will provide solid data on the abundance, diversity, and reproductive success of birds in plots of different vegetation structure; relation between insect abundance and avian density; and, potentially, relation between fruit abundance and avian density later in the season. Data needed from other studies include vegetation structure and insect and fruit abundance; data provided for other studies include information on the potential consequences of changes in other trophic levels. This study will be a major contribution to the understanding of silvicultural treatment effects on biodiversity.

Hydrologic Factors Influencing Slope Stability: Changes in Subsurface Flow and Piezometric Response to High-Intensity Rainfall After Clearcut and Selection Harvest[8]

Introduction and objectives—The study will define and quantify subsurface hydrologic responses to high-intensity, long-duration storms in relatively shallow soils on hillslopes in southeast Alaska. Specific research objectives are:

- Quantify responses of shallow ground-water tables in relatively steep upland basins to high-intensity and long-duration rainfall events. Cooperation with USDA Forest Service, regional and area watershed management staffs is anticipated.
- Determine the influence of soil depth, soil type, basin configuration, and slope position on hydrologic responses. Cooperation with National Forest watershed management staff is anticipated.
- Evaluate the impacts of clearcutting and alternative silvicultural and harvesting systems on hydrologic response in steep drainages. Cooperation with area and PNW Research Station silvicultural specialists is anticipated in all phases.
- Develop a method usable on an areal basis by forest engineers and other Forest Service professionals to predict the resulting decrease in soil shear strength caused by increasing ground-water levels. These data may be incorporated into overall slope-hazard models such as those being developed by Oregon State University and Colorado State University civil engineers.
- Evaluate the spatial distribution of selected soil-strength and ground-water parameters, as they would affect potentially unstable slopes.

---

[8] Swanston, Douglas N.; Erhardt, Robert; Kahklen, Keith [and others].1994. Study plan. Unpublished report. On file with: Forestry Sciences Laboratory, 2770 Sherwood Lane, Suite 2A, Juneau, AK 99801.

Methods—A subset of the experimental silvicultural treatment units will be instrumented with piezometers (ground-water wells). A network of seven piezometers located down the center and along the sides of hillslope hollows, at the bedrock-soil interface, will be connected to a continuously recording datalogger. These piezometers utilize a pressure transducer placed at the bottom of each well to measure the height of water table rise. Matric potentials measured by the pressure transducers then are logged into a central data-acquisition system.

These recording piezometers will monitor the complete temporal spectrum of shallow ground-water fluctuations. They will be constructed of polyvinyl chloride (PVC) tubing fitted at the lower end with a commercial PVC slotted well tip to pass water. A standard 1-inch (outside diameter) pressure transducer will be placed in the bottom of the tube and connected electronically to the datalogger. These will be designed to automatically monitor water levels every hour or half-hour.

Rain gauges that record data will be placed in clearings at an elevation similar to the mean elevation of the piezometer sites to measure precipitation inputs and the influence of antecedent moisture conditions, precipitation intensity, and precipitation duration on ground-water fluctuations.

During the first year of the study, the piezometer and rain gauge networks will be installed. Hydrological data will be collected from September to November (possibly including part of December), corresponding to the months of peak precipitation amounts and intensities. During the second year of the study, each of the selected drainages will be surveyed in order to construct detailed topographic maps. Soil depth profiles will be taken in all drainages. Also, soils will be characterized based on morphological and engineering soils criteria. Hydrologic properties of soils, such as infiltration rate and hydraulic conductivity, will be measured when appropriate for the development of predictive ground-water models. Other geologic and soils parameters will be measured as needed for background characterization and model development.

The response of shallow ground-water levels to individual or composite storms will be measured for each drainage. The importance of such variables as drainage configuration, slope position, and soil depth on ground-water response can be tested by regression techniques. Measured maximum piezometric contours will be plotted for each drainage for various precipitation and antecedent moisture conditions. Some replication will be achieved by having several storms of the same magnitude during the prelogging period. Precipitation and ground-water data can be initially correlated for each site and drainage configuration in much the same manner as is done by Swanston (1967). In addition, a multivariate-analysis approach may be useful for predicting maximum piezometric rise by incorporating such parameters as soil depth, upslope drainage area, slope position, and antecedent soil moisture. These relations tend to be site specific and would have to be judiciously extrapolated to field sites by relying on detailed descriptions of geology, soils, and hydrology. This type of information is needed in these areas for engineering slope-stability hazard analysis (Torheim 1977) and can be used in the more sophisticated probabilistic slope hazard rating models (Ward and others 1979).

To broaden the scope of inference of the hydrologic data from the study sites, a more theoretically based model could be used. Such a modeling effort would require quantitative inputs of soil depth, hydraulic conductivity, precipitation distribution, and other soils and hydrologic variables. This type of model should first be applied to a uniform slope case to test the simplest possible two-dimensional system.

To evaluate the impacts of different silvicultural systems on hydrologic response at the harvested sites, at least 2 years of postlogging data should be collected. Postlogging data, such as maximum piezometric rise for given storm magnitudes, can be directly compared to prelogging data by using regression methods. Replication will be achieved by having several storms of the same magnitude during the 4-year period. Ground-water responses during the postlogging period can be analyzed in the manner described for the prelogging period. If for any of the study area drainages there is no significant impact of harvesting on subsurface hydrology, then the 4-year period can be combined to provide a broader database for the various empirical and more theoretical hydrologic modes.

Integration and applications—Presentation of results of this study will be made at various national and international scientific and technical meetings. Publications are anticipated through USDA Forest Service reports and appropriate hydrology, soils, or environmental journals.

Effects of Alternative Timber Harvest Regimes on the Ecology of Headwater Streams[9]

Introduction and objectives—The objective of this study is to determine how alternative timber harvest techniques affect transport of macroinvertebrates (terrestrial and aquatic) and organic detritus (fine and coarse particulate organic matter) from class III and IV "headwater" streams to downstream class I and II salmonid-rearing habitats.

We will test the following null hypotheses:

- Applied timber-harvest techniques have no effect on the transport (density and biomass) of terrestrial and aquatic macroinvertebrates from associated headwater streams to salmonid-rearing habitats.
- Applied timber-harvest techniques have no effect on species composition and richness of terrestrial and aquatic macroinvertebrates transported from associated headwater streams to salmonid-rearing habitats.
- Applied timber-harvest techniques have no effect on the transport of organic detritus (expressed as ash-free dry mass, particles greater than 250 micrometers) from associated headwater streams to salmonid-rearing habitats.

Methods—Sampling stations will be established along headwater streams (within treatment units) near the downstream edge of treated plots. Transport of macroinvertebrates and organic detritus (greater than 250 micrometers) will be measured at these stations over 7-day intervals three times per year (in spring, summer, and fall). Terrestrial and aquatic macroinvertebrate drift will be sampled over seven 24-hour intervals with a 250-micrometer mesh net. The macroinvertebrates collected will be identified to the lowest reliable taxon. Abundance, biomass, and species richness and composition will be compared among treatments. Transport of detritus will be measured over seven 24-hour intervals with a 250-micrometer mesh net. Ash-free dry mass will be determined for each sample and compared among treatments. Transport sampling will be used before and after application of timber harvest treatment and repeatedly sampled for the duration of the study.

---

[9] Wipfli, Mark S.; Gregovich, Dave; Bryant, Mason D.1994. Study plan. Unpublished report. On file with: Forestry Sciences Laboratory, 2770 Sherwood Lane, Suite 2A, Juneau, AK 99801.

Harvest units (i.e., treatments) will be experimental units (i.e., replicates), and streams (more than one selected per harvest unit) will be subunits. Data from transport (macroinvertebrates and detritus) sampling will be analyzed by using analysis of variance. Spatial and temporal variability will be contrasted before and after treatments are applied. Statistical power will be calculated for experiments where hypotheses are not rejected.

Integration and applications—These studies are closely linked with other studies relating to the terrestrial plant community; plant communities contribute both plant material (Vannote and others 1980) and terrestrial invertebrates (Wipfli 1997) to streams and also control light intensity entering streams, affecting primary productivity, thereby affecting aquatic macroinvertebrate assemblages and production (Wallace and others 1997). These studies also will relate to hydrogeologic studies; benthic communities are largely influenced by associated predominant geology (Coleman and Dahm 1990).

These studies will supply information about the effects of alternative silvicultural practices on the structure and function of streams, stream food webs, and ultimately fish. Information gained from these studies will be published in scientific journals, thereby contributing to the literature of stream ecology, and has been and will continue to be presented throughout several technology transfer sessions; this information will be available and useful to forest managers in making forest management decisions related to fisheries.

Retrospective Study

Overview

Many of the experimental study results will be available 5 years or more after treatment, but the need to implement alternatives to clearcutting is immediate. Recognizing this need, we plan short-term, retrospective studies of stand response to past partial cutting to provide interim guidance to land managers. We will examine stands that represent a wide range of time since harvest, harvest intensities, and geographic distribution. Historical or management records, along with stand-reconstruction techniques, will be used to determine the pretreatment stand conditions and the harvest date, intensity, and pattern. Existing conditions within the harvested stands will be analyzed and compared to those of adjacent uncut stands to estimate harvest effects. We will use this retrospective approach to describe postharvest changes in stand structure, understory plant diversity and abundance, and damage agents—such as wounding, windthrow, decay, and mistletoe.

Most of the older (1900 to 1950 harvest dates) selectively cut stands are within yarding distance from salt water or along major rivers. This will greatly limit the range of site conditions available for sampling; most of these sites are at lower elevations and are less steep than is commonplace in modern harvest areas. Also, important differences exist between historical and modern partial cutting in terms of the equipment used, the amount of soil disturbed, and the quality and quantity of coarse woody debris left on site, so caution must be used when interpreting and applying results. During the last 5 to 10 years, higher elevation and steeper sites have been selection-cut, mostly by helicopter logging on private lands. These stands include a range of partial cutting, from single-tree selection to group selection, and will be examined to expand the scope of inference of the retrospective research.

Retrospective Analysis of Partial Cutting Effects on the Structure and Dynamics of Late-Successional Hemlock-Spruce Stands and Associated Vegetation[10]

Introduction and objectives—We will use a retrospective approach to examine historical partial cutting in southeast Alaska and to determine its effects on stand structure, growth rates, species composition, regeneration, and mortality. Understory plant diversity and abundance, particularly vascular plants deemed important for deer forage, will be examined. Lastly, we will investigate the relations between partial cutting and the presence and severity of important damage agents. Our objective is to address several issues that have been raised by earlier researchers (Harris and Farr 1974) regarding clearcutting and potential alternatives, specifically:

- Does partial cutting reduce the proportion of Sitka spruce in western hemlock-Sitka spruce stands?
- Are residual trees left after partial cutting of poor quality and low vigor, and does this lead to diminished future yields?
- Does partial cutting increase the level of hemlock dwarf mistletoe infestation?
- Because both western hemlock and Sitka spruce are thin-barked species and easily wounded during logging, will partial cutting increase tree wounding and subsequent decay?
- Does partial cutting significantly increase the frequency of windthrow?
- Will partial cutting maintain or enhance stand structural diversity?
- Will partial cutting maintain or enhance understory plant diversity and abundance, particularly for importance species for deer forage?

Methods—Study sites will be selected to span a range of time since cutting, cutting intensity, and geographic distribution throughout southeast Alaska (fig. 2). Study areas will be selected from potential sites identified from various sources, including USDA Forest Service Ranger District files, historical records and maps, and information from local residents. Study sites will be screened by using the following criteria: (1) stands cut 10 to 100 years ago; (2) only one harvest entry; (3) a partially cut area of at least 10 hectares, with a range of cutting intensity within that area, including an uncut area; and (4) relatively uniform topography, soils, forest type, and plant associations within the stand.

Stands meeting the selection criteria will be examined to determine the number and size of cut stumps, the number of residual overstory trees, stand stocking, area harvested, and general stand conditions. Within each harvest area, light, medium, and heavy cutting treatments will be delineated by the number and size of cut stumps and the number of obvious residual trees. This information will be used to establish three partially cut plots and one nearby uncut "control" plot per stand. These circular, 0.2-hectare plots will be centrally located within their respective areas to minimize edge effects. Preharvest stand basal area and the basal area harvested will be determined by stand reconstruction. Site characteristics such as elevation, slope, aspect, plant association, and soil type will be determined. Fifteen to twenty stands will be examined in the first phase of this study.

In each plot, tree species, d.b.h., height, and crown position will be measured for all live trees to provide current stand condition. Species, d.b.h., and decay class will be determined for snags to provide information on tree mortality. A subsample of tree increment

[10] Deal, Robert L.; Yount, Louise S.; Palkovic, Patricia [and others]. 1994. Study plan. Unpublished report. On file with: Forestry Sciences Laboratory, 2770 Sherwood Lane, Suite 2A, Juneau, AK 99801.

cores or stem sections will be collected for each tree species and crown class for tree-ring analysis to determine tree age, diameter, basal-area growth, and cutting date for each stand.

Stands will be reconstructed (Henry and Swan 1974, Lorimer 1985, Oliver 1982) to the cutting date by using cut stumps, current live trees, and snag information. Tree increment cores and stem sections will be used to develop stand and species-specific regression equations to estimate tree d.b.h. at the time of cutting. The stand-specific regression equations then will be applied to all live trees in the current stand to predict their d.b.h. at the cutting date and estimate former stand basal area (excluding basal area cut and mortality estimates). Stem taper equations will be used to determine tree d.b.h. from cut stumps. Snag class and snag ages will be used to determine snag d.b.h. at the time of cutting and stand mortality since cutting. Basal area cut, live-tree basal area at the time of cutting, and stand mortality since cutting will be combined to determine the proportion of basal area cut for each harvested area.

Tree diameter distributions; the number of trees, snags, and cut stumps per unit area; tree species composition; and stand basal areas will be determined. The cutting intensity, current stand density, and species composition of each stand will be described. Tree species composition, tree-age cohorts, and stand growth will be analyzed to determine if there are differences among cut and uncut plots. Tree-ring analyses will be used to investigate the effects of partial cutting on the growth of hemlock and spruce trees, different tree-age cohorts, and size classes of residual trees.

The density and size-class distribution of conifer seedlings will be measured on eight 1-square meter plots within each of the 0.2-hectare plots. These eight plots will be evenly divided between the two most common seedbed types (logs and undisturbed forest floor). Seedling growth rate, height, and age measurements will be taken on one or two seedlings per species for each seedling size class present on each plot. Seedling occurrence will be related to three response variables: harvest treatment (cut or uncut), seedbed type, and shrub cover.

Understory vegetation will be sampled with ten 1- by 1-meter quadrats and ten 2-meter-radius shrub plots within each of the 0.2-hectare main plots. Cover classes for all herbs, mosses, lichens, liverworts, and tree seedlings less than 0.1-meter tall will be estimated within each quadrat. Cover classes will be estimated for shrubs and tree seedlings greater than 0.1-meter tall within the shrub plots. The cover data for the 10 quadrats and shrub plots will be combined and averaged within each 0.2-hectare plot to estimate average abundance for each plant species found on the 0.2-hectare plots. Species diversity and abundance will be estimated, and multivariate analyses will be used to assess plant community structure by treatment. Also the average cover for eight important deer-forage plant species (Hanley and McKendrick 1985, Kirchhoff and Hanley 1992) will be used to determine if their abundance changes after partial cutting.

Each hemlock tree will be assigned a fluting rating of zero (absent), one (few folds, which are not deep), or two (many or deep folds). Also, each hemlock tree will be given a DMR according to standard methods (Hawksworth 1977), where each third of the live crown is rated separately and summed to give an overall tree rating of zero (absent) to six (severe). Bole wounds larger than 100 square centimeters will be recorded for all plot trees, but only wounds estimated to have been produced at the time of harvest or since then will be included in our analysis.

Information on dead trees with d.b.h. greater than 25 centimeters or greater will be recorded: d.b.h., species, decay class, and situation (uprooted, standing dead, or broken bole). Several methods will be used to estimate time since death for each decay class. We will date bole wounds on adjacent trees to determine when trees were uprooted. Only trees confirmed to have died after harvest will be used in reconstructing tree mortality trends.

Integration and applications—The inventory of potential retrospective study sites will be published by the PNW Research Station. Results of this study will be presented in a doctoral dissertation, masters theses, and scientific journal articles. To assist the application of study results to management prescriptions, we will produce a synthesis of this work and other applicable research results, with recommendations for management. In addition, we will present our results and recommendations to appropriate Alaska Region workshops and training sessions, such as the annual joint workshop for silviculturists, ecologists, and biologists.

Project Funding, Management, and Cooperators

The Washington Office of the USDA Forest Service, through an Ecosystem Management Research Initiative, provided funding for the research costs of this study in fiscal years 1994-98. In addition, the PNW Research Station and the Alaska Region provided significant additional funding to ensure the success of this project. Since fiscal year 1999, research funding has been supplied in the PNW Research Station base funding. Costs related to environmental analysis and timber-sale planning, layout, and administration are borne by the Alaska Region.

A letter of agreement issued jointly by the PNW Research Station and the Alaska Region will guide this study. The senior author will provide technical coordination among researchers and between management and research. Richard Zaborske, Alaska Region silviculturist, will coordinate activities of the National Forest System (NFS) team members.

The PNW Research Station, the NFS Alaska Region, and State and Private Forestry (Alaska Region) will cooperate in project planning and implementation. Scientists from several PNW Research Station programs will form an interdisciplinary team to conduct this research, including Resource Management and Productivity, Aquatic and Land Interactions, Managing Natural Disturbance Regimes, and Social and Economic Values Program. This team will work closely with their NFS counterparts at the Alaska Region, Area, and Ranger District levels to plan and implement studies. University cooperators include Oregon State University, Humboldt State University, and the University of Montana.

Acknowledgments

This publication is a contribution from the USDA Forest Service study, *Alternatives to Clearcutting in the Old-Growth Forests of Southeast Alaska*, a joint effort of the Pacific Northwest Research Station, the Alaska Region, and the Tongass National Forest. The authors thank the people and organizations that supported and contributed to the ATC study. The Washington Office provided funding through the Ecosystem Management Research Initiative. The Alaska Region and Tongass National Forest provided essential assistance in establishing the study treatments. Richard Woodsmith and Robert Erhardt, PNW Research Station, made helpful suggestions on the text. Tim Max, PNW Research Station, reviewed the experimental design and other statistical matters. Kermit Cromack, Jr., and John Tappeiner, Oregon State University, and John Zasada, North Central Research Station, provided reviews of this study plan. Phil Janik (former Alaska Regional Forester) and Fred Everest (former PNW Research Station Aquatic and Land Interactions Program Manager) worked diligently to garner support for the ATC study. Lastly, the authors recognize the late Wilbur Farr, PNW Research Station, for his leadership at the onset of this study.

English Equivalents

1 centimeter = 0.394 inch

1 meter = 3.28 feet

1 square meter = 10.76 square feet

1 cubic meter = 35.3 cubic feet

1 hectare = 2.47 acres

1 square meter per hectare = 4.356 square feet per acre

1 cubic meter per hectare = 14.29 cubic feet per acre

1 kilometer = 0.621 mile

1 micrometer = 1 micron

Literature Cited

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

Alaback, P.B. 1984. Plant succession following logging in the Sitka spruce-western hemlock forests of southeast Alaska: implications for management. Gen. Tech. Rep. PNW-173. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 26 p.

Alaback, P.B. 1989. Dynamics of old-growth temperate rainforests in southeast Alaska. In: Proceedings of the second Glacier Bay science symposium; 1988 September 19-22; Gustavus, AK. [Place of publication unknown]: [Publisher unknown]: 150-153.

Alexander, R.R. 1963. Harvest cutting old-growth mountain spruce-fir in Colorado. Journal of Forestry. 61: 115-119.

Alexander, R.R. 1973. Partial cutting in old-growth spruce-fir. Res. Pap. RM-110. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 16 p.

Baver, L.D.; Gardner, W.H.; Gardner, W.R. 1972. Soil physics. 4th ed. New York: John Wiley and Sons, Inc. 498 p.

Beaty, C.S. 1972. The effect of moisture on slope stability: a classic example from southern Alberta, Canada. Journal of Geology. 80: 362-366.

Bishop, D.M.; Stevens, M.E. 1964. Landslides on logged areas in southeast Alaska. Res. Pap. NOR-1. [Juneau, AK]: U.S. Department of Agriculture, Forest Service, Northern Forest Experiment Station. 18 p.

Burroughs, E.R.; Chalfant, G.R.; Townsend, M.A. 1976. Slope stability in road construction. Portland, OR: U.S. Department of the Interior, Bureau of Land Management. 102 p.

Chamberlin, T.W.; Harr, R.D.; Everest, F.H. 1991. Timber harvesting, silviculture, and watershed processes. In: Meehan, W.R., ed. Influences of forest and rangeland management on salmonid fishes and their habitats. Spec. Publ.19. Bethesda, MD: American Fisheries Society: 181-205.

Cleveland, G.B. 1973. Fire + rain - mudflow; Big Sur, 1972. California Geology. 26: 127-239.

Coleman, R.L.; Dahm, C.N. 1990. Stream geomorphology: effects on periphyton standing crop and periphyton. Journal of the North American Benthological Society. 9: 293-302.

Curtis, R.O. 1983. Procedures for establishing and maintaining permanent plots for silvicultural and yield research. Gen. Tech. Rep. PNW-155. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 56 p.

Deal, R.L.; Oliver, C.D.; Bormann, B.T. 1991. Reconstruction of mixed hemlock-spruce stands in coastal southeast Alaska. Canadian Journal of Forest Research. 21: 643-654.

DelaSalla, D.A.; Hagar, J.C.; Engel, K.A. [and others]. 1996. Effects of silvicultural modifications of temperate rainforest on breeding and wintering bird communities, Prince of Wales Island, southeast Alaska. Condor. 98: 706-721.

De Santo, T.L.; Wilson, M.F. [In press]. Predation of artificial nests and predator abundance in natural and artificial coniferous forest edges in southeast Alaska. Journal of Field Ornithology.

Dyrness, C.T. 1967. Mass soil movements in the H.J. Andrews Experimental Forest. Res. Pap. PNW-42. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 12 p.

Farr, W.A.; Harris, A.S. 1971. Partial cutting of western hemlock and Sitka spruce in southeast Alaska. Res. Pap. PNW-124. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 10 p.

Farr, W.A.; LaBau, V.L.; Laurent, T.H. 1976. Estimation of decay in old-growth western hemlock and Sitka spruce in southeast Alaska. Res. Pap. PNW-204. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 24 p.

Fredricksen, R.L. 1963. A case history of a mud and rock slide on an experimental watershed. Res. Note PNW-1. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 4 p.

Hanley, T.A. 1984. Relationships between Sitka black-tailed deer and their habitat. Gen. Tech. Rep. PNW-168. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 21 p.

Hanley, T.A. 1993. Balancing economic development, biological conservation, and human culture: the Sitka black-tailed deer *Odocoileus hemionus sitkensis* as an ecological indicator. Biological Conservation. 66: 61-67.

Hanley, T.A.; McKendrick, J.D. 1983. Seasonal changes in chemical composition and nutritive value of native forages in a spruce-hemlock forest, southeastern Alaska. Res. Pap. PNW-312. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 41 p.

Hanley, T.A.; McKendrick, J.D. 1985. Potential nutritional limitations for black-tailed deer in a spruce-hemlock forest, southeastern Alaska. Journal of Wildlife Management. 49(1): 103-114.

Hanley, T.A.; Robbins, C.T.; Spalinger, D.E. 1989. Forest habitats and the nutritional ecology of Sitka black-tailed deer: a research synthesis with implications for forest management. Gen.Tech. Rep. PNW-GTR-230. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest and Range Experiment Station. 52 p.

Hanley, T.A.; Rose, C.L. 1987. Influence of overstory on snow depth and density in hemlock-spruce stands: implications for management of deer habitat in southeastern Alaska. Res. Note PNW-RN-459. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 11 p.

Harris, A.S. 1989. Wind in the forests of southeast Alaska and guides for reducing damage. Gen. Tech. Rep. PNW-GTR-244. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 63 p.

Harris, A.S.; Farr, W.A. 1974. The forest ecosystem of southeast Alaska. 7: Forest ecology and timber management. Gen. Tech. Rep. PNW-GTR-25. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 109 p.

Harris, A.S.; Farr, W.A. 1979. Timber management and deer forage in southeast Alaska. In: Sitka black-tailed deer: Proceedings of a conference; 1978 February 22-24; Juneau, AK. Alaska Series No. R10-48. Juneau, AK: U.S. Department of Agriculture, Forest Service, Alaska Region: 15-24.

Hawksworth, F.G. 1977. The 6-class dwarf mistletoe rating system. Gen. Tech. Rep. RM-48. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 7 p.

Hennon, P.E.; DeMars, D.J. 1997. Development of wood decay in wounded western hemlock and Sitka spruce in southeast Alaska. Canadian Journal of Forest Research. 27: 1971-1978.

Hennon, P.E.; McClellan, M.H. 1999. Heart rot fungi and other causes of small-scale disturbance in the temperate rain forests of southeast Alaska. In: Trummer, L.M., comp. Proceedings of the 46th Western international forest disease work conference; 1998 September 28-October 2; Reno, NV. Anchorage, AK: U.S. Department of Agriculture, Forest Service: 97-105.

Henry, J.D.; Swan, J.M.A. 1974. Reconstructing forest history from live and dead plant material: an approach to the study of forest succession in southwest New Hampshire. Ecology. 55: 772-783.

Hutchinson, J.N.; Bhandari, R.K. 1971. Undrained loading: a fundamental mechanism of mudflows and other mass movements. Geotechnique. 21: 353-358.

Hutchison, O.K.; LaBau, V.J. 1975. The forest ecosystem of southeast Alaska. 9: Timber inventory, harvesting, marketing, and trends. Gen. Tech. Rep. PNW-34. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 57 p.

Isaac, L.A. 1956. Place of partial cutting in old-growth stands of the Douglas-fir region. RP-16. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 48 p.

Kessler, W.B.; Kogut, T.E. 1985. Habitat orientations of forest birds in southeastern Alaska. Northwest Science. 59: 58-65.

Kirchhoff, M.D.; Hanley, T.A. 1992. A quick cruise method for assessing winter range in southeast Alaska. Habitat Hotline. Juneau, AK: U.S. Department of Agriculture, Forest Service, Alaska Region; 92-1(July): 5 p.

Kirkland, B.P.; Brandstrom, A.J.F. 1936. Selective timber management in the Douglas-fir region. Washington, DC: U.S. Department of Agriculture, Forest Service. 122 p.

Lorimer, C.G. 1985. Methodological considerations in the analysis of forest disturbance history. Canadian Journal of Forest Research. 15: 200-213.

Meehan, W.R. 1974. The forest ecosystem of southeast Alaska. 3: Fish habitats. Gen. Tech. Rep. PNW-15. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 41 p.

Meehan, W.R., ed. 1991a. Influences of forest and range management on salmonid fishes and their habitats. Spec. Publ. 19. Bethesda, MD: American Fisheries Society. 751 p.

Meehan, W.R., ed. 1991b. Introduction and overview. In: Meehan, W.R., ed. Influences of forest and rangeland management on salmonid fishes and their habitats. Spec. Publ. 19. Bethesda, MD: American Fisheries Society: 1-15.

Meehan, W.R.; Merrell, T.R., Jr.; Hanley, T.A., eds. 1984. Fish and wildlife relationships in old-growth forests: Proceedings of a symposium; 1982 April 12-15; Juneau, AK. Morehead City, NC: American Institute of Fishery Research Biologists. 425 p. Sponsored by the American Institute of Fishery Research Biologists, The Wildlife Society, and the Alaska Council on Science and Technology.

Murphy, M.L.; Meehan, W.R. 1991. Stream ecosystems. In: Meehan, W.R., ed. Influences of forest and rangeland management on salmonid fishes and their habitats. Spec. Publ. 19. Bethesda, MD: American Fisheries Society: 17-46.

Nichols, M.L. 1931. The dynamic properties of soil. 1: An explanation of the dynamic properties of soils by means of colloidal films. Agricultural Engineering. 12: 259-264.

Oliver, C.D. 1982. Stand development—its uses and methods of study. In: Means, J.E., ed. Forest succession and stand development research in the Pacific Northwest: Proceedings of a symposium; [Date of meeting unknown]; [Location of meeting unknown]. Corvallis, OR: Forestry Research Laboratory, Oregon State University: 100-112.

Parker, K.L.; Robbins, C.T.; Hanley, T.A. 1984. Energy expenditures for locomotion by mule deer and elk. Journal of Wildlife Management. 48: 474-488.

Phillips, R.W. 1971. Effects of sediment on the gravel environment and fish production. In: Krygier, J.T.; Hall, J.D., eds. Proceedings, forest land uses and stream environment symposium; 1970 October 19-21; Corvallis, OR. Corvallis, OR: Continuing Education Publications, Oregon State University: 64-74.

Pierson, T.C. 1977. Factors controlling debris-flow initiation on forested hillslopes in the Oregon Coast Range. Seattle: University of Washington. 167 p. Ph.D. dissertation.

Quigley, R.M. 1975. Comments on hazard land zoning. Geoscience Canada. 2: 11-112.

Rice, R.M.; Fogging, G.T. 1971. Effect of high intensity storms on soil slippage on mountainous watersheds in southern California. Water Resources Research. 5: 647-659.

Roe, A.L.; DeJarnette, G.M. 1965. Results of regeneration cutting in a spruce-subalpine fir stand. Res. Pap. INT-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 14 p.

Sieving, K.E.; Willson, M.F. 1998. Nest predation and avian species diversity in northwestern forest understory. Ecology. 79: 2391-2402.

Smith, R.B. 1969. Assessing dwarf mistletoe on western hemlock. Forest Science. 15: 278-285.

Stephenson, G.R.; Freeze, R.A. 1974. Mathematical simulation of subsurface flow contributions to snowmelt runoff, Reynolds Creek Watershed, Idaho. Water Resources Research. 10: 284-294.

Swanson, F.J.; Swanston, D.N. 1977. Complex mass-movement terrains in the western Cascade Range, Oregon. Reviews of Engineering Geology. 3: 113-124.

Swanston, D.N. 1967. Soil-water piezometry in a southeast Alaska landslide area. Res. Note PNW-68. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 17 p.

Swanston, D.N. 1969. Mass wasting in coastal Alaska. Res. Pap. PNW-83. Juneau, AK: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 15 p.

Swanston, D.N. 1973. Judging landslide potential in glaciated valleys of southeastern Alaska. Explorers Journal. 51: 214-217.

Taylor, R.F. 1933. Site prediction in virgin forests of southeastern Alaska. Journal of Forestry. 31: 14-18.

Taylor, T.F. 1979. Species list of Alaskan birds, mammals, freshwater and anadromous fish, amphibians, reptiles, and commercially important invertebrates. Alaska Region Report 82. Juneau, AK: U.S. Department of Agriculture, Forest Service, Alaska Region. 102 p.

Thompson, A.J.; Alfaro, R.I.; Bloomberg, W.J.; Smith, R.B. 1985. Impact of dwarf mistletoe on the growth of western hemlock trees having different patterns of suppression and release. Canadian Journal of Forest Research. 15: 665-668.

Tokarczyk, R.D.; Adams, T.C.; Baker, R. [and others]. 1979. Pansy Basin advanced logging studies 1973-1977. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; final report. [Not paged].

T**orheim, R.H. 1977.** Transportation engineering handbook, Suppl. 6. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 95 p.

Trummer, L.M.; Hennon, P.E.; Hansen, E.M.; Muir, P.S. 1998. Modeling the incidence and severity of hemlock dwarf mistletoe in 110-year-old wind-disturbed forests in southeast Alaska. Canadian Journal of Forest Research. 28: 1501-1508.

U.S. Department of Agriculture, Forest Service. 1991. Supplement to the draft environmental impact statement, Tongass National Forest land management plan revision. R10-MB-149. Juneau, AK. 994 p.

Vandre, B.C.; Swanston, D.N. 1977. A stability evaluation of debris avalanches caused by blasting. Bulletin of the Association of Engineering Geologists. 14: 205-223.

Vannote, R.L.; Minshall, G.W.; Cummins, K.W. [and others]. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences. 37: 130-137.

Wallace, J.B.; Eggert, S.L.; Meyer, J.L.; Webster, J.L. 1997. Multiple trophic levels of a forest stream linked to terrestrial litter inputs. Science. 277: 102-104.

Wallmo, O.C.; Schoen, J.W. 1980. Response of deer to secondary forest succession in southeast Alaska. Forest Science. 26: 448-462.

Ward, T.J.; Li, R.M.; Simons, D. 1979. Mathematical modeling approach for delineating landslide hazards in watersheds. In: Proceedings of the 17th annual engineering geology and soils engineering symposium; [Date of meeting unknown]; Moscow, ID. [Place of publication unknown]: [Publisher unknown]: 109-149.

Williamson, R.L.; Ruth, R.H. 1976. Results of shelterwood cutting in western hemlock. Res. Pap. PNW-201. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 25 p.

Willson, M.F.; Comet, T. 1996a. Bird communities of northern forests: ecological correlates of diversity and abundance in the understory. Condor. 98: 350-362.

Willson, M.F.; Comet, T. 1996b. Bird communities of northern forests: patterns of diversity and abundance. Condor. 98: 337-349.

Wipfli, M.S. 1997. Terrestrial invertebrates as salmonid prey and nitrogen sources in streams: contrasting old-growth and young-growth riparian forests in southeastern Alaska, USA. Canadian Journal of Fisheries and Aquatic Sciences. 54: 1259-1269.

Wright, E.; Isaac, L.A. 1956. Decay following logging injury to western hemlock, Sitka spruce, and true firs. Tech. Bull. 1148. Washington, DC: U.S. Department of Agriculture, Forest Service. 34 p.

Appendix—Reconciliation of Reviewer Comments

Reviewers

Dr. Kermit Cromack, Jr., Professor, Department of Forest Science, Oregon State University, Corvallis, OR

Dr. John C. Tappeiner, Professor, Department of Forest Resources, Oregon State University, Corvallis, OR

Dr. John Zasada, Project Leader, USDA Forest Service, North Central Forest Experiment Station, Rhinelander, WI

Site Variability and Sampling Issues

Comment: The natural variability within and between stands presents both problems and opportunities. Responses may differ between blocks or within stands. You may not have replication in the true sense, rather a group of case studies. Try to locate experimental units on the same slope and aspect.

Response: We agree that there will be significant stand-to-stand variation with large treatment units such as ours, but we feel that the benefits of operational-scale units far outweigh problems caused by natural variability. To achieve greater uniformity, we would need to use much smaller experimental units, which would compromise many of the study objectives, particularly those for birds and visual quality. Opportunities exist for locating blocks 2-6 within areas of uniform slope and aspect, and we will pursue this vigorously.

Comment: Harvesting blocks in different years will make analysis difficult, as different variables may affect early succession from one year to the next.

Response: We have chosen to include year of harvest as a blocking variable. It is operationally impossible on the part of both the Station and Region to implement all six blocks in one field season. Climatic variables would be the chief source of year-to-year variation in succession, but the climate of southeast Alaska is relatively equable. Should an unusually harsh or benign weather pattern develop, its presence would be noted during the analysis and interpretation of the responses to treatment.

Comment: The permanent plot sampling will work well as described for trees, but two modifications are suggested: (1) use large-scale photography to monitor response of all trees, and (2) locate some understory plots to monitor the response of particular conditions, such as patches of hemlock regeneration or clones of important understory shrubs and forbs.

Response: (1) We agree that large-scale photography would be advantageous and cost efficient. We will investigate the use of low-altitude airborne still photography and video to document initial and postharvest stand conditions. Systems linking airborne video and the GPS may be of great use. The plan will be modified after a survey and evaluation of available technologies. (2) One of the attractive features of the experimental study is that it provides a template for various detailed ecological studies at the population, community, and process level. The proposed study is an example of the type of study we will encourage at our sites.

Comment: To better determine understory dynamics, examine the buried seed pool and monitor early posttreatment understory responses annually, rather than at 5-year intervals.

Response: A study of the soil seed bank is another example of a potential add-on study as described above. Annual sampling of understory vegetation may be beyond our available resources and may be unnecessary. Most forest forbs and shrubs in southeast Alaska cannot be characterized as strictly early or late seral and generally persist through extended phases of forest succession.

Comment: Are you measuring and describing the vertical structure of the vegetation?

Response: Yes, to some extent. Tree crown size, live-crown ratio, and form will be measured on the permanent plots. We are currently evaluating systems for quantifying canopy structure and hope to find or devise a suitable system to apply to this study.

Marking Guidelines

Comment: The response to a gap or clump will depend on the local conditions before treatment. Rather than locate these features in a systematic or random fashion, it would be better to locate them to protect or take advantage of existing conditions within the stand, just as an "artful" landowner might do.

Response: Patches (whether gaps or clumps) will be located by an interdisciplinary team that includes an ecologist, silviculturist, wildlife biologist, and soil scientist. The team will not locate patches systematically, but rather in response to features of the existing stand. See the draft marking guides appended to this plan for further information.

Comment: Which trees will be selected for retention in the single-tree selection systems and in the clearcut with wildlife trees? Dominants have the best root systems and large live crowns that allow them to survive and thrive after partial cutting. Suppressed trees are easily damaged during harvesting and often respond poorly to the opening of a stand. Leave dominant trees as much as possible.

Response: See the draft marking guides for further information.

Characterization of Site Conditions and Response

Comment: Some measurement of the physical environment (light, air and soil temperature, wind speed, and precipitation) should be included to describe sites and their response to treatment.

Response: We agree that some measure of these parameters is essential. Some of these data will be collected in the course of the hydrological and slope stability studies. We will survey and evaluate methods suited to our conditions and develop a plan for acquiring these data.

Comment: A related concern is the use of basal area only to express stand density. What does 100 percent of initial basal area mean in terms of light availability or other environmental variable? Another measure such as light levels below the canopy or canopy area index would make the results more generally useful.

Response: The stands chosen for this study will probably differ greatly in initial canopy cover, so we agree that some measure of light availability is required and that a method of relating stand density to light availability should be developed. We will survey and evaluate methods suited to our conditions and develop a plan for acquiring these data.

Management and Organization of Research

Comment: On a study as large and complex as this, communication with involved NFS personnel will be essential for correct implementation.

Response: NFS personnel have been involved with the development of the study goals and objectives, the treatment design and study plan, the silvicultural prescriptions, and the marking guides. Our collaboration is continuing in the implementation phase, and the Station will have a representative at the experimental sites during all critical phases, especially during tree marking, felling, and yarding. See the "Project Funding, Management, and Cooperators" and the "Experimental Study Design" sections of the study plan for more detail.

Comment: Studies may be integrated, but they still appear to be unrelated as presented. A conceptual model showing linkages between studies would be useful to include. The model should identify gaps that exist.

Response: We will develop such a model.

Comment: How will the enormous amount of data be managed?

Response: The current plan does not address this and as it stands, data management will be the responsibility of the principal investigators. Given the need for integration, the long-term nature of the study, and the number of investigators potentially involved, we will develop a data management plan for this project. Rather than reinvent the wheel, we will consult with experienced data managers at the Forest Science Data Bank (Oregon State University), the Long-Term Ecosystem Productivity group in the PNW Research Station, and other relevant projects to find a system that meets our needs.

Scope of Research

Comment: How will this study address concerns about second-growth management? Many of these treatments could be applied to younger forests, but they will respond differently.

Response: We have deliberately limited our inquiry to the response of late-successional forests; as this is the area of greatest current concern. The Resource Management and Productivity Team at the Juneau Forestry Sciences Laboratory will develop a research problem analysis for second-growth management in the Alaska Region.

This page has been left blank intentionally.
Document continues on next page.

This page has been left blank intentionally.
Document continues on next page.

Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, Oregon 97208-3890.

U.S. Department of Agriculture
Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, OR 97208