

Silviculture of the Coastal Sitka Spruce-Western Hemlock Type

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HIGH GROWTH RATES in young-growth Sitka spruce (*Picea sitchensis*)—western hemlock (*Tsuga heterophylla*) forests plus increasing demand for spruce and hemlock logs have stimulated interest in silvicultural practices tailored to this forest type. I will outline some pertinent silvical characteristics of these two species and describe current management practices in the Pacific Northwest.

The spruce-hemlock type occurs in a narrow coastal strip from northern California to Kodiak Island, Alaska. The climate is dominated by prevailing westerly winds from the Pacific Ocean and is characterized by equable temperatures, high precipitation, and prolonged cloudiness. The summer dry season, so common in much of the Pacific Northwest and California, is not pronounced in this coastal strip because of frequent summer fogs that often develop into light rain or drizzle. Annual precipitation ranges from about 40 to over 150 inches and occurs mostly as rain. The frost-free period varies from 10 months in the south to only 4 to 5 months in the north where the shorter season is partly offset by long summer days. These spruce-hemlock rain forests are highly productive throughout but appear to reach opti-

imum development on the west side of the Olympic Peninsula in Washington. This area, plus the northern Oregon coast and much of coastal British Columbia, has forest growth conditions among the best found in North America. The growing season is about 9 months, with April-to-September precipitation about 20 inches and annual precipitation near 90. July temperatures average about 60° F and January temperatures near 40°.

Soil parent materials in coastal Oregon and Washington are usually marine shales, coastal plain sediments, Pleistocene dunes, and some basalt. In addition, considerable glacial outwash occurs on the Olympic Peninsula. Soils developed are mainly Brown Latosols, Podzols, and groundwater Podzols with alluvial soils along coastal streams (3). Soils are generally deep, porous, and coarse textured. An impervious layer is sometimes present in the subsoil.

Logging methods in the spruce-hemlock type are severely limited by topographic and soil conditions. Topography often is so irregular, abrupt, and dissected by small canyons that cable logging is the only practical harvesting method. Tractor logging is possible on gentle slopes, but high soil moisture makes the operating season short and uncertain. Some areas are too wet to allow tractor logging during any season.

Large-scale harvesting of old growth was quite limited until the great demand for Sitka spruce for airplane stock during World War I. Given this start, logging has continued at a fairly steady rate. Many of today's fast-growing young stands in the Pacific Northwest originated on the early logging areas. Others became established following extensive blowdown; the Olympic "blow" of 1921 provides the most notable example. Still others originated following fire.

The Species

Sitka spruce is the largest of our native spruces with trees reaching 270 feet in height and 10 feet in diameter. Many old-growth trees have a characteristic butt swell that can complicate cruising, log handling, and processing. In fully stocked second-growth stands, crowns are conical, short, and rather open. Spruce often grows more vigorously than associated western hemlock and assumes a dominant position in the crown canopy. Branch wood is resinous and branch stubs often persist to rotation age, thereby limiting production of clear wood. Spruce produces some epicormic branches even in dense natural stands, and in more open, managed stands this tendency may also limit quality log production.

The thin bark of Sitka spruce is easily damaged during logging opera-

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tions and logging wounds often provide entrance for decay organisms. In one study, 58 percent of the logging scars were infected. Brown crumbly rot, caused by red belt fungus (*Fomes pinicola*), was the most destructive and most common of 11 fungi identified (10). Shoestring root rot (*Armillaria mellea*) is found in young-growth spruce but extent of damage is unknown. Sitka-spruce weevil (*Pissodes sitchensis*) attacks and kills terminal shoots much as the white pine weevil attacks white pine in the Northeast, but damage to spruce does not seem as widespread or severe. The spruce aphid (*Aphis abietina*) has killed a considerable volume of spruce, particularly near tidewater. Ambrosia beetles (*Gnathotrichus sulcatus* and *Trypodendron bivittatum*) attack spruce logs and cause considerable degrade due to pinholes and sapstain (6).

Western hemlock is the largest of our native hemlocks with trees attaining 250 feet in height and 6 feet in diameter. Hemlock does not grow to the massive size of Sitka spruce but loses its lower limbs sooner and produces a long, clear symmetrical bole without epicormic branching. Like spruce, hemlock has thin bark and is easily damaged during logging operations. Hemlock is more shade tolerant than spruce. It survives and grows better in the understory, indicating a definite succession from spruce to hemlock. It appears that spruce has been maintained on most sites by recurring disturbance caused by fire, blowdown, or erosion and, more recently, by clear cutting. Hemlock can tolerate a greater variety of site conditions. Unlike spruce, its range extends hundreds of miles inland to drier sites and higher elevations where it may be found in pure stands, but more often as a secondary species in the widespread Douglas-fir timber type. Associated species in the Pacific Northwest part of the spruce-hemlock type include Douglas-fir (*Pseudotsuga menziesii*), western redb cedar (*Thuja plicata*), Pacific silver fir (*Abies amabilis*), red alder (*Alnus rubra*), and lodgepole pine (*Pinus contorta*).

Dwarf mistletoe (*Arceuthobium campylopodum*) is a common parasite on western hemlock, causing widespread growth loss and mortality in old-growth stands. It occurs in young growth as well, usually by infection of advance reproduction before removal of the overstory. As in spruce, logging wounds often become infected with decay organisms. Hunt and Krueger (5) found 61 percent of sampled logging scars to be infected with *Fomes annosus* and *Stereum sanguinolentum*, the most common decay organisms. Hem-

TABLE 1.—STAND STATISTICS FOR NORMAL STANDS, 40 PERCENT OR MORE HEMLOCK, SITE INDEX 170, PACIFIC NORTHWEST (1)

Item	Age (years)		
	20	40	60
Trees over 1.5 inches dbh:			
Trees per acre (number)	2,720	640	265
Average dbh (inches)	3.3	8.6	14.6
Average stand height (feet)	34	83	121
Basal area per acre (square feet)	162	259	309
Volume per acre (cubic feet)	2,600	9,400	16,100
Trees over 6.5 inches dbh:			
Volume per acre (cubic feet) ¹	8,800	15,900
Volume per acre (board feet, International ¼-inch kerf) ²	43,000	103,000
Trees over 11.5 inches dbh:			
Volume per acre (board feet, Scribner) ³	18,000	79,000

¹Stump and tips included.

²Scaling length for logs, 16 feet; stump, 2 feet; top diameter inside bark, 6 inches; trim allowance per log, 0.3 foot.

³Scaling length for logs, 16 feet; stump, 2 feet; top diameter inside bark, 8 inches; trim allowance per log, 0.3 foot.

lock is susceptible to sunscald following exposure of young stems by thinning, and sunscald lesions become infected with decay organisms. Shoestring root rot causes damage in hemlock as it does in spruce.

The western hemlock looper (*Lambdina fuscicollis lugubrosa*) is an important insect attacking western hemlock, with several major outbreaks during the last 75 years. A 70,000-acre infestation in southwestern Washington was sprayed in 1963, part with DDT and part with some experimental insecticides. Defoliator outbreaks of this kind are often followed by infestations of the western larch round-headed borer (*Tetropium velutinum*) which kills the weakened hemlocks. The black-headed budworm (*Acleris variana*) is an important defoliator of western hemlock and often feeds on intervening spruce as well. The main damage caused by this insect in Oregon and Washington has been growth suppression, but severe mortality has occurred farther north (6).

Both Sitka spruce and western hemlock are considered prolific seed producers in the Pacific Northwest, with good cone crops every 3 to 4 years and light crops intervening. Seed crop failures do occur but are uncommon (2, 8). Seeds are small, light, and readily disseminated one-quarter mile—much farther on strong winds. Since moisture is almost always adequate, seedlings survive well on a wide variety of seedbeds including mineral soil, humus, and decaying litter, logs, and stumps. Hemlock survives a little better than spruce on organic seedbeds while spruce does somewhat better on bare soil and gravel banks. In general, hemlock seedlings outnumber spruce. The ability of both species to grow on down logs and stumps helps them to become established in areas that otherwise would be dominated by competing brush.

Both species are considered shallow-rooted and susceptible to windthrow. Root penetration is commonly limited by the high water table or by an impervious layer in the soil. Root plates on uprooted trees indicating rooting depths of 6 inches or less are readily found in blowdown areas. When roots are not restricted by soil conditions, rooting depth may exceed 6 feet.

The Forests

Most spruce-hemlock timber in Alaska and British Columbia is old growth. In Oregon and Washington much of the old growth has been harvested, and interest is now focused on young-growth management. Young stands have prodigious growth rates. Yield tables for natural, predominantly western hemlock stands, site index 170, show very high volumes (Table 1). Within a 60-year rotation, and with the assumption that trees 6.5 inches dbh and over will be utilized, mean annual growth is 1,717 board feet per acre per year (1). Under intensive management, yields would be increased by salvaging mortality and transferring growth to marketable trees.

Most young timber is predominantly hemlock by number of trees and volume (Fig. 1). In many areas, spruce trees are the largest in the stand, with their crowns often emergent above the general canopy. Near the ocean, spruce often occurs in pure stands where it follows the less tolerant lodgepole pine in invasion of coastal sand dunes as they become stabilized. A short distance inland, spruce is usually invaded rapidly by western hemlock to form the typical spruce-hemlock type (4). At the eastern extremity of the type, spruce tends to drop out of the stand and be replaced by Douglas-fir or Pacific silver fir. On poorly drained sites, which are quite common on the west side of the Olympic Peninsula, western redb cedar grows better than either

spruce or hemlock and becomes the dominant tree.

Silvicultural Practices

Clearcutting, with reliance on natural seeding from adjacent timber borders or blocks, is the most commonly used silvicultural system in the Sitka spruce-western hemlock type. In past years, continuous clearcutting of large ownerships was the rule. Now many foresters practice patch clearcutting with the clearcut area restricted to 100 acres or less. Others, particularly those still having large areas of old growth, cut areas several hundred acres in size. The smaller patch clearcuts have the advantage that they break the slash up into smaller units, receive more seed from surrounding timber, and are generally considered more desirable esthetically. Large clearcuts are more efficient to log, have proportionately less border exposed to windfall and fire, and permit more flexibility in locating windfirm cutting boundaries.

Natural regeneration of spruce and hemlock is usually a combination of advance hemlock reproduction that survived the logging operation and new seedlings from seed cast by nearby timber. It is usually adequate. Today's dense, fairly continuous, young stands on old cutovers testify to its general adequacy even with continuous clearcutting.

However, nonstocked and poorly stocked areas do occur, the problem usually being competing vegetation rather than lack of viable seed. One problem is encroachment of red alder on sites being managed for conifer production, and the usual practice is to spray with herbicides and release the conifer seedlings. A foliage spray of 2,4-D in a water carrier and applied by helicopter has been very effective. A recent trend is to use 2,4-D plus

2,4,5-T in diesel oil, applied during alder bud bursting and just prior to bud bursting of the conifers. This gives better penetration into alder crowns and also affects some of the brush species normally present under alder.

Another regeneration problem is competition from salmonberry (*Rubus spectabilis*) and associated brush species. Understocked mature spruce-hemlock stands usually develop a dense brush understory, especially along creeks and in other wet areas where trees are widely spaced and brush grows dense and tall. Removal of the overstory exposes the brush plants to full sunlight, and they often proceed to dominate the site and exclude conifer reproduction. Current brush control practices include: (1) planning the logging operation to destroy as much of the brush as possible, (2) planting as soon as possible and with the best available planting stock, and (3) chemical brush control. Salmonberry is hard to kill with herbicides. It now appears that good success can be achieved with a foliage spray of Amitrole T in a water carrier or a stem spray of 2,4-D plus 2,4,5-T in diesel oil applied at bud bursting (7). In most cases, planting alone has given the trees enough head start to keep above the brush, although some areas require herbicide treatment or even tractor scarification prior to planting.

Where the problem is only lack of seed source, spruce and hemlock are being successfully regenerated by sowing with endrin-treated seed.

The most critical silvicultural problem in the spruce-hemlock type is blowdown. Each year storms take a toll in uprooted and broken trees, and occasionally, as in 1921, 1951, and 1962, blowdown from a single storm exceeds

a billion board feet. Winter windstorms usually move in from south to west directly off the Pacific Ocean. They are often preceded by heavy rains with resulting saturation of soil around tree roots by the time gale winds exert maximum pressure on the crowns. Southwest stormwinds sweep down into clearcut areas and strike trees exposed along the north and east boundaries. This is where most blowdown occurs. Most trees grow in dense stands with only limited opportunity to build up windfirmness. Abrupt exposure of such trees along a stand border leaves them particularly susceptible to uprooting or breakage.

Uprooting is increased in areas where a high water table or impenetrable layer in the soil causes trees to be shallow-rooted, and such areas should be avoided in cutting line location. It appears that cutting boundaries on windward slopes are more stable than those on leeward slopes. Very young, poorly stocked, and mixed conifer-alder stands appear to be windfirm and make good stand borders. Individual trees to be exposed along the boundary should be selected with care. Sitka spruce may be more windfirm than western hemlock and dominant trees more stable than lesser crown classes. Trees with more than normal taper and enlarged leeward prop roots seem most windfirm. Trees showing any sign of decay in the roots or along the bole are susceptible to blowdown (9). A final precaution is to avoid locating a cutting line that will funnel southwest stormwinds into the northeast corner of a clearcut thereby increasing their velocity as they strike border trees.

Even though wind damage can be reduced by careful layout of cutting boundaries, it continues to be a major problem in several areas. Salvage of recurring blowdown, particularly around patch cuttings, has resulted in high logging costs and disrupted logging plans. Because of this, some foresters are converting from patch cutting to a progressive strip system of clear cutting which would minimize or eliminate the northeast boundaries where most losses occur. Strips are the width of a high-lead setting, about 1,000 to 1,400 feet, and as long as possible. The first strip is cut at right angles to southwest stormwinds and along the northeast boundary of the ownership or the planning unit. The second strip is cut parallel to and on the southwest side of the first, and so on progressively into stormwinds to reach the southwest boundary of the planning unit by the end of the rotation. By that time, the new stand would have a steplike distribution of age classes from zero on the southwest

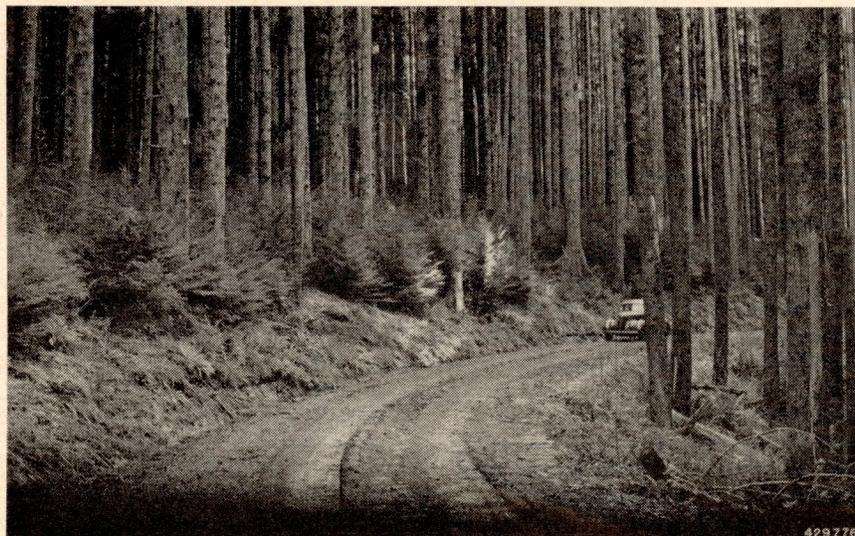


Fig. 1.—Dense young-growth Sitka spruce-western hemlock stand that seeded in following fire. Reproduction in understory is pure hemlock.

side of the unit to rotation age on the northeast. Stormwinds would be lifted up and over the stand by the increasing heights of the trees with no cutting boundary exposed to southwest winds.

Progressive strip cutting would then start over again with the first strip in the mature timber along the northeast boundary of the unit. This system should eliminate most blowdown associated with cutting but has the disadvantage of creating a large area of continuous slash and having the seed source always to the southwest. Southwest winds off the Pacific are always moist and have little effect on opening of cones. Consequently, a good deal of spruce and hemlock seed dispersal occurs on occasional relatively dry east winds. It should be mentioned that in some localities east winds become strong enough to cause blowdown, although this has never been as serious as that caused by southwest winds.

The increasingly common practice in the spruce-hemlock type is to leave logging slash unburned. Fire danger generally is low because of the wet climate, hemlock and spruce slash deteriorate rapidly, and advance reproduction usually is present. On the other hand, logging defective old-growth stands often leaves huge slash accumulations, and periods of critical fire weather can and do occur. If planting is planned to give the trees a head start on the brush or improve species composition, broadcast burning sets back the brush plants and opens up the area for planting.

These conflicting factors have led to strong differences of opinion on burning. Foresters tend to favor broadcast burning when they have heavy slash accumulations, summer drought conditions above average for the type, or a high proportion of western redcedar slash. Some burn to set back the brush and facilitate planting. Others wait until rather late in the fall and burn only heavy accumulations at landings. Public foresters often are faced with increased fire risk due to heavy public use, and this tips the scale in favor of burning. In general, the slash problem is decreasing with the shift of harvesting operations from old- to young-growth stands and steadily improving utilization.

Another silvicultural practice is pre-logging of small trees from old-growth stands in advance of the main logging operation. Trees are usually designated as all those below a specified diameter and are taken out with small equipment that can handle them efficiently. The prime cut is taken out later with heavy equipment. The increased efficiency in log handling tends to offset the cost of setting up two

kinds of equipment. Total yield is increased because prelogging avoids breakage of small timber that otherwise would occur during felling and yarding the large old growth. Prelogging may facilitate establishment of advanced regeneration, and in this respect, the system resembles a two-cut shelterwood system.

The shelterwood system of harvest cutting is receiving increased attention in the spruce-hemlock type. It has the advantage of getting the new crop established before the preceding one is harvested and has the potential for preventing encroachment by relatively intolerant red alder. Thinnings in 100-year-old stands have led to establishment of considerable hemlock and some spruce reproduction in the understory, so intensive thinning programs envisioned for young stands may lead naturally into the shelterwood system. Its esthetic advantages over clear cutting are important in scenic coastal areas. A disadvantage is that heavy cuttings in mature stands increase blowdown hazard.

Silvicultural practices for intensive management of young-growth spruce-hemlock are still in an early stage of development. New access roads are being built or old railroad grades converted to truck roads. Blowdown is being salvaged, remnants of old-growth stands removed, and thinning programs started. Hemlock predominates in the young stands because advance regeneration under old growth is nearly pure hemlock and, after clear cutting, hemlock seedlings usually outnumber those of other species. Recognizing this, most foresters use spruce rather than hemlock for seeding and planting, anticipating that enough hemlock will establish naturally.

In many cases, however, foresters prefer a mixture of Douglas-fir in the stand and seed or plant this species either alone or with spruce. They feel the mixture of Douglas-fir, spruce, and hemlock may yield the highest economic return because of high fir stumpage values. Douglas-fir grows rapidly and assumes a dominant position in the stand. Some foresters plan to take part of the dominant trees in early thinnings and, with fir in the stand, hope that commercial thinning will be possible earlier in the rotation. Fir also has an advantage in being more windfirm than hemlock and probably more windfirm than spruce.

This entire question of species-site relations needs careful study. Differences in site factors such as soil moisture, soil type, and aspect create quite different habitats, and we need to know the species or species combination best suited to each habitat.

Most thinnings so far have been in

stands near or even past rotation age and could be classified as preharvest or harvest cuttings. But utilization standards are improving, and commercial thinning in younger stands is now possible in limited areas. Precommercial thinning is also receiving increasing interest and research. Competition for growing space begins early in spruce-hemlock stands, and large numbers of trees are forced out as the stands develop. Effects of thinning in redistribution of growth potential to selected trees and salvage of anticipated mortality should be especially beneficial in these vigorous stands. Spruce and especially hemlock, being tolerant conifers, should maintain essentially optimum cubic volume production over a wide range of stocking density and thus give the silviculturist considerable latitude in thinning programs. The upper limits of this optimum range are probably of little consequence. They will be avoided because of small log sizes. Lower limits below which the site is not fully utilized need to be determined.

Steep topography, high soil moisture, and shallow rooting present special problems in intensive management. Tractors, even when not ruled out by steep slopes or wet soil, may damage surface roots and provide entrance for decay organisms with resulting growth loss and blowdown. Cable thinning methods have been tried experimentally and appear promising, but much work needs to be done on thinning techniques.

Summary

In summary, I would say that our silvicultural skills, though rough, have been able to cope with some of the most obvious problems in Sitka spruce-western hemlock management. Most areas are fully stocked and very often overstocked with trees. Techniques are available for regeneration of problem areas. Blowdown will always be a problem, but we know ways to minimize it by careful location of cutting lines and arrangement of cuttings. I suspect blowdown will be less of a problem when we deal entirely with young-growth stands. Very young trees seem quite windfirm, and windfirmness may be improved through thinnings that redistribute growth to fewer and larger trees. We do need research on how to develop windfirmness in individual trees.

We are just getting into intensive management of young stands. Yields in natural stands are very high, and the opportunity for substantial increases in usable wood through intensive management is indeed challenging. Especially here do we need more silvicultural information on initial spacing

of trees and thinning schedules to provide optimum levels of growing stock, on efficient cable thinning and tractor thinning techniques that will minimize damage to young trees, on the impact of whatever root and bole injury does occur, and on species-site relations to determine the best species or species combination for various habitats. There is a challenging job ahead.

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