Douglas fir (*Pseudotsuga menziesii*)

Douglas fir is the largest and tallest member of the pine family. Living trees have been documented up to 485 cm in diameter, up to 99.4 m tall, and with volumes up to 349 m^3. Even larger and taller trees once existed in western Washington. It is also the most widespread of all western trees. It can be found growing from southern Mexico to central British Columbia (a distance of 5,000 km) and from Colorado to the coast (another 1,600 km). Even in western Washington, it grows in all but the wettest locations – anywhere with a fire history (Figure 36). Throughout much of its native range in the Rocky Mountains, it has high relative shade-tolerance, capable

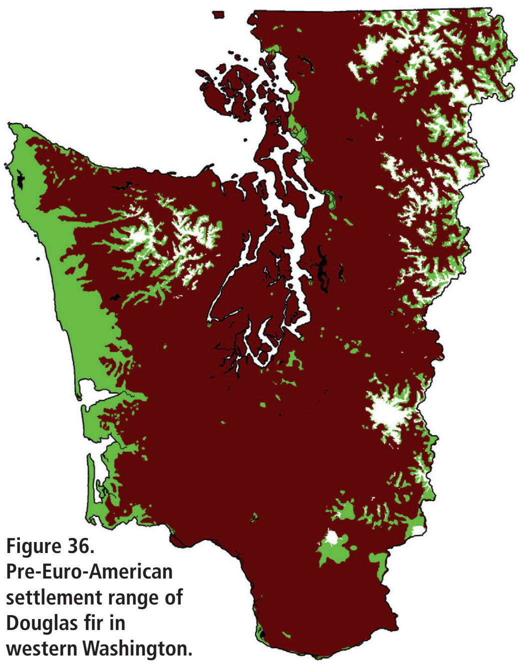


Figure 36. Pre-Euro-American settlement range of Douglas fir in western Washington.

Figure 37. Left: Windswept Douglas fir at 1500 m near timberline on Hurricane Ridge in Olympic National Park. **Right: Windswept Douglas fir at sea level** at Point Wilson near Port Townsend

of regenerating in the understory of other tree species (primarily pines). This subspecies is called *Pseudotsuga menziesii glauca*. The coast form, which grows from Vancouver Island south into the Sierra Nevada of California, is subspecies *menziesii*. This subspecies behaves largely as a long-lived pioneer tree, due in part to the tree species with which it is found growing, and the higher productivity and denser forests found along the coast,.

This great adaptability is well displayed in the forests of western Washington. It can be found windswept, growing at 1,500 m elevation along the eastern ridges in Olympic National Park, and just a few kilometers away, windswept again, along the shores of the Straits of Juan de Fuca (Figure 37).

A generalist species, Douglas fir grows in a wide range of habitats and assumes a wide range of identities. Like many tree species, size and age are poorly correlated in Douglas fir. It can become a large tree in just a few decades, or grow for centuries and still remain small (Figure 38).

The wood of Douglas fir is considered intermediate in terms of decay resistance. Species such as western redcedar or coast redwood (*Sequoia sempervirens*)

Figure 38. Poor correlation between size and age in Douglas fir. Left: 80 year-old tree growing on a productive site in the Willapa Hills is already 130 cm in diameter. Right: 400 year-old trees on a poor site in the south Cascades. Center tree is only 61 cm in diameter.

are far more decay resistant, while Sitka spruce or western hemlock are far less resistant. Decay resistance helps this species live to great age; trees 600-800 years old are not uncommon in certain parts of its range with long fire return intervals. Trees 1,000 years or older have been recorded from several parts of its range, including several individuals between 1,300 and 1,400 years old.

Certain characteristics of Douglas fir change predictably during its lifespan, including bark characteristics, epicormic branching in the lower crown, and tree shape and crown form. The next sections will examine these in detail.

Bark characteristics

Douglas fir is probably the most fire-resistant of all the trees native to western Washington, due largely to the protective bark that it develops as it ages. Old trees have very coarse and rugged bark, which occasionally can reach a thickness of 35 cm. The thin bark of young trees begins to thicken and develop vertical fissures as trees mature. For the first 100-200 years, the bark is hard and boney, and usually brown to gray (Figure 39). At some locations within western Washington, crustose lichens or mosses may adorn the bark at this stage. This is the most common

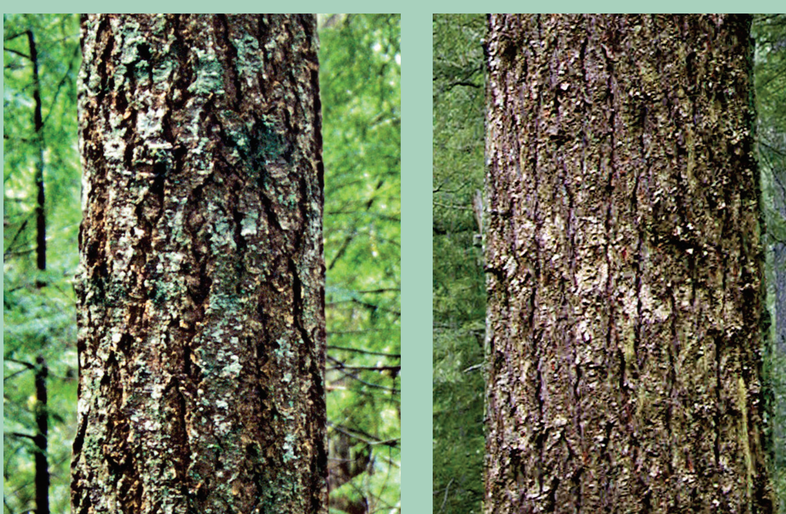


Figure 39. Bark of two trees from the south Cascades. Left: 100 years. Right: 150 Years

Figure 40. The 1902 Yacolt Burn stand. The hard, boney bark of the densely-stocked stand is evident. Crustose and fruticose lichens adorn the bark.

Figure 41. A 170 year-old stand in the Hoh Rain Forest. Trees are very large for their age, but still have the hard bark of a mature stand. Mosses, rather than lichens, grow on the bark.

condition of many of our second-growth forests, whether they developed naturally or following harvest (Figure 40). Even on productive sites, where Douglas fir trees can become very large at maturity, the characteristic younger bark appearance remains (Figure 41).

It is often difficult to assess the ages of trees in late maturity and in the vertical diversification phase. At the stand level, all of the characteristics of an old-growth forest may be present, including large trees, logs, snags, and a diversity of canopy heights within the western hemlock community (Figures 42 and 43). With the exception of the forest floor bryophytes, all of the green in Figure 42 is hemlock foliage, even though the view of trunks is completely dominated by Douglas fir. These trees are 55-70 m tall, and they have very little foliage below 30 m. Even these large Douglas firs share many characteristics with younger trees, including crown characteristics and youthful bark. The colorful, flakey bark of older trees begins to appear near the tree base, which is what people quickly see when walk-

Figure 42. A 280 year-old stand at Mount Rainier National Park. The bark is becoming more colorful and flaky near the base of the tree, but branch wounds are still evident.

Figure 43. A 330 year-old stand in the south Cascades. Colorful, flaky bark extends up the stem; branch wounds no longer evident. Tree in front center is a western hemlock.

ing around in such a forest. An inspection of the tree bole, however, reveals that the harder bark of a younger tree is still present for most of the height of the tree.

Bark grows outward from the cambium; wood is formed on the inside of the cambium. As the tree grows, new bark forms underneath older bark, forcing it outward. The bark develops fissures in some trees as it expands, since the outer layers of bark were formed when the tree diameter was smaller. On trees with thick bark, the outermost bark is the oldest (Figure 44). Thin barked trees either do not make very much bark each year (alders) or have bark that exfoliates regularly (spruces). Douglas fir produces large amounts of bark which it retains it for a long time. This is characteristic of many fire-resistant tree species. Many older Douglas firs in the Puget Trough have charcoal on their outer bark, an indication that they survived a previous bout with fire (Figure 45).

The final stage of bark development in Douglas fir is characterized by the development of the colorful papery bark of an ancient tree (Figure 38 – right). At this stage

Figure 44. Close up of a 250+ year-old tree in the Puget Trough. Note thick bark but the color is still the brownish-gray of youth. On a few of the outermost bark flakes, the smooth, juvenile bark has yet to be shed.

Figure 45. A 300+ year-old tree in the Puget Trough. The hard, boney bark of youth is now completely vanished and colorful flakey bark is beginning to appear. Also note the charcoal — which usually indicates the presence of more than one age class of Douglas fir.

the bark can take on many different appearances, depending on exposure, lean, and neighboring trees. Since it is soft and papery, it can easily come off in sheets, as illustrated by the bark on a leaning tree. Over the centuries, small branches, leaves and other small bits of debris are continually shed from the canopy during storms or other events. On a leaning tree, the upper surface of the bark is exposed to this constant rain of debris, gradually sloughing off the outermost ridges of bark and creating a smooth surface (Figure 46). The bark is not damaged by this process; only the outermost ridges of bark, produced centuries earlier, are removed. The hard bark of youth is not always shed when the softer, papery bark is produced. On protected locations, such as on the underside of a leaning tree, the bark can remain very thick (Figures 46 and 47).

Lower crown characteristics

The growth of Douglas fir is whorl-based, like that of many conifers. Whorl-based growth occurs at the end of the growing season when the terminal leader pro-

Figure 46. Leaning 600+ year-old tree displays the two major bark types on old Douglas firs. The protected side has very thick bark from centuries of accumulation. The exposed side is smooth. It still has plenty of thickness to protect the tree, it has just lost the outermost ridges.

Figure 47. The protected side of a very large tree showing the 30+ cm bark thickness that they can occasionally obtain.

duces several buds at the tip. One of these buds will be the new terminal leader for the next growing season; the remainder will be branches. Pines, firs, spruces, and Douglas firs all share this pattern (Figure 48). Since the original branches are formed at the terminal leader, their pith is directly connected to the pith of the trunk. The trunk has virtually no diameter when this occurs; hence original branches remain perpendicular to the trunk, even as the trunk gets larger. Since this pattern repeats every year, the distance between whorls corresponds to one year of tree growth. Trees that maintain this morphology are termed ***model conforming***, since they are following their architectural model of growth.

In Douglas fir, the lower crown begins to recede once a stand has achieved canopy closure. The lower branches die when they become too heavily shaded. Once dead, they often rot at their base and drop off the tree, leaving just a small scar in the otherwise typical bark (Figure 49, Figure 38 left). If shading occurs rapidly and many branches die at once, these stubs may be visible in groups for

Figure 48. Whorl-based growth. Easily visible behind Karl are whorls of 4-6 branches coming out of the tree at the same height. This pattern is repeated every 80 cm or so in this tree, which was the annual height growth of the tree when these were formed.

many years, radiating around the stem (Figure 50). Ultimately, these will also drop off and their presence will be masked years later by the continually expanding bark. The complete masking of these patterns, however, may take anywhere from several decades to more than a century. During that interval, the bark will be thinner at these spots than in the surrounding areas. If changes occur, such as the opening up of the canopy during maturation, epicormic branches may begin to form at some of these old wounds.

Since epicormic branches start from dormant buds located on the cam-

Figure 49. Whorls of branch wounds still visible below the main crown in this 150+ year-old tree.

Figure 50. Stubs from dead branches being retained below the main crown in this 200+ year-old tree.

Figure 51. Epicormic branches in the lower crown of a 250+ year old tree showing the haphazard and often tangential direction they take upon leaving the trunk.

Figure 52. Lower crown of a 200+ year-old tree showing large original branches at the top of the picture and epicormic branches at the crown base.

Figure 53. A massive, radiating epicormic branch system on a giant tree.

Figure 54. A small secondary trunk emerging from a large epicormic branch system.

bium on the outside of the trunk, their growth is not restricted to be perpendicular to the bole. Indeed, since these new branches are responding to increased light levels, they will often grow every which way, and may be completely tangential to the trunk (Figure 51). As light conditions in the lower crown improve due to further canopy openings, more and more epicormic branches may be produced. Trees at late maturity or in the vertical diversification phase are often composed of an upper crown of original branches and a lower crown composed of the stubs of dead original branches surrounded by many younger epicormic branches (Figure 52).

Since it is uncommon for very old trees to grow appreciably in height, they do not produce any more original branches. Instead, existing branches, either original or epicormic, are maintained through the process of within-branch epicormic shoot production. This process occurs at the branch level, not the tree level. The individual branches can reach massive proportions in these old trees (Figure 53), often producing secondary trunks of their own (Figure 54).

Crown form and tree vigor

As a Douglas fir tree ages, it transforms itself from a simple, whorl-based growth form, to a highly individualistic shape. The individuality is due in part to the long lifespan of the species. As time proceeds, shading from neighbors, damage from storms or falling trees, the effects of decay, and differences in their specific growth environments all combine to make each tree unique.

In homage to the ponderosa pine crown classes developed by Keen (1943), crown profiles of Douglas fir at four ages (1–4) and four vigor classes (A–D) for western Washington forests are presented in Figure 55. Trees depicted at the left of the drawings (A classes) are the most vigorous, with decreasing vigor proceeding to the right. These are presented to a unified scale in Figure 55, and on the following pages are at different scales with approximate heights and ages for the four series. Not all of the trees in one series will make it to the next series. For example, competition-based mortality will ensure that most of trees in classes 1C and 1D do not make it to the next stage.

Vigor can be thought of as how much leaf mass there is compared to how much respiring tissue the tree has. Class A trees all have large amounts of leaf mass and represent rapidly growing trees. In contrast, class D trees have low amounts of

Figure 55. Crown form and tree vigor.

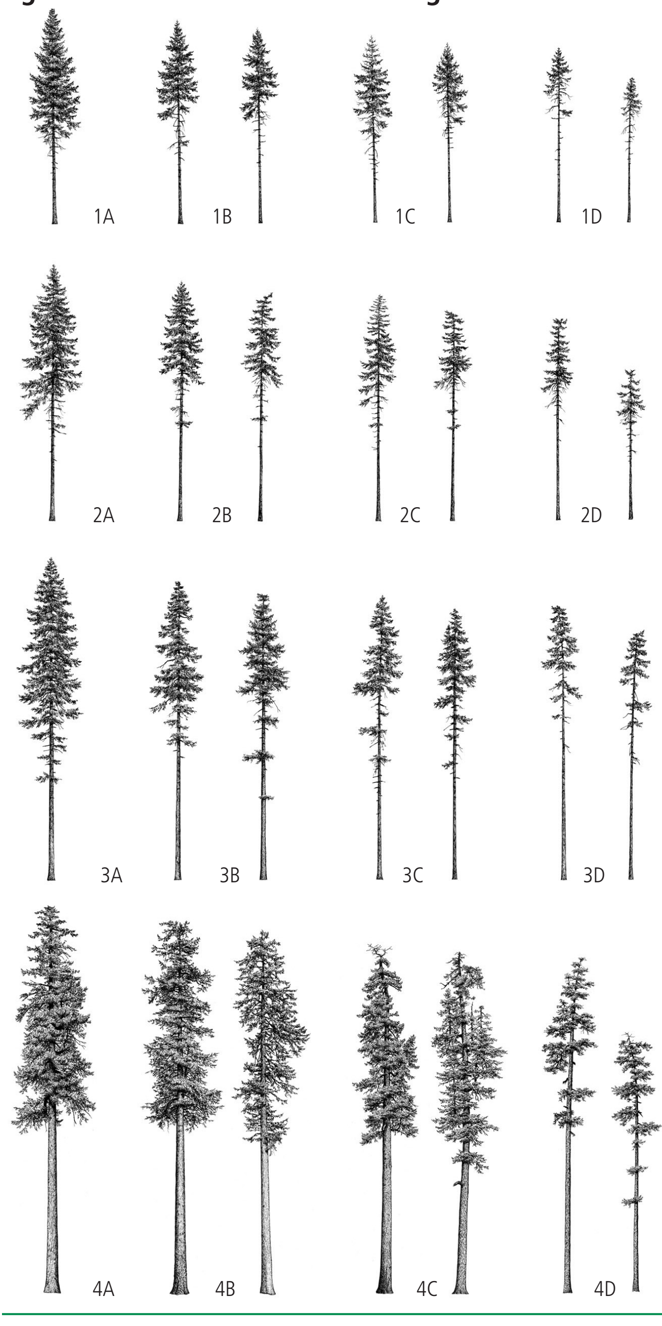
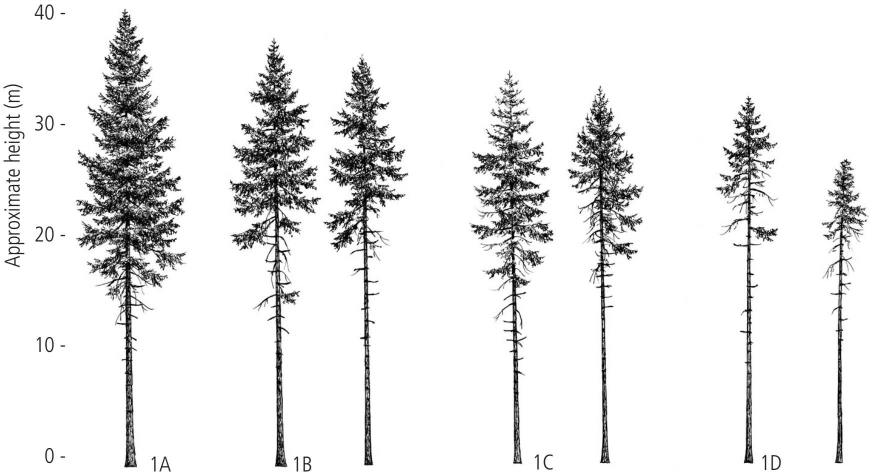


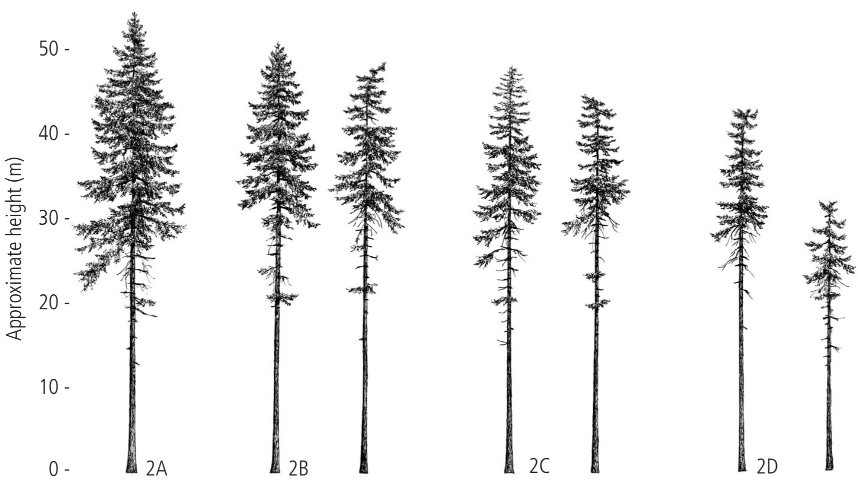
Figure 55. Crown form and tree vigor. The Douglas firs depicted are idealized forms representing four age classes (1-4) and four vigor classes (A-D) in western Washington. The 28 trees are all at the same scale. On the following pages the four age classes are presented individually, with scales added.

Figure 55. Continued

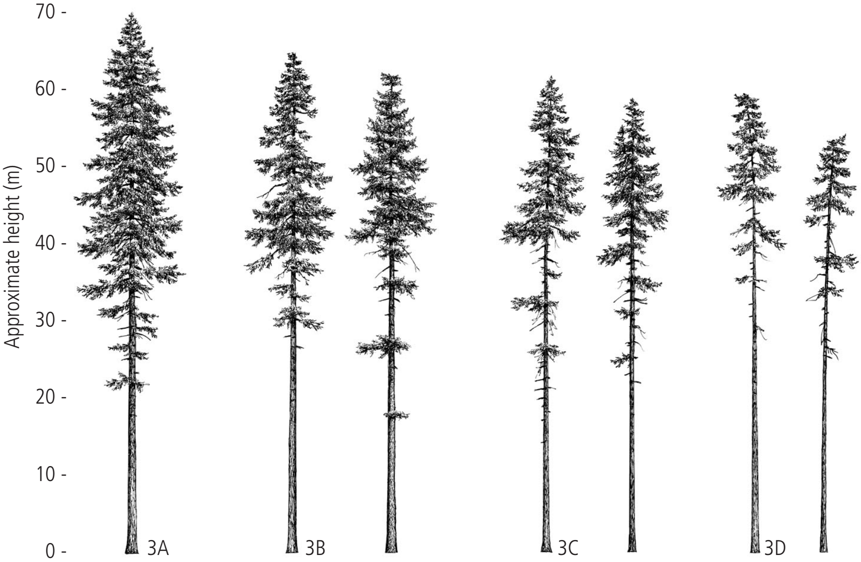
Age class 1 60-100 years



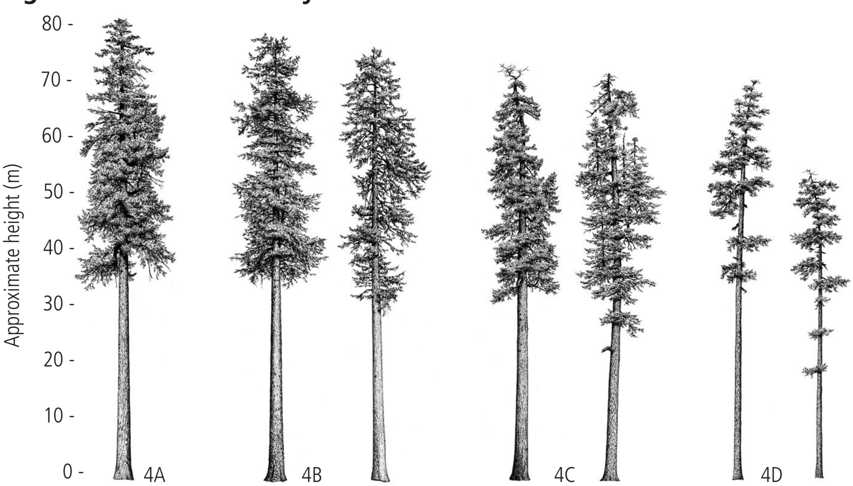
Age class 2 140-180 years



Age class 3 260 - 340 years



Age class 4 400 - 600 years



Douglas fir

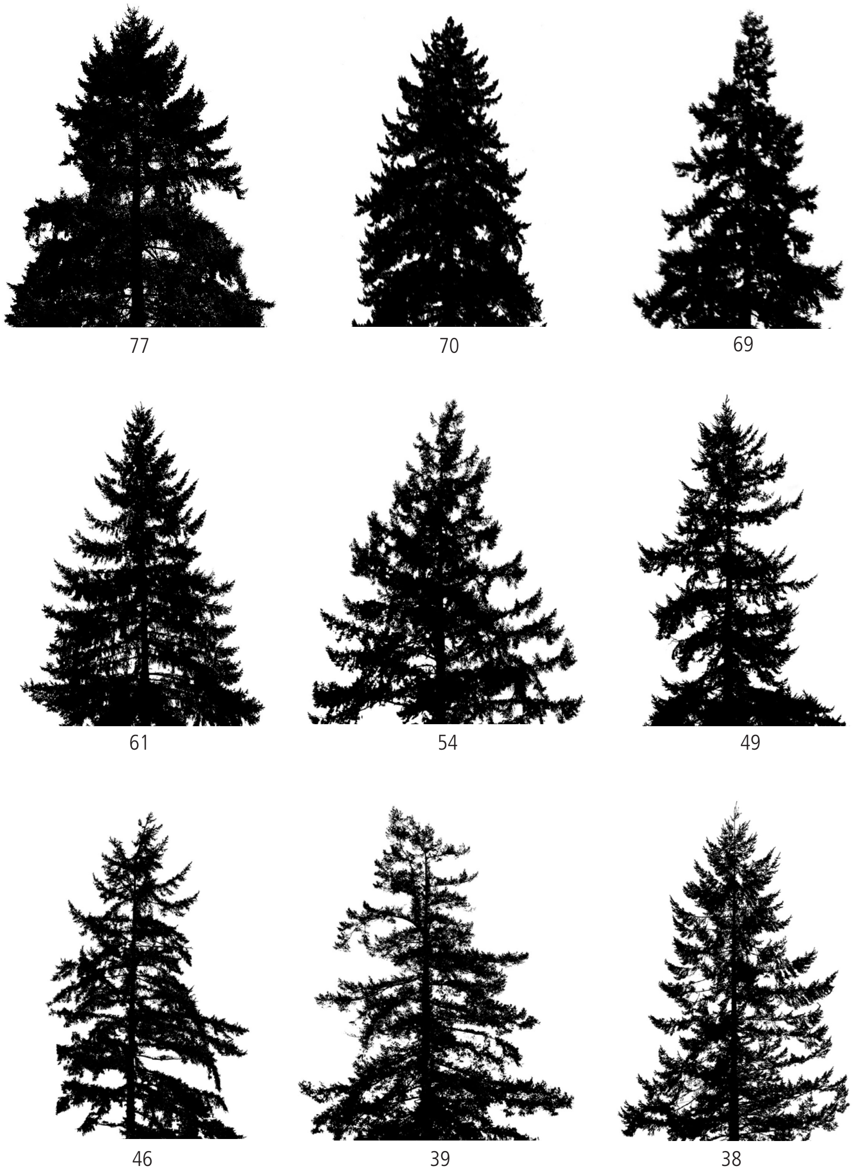
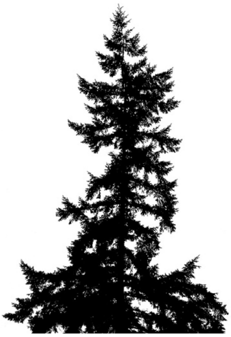


Figure 56. Crown opacity. An indirect measure of tree vigor. Numbers represent the percentage of sky that is blocked by the crown silhouette. Low numbers represent trees in decline that will probably not last long.

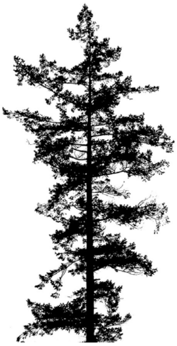
68

66

48



47



30

16

foliage and thus will probably not be able to sustain the amount of respiring tissue of all of their leaves, roots, and cambium.

Leaf mass is difficult to quantify, but it is related to the amount of sapwood area in the trunk, since this is the main transport of water and nutrients up from the soil. The density of the crown is also correlated with the amount of foliage. Crown opacity is a measure of the amount of sky that is blocked by the silhouette of a crown, and is another measure of tree vigor (Figure 56).

Rating system for determining general age of Douglas fir legacy trees

Choose one score from each category and sum scores to determine developmental stage

Bark condition, lower one-third of tree	**Score**
Hard, boney bark with small fissures	0
Hard bark with deep fissures	1
Hard bark with charcoal present	2
Soft, flaky bark with deep fissures	2
Flaky bark with charcoal present	3
Knot indicators, lower one-third of tree	
Branch stubs present	0
Old knot/whorl indicators visible	1
No knot/whorl indicators visible	2
Lower crown indicators	
No epicormic branches	0
Small epicormic branches present	1
Large and/or gnarly epicormic branches present	2

Scoring Key

< 2	Biomass accumulation/stem exclusion (35–80 years)
2–3	Maturation I – Forests originating after Euro-American settlement (70–160 years)
4–5	Maturation II – Forests originating before Euro-American settlement (140–240 years)
> 5	Old-growth (210+ years)

Longevity and death

A Douglas fir tree that has survived the myriad agents of mortality (root disease, stem rot, bark beetles, etc.) to become a canopy tree in an old-growth forest must still contend with the velvet top fungus (*Phaeolus schweinitzii*). This slow-growing fungus is often overlooked by many foresters, because it can often take 250-300 years before it makes its presence known (Figure 57). For stands of this age or older, it is the primary cause of Douglas fir mortality. This fungus causes decay in the upper roots and lower stem of old trees, weakening them. The sapwood of the tree is unaffected; many infected trees appear healthy and vigorous. Structurally, however, they have been compromised and a minor windstorm is often the final blow. Tip-ups with small root plates or snapped boles near the base indicate death caused by velvet top fungus (Figure 58).

Figure 57. Conks of the velvet top fungus. Photo: Jerry Franklin

Figure 58. Death by velvet top fungus. Top: The tip-up of a 361 cm diameter Douglas fir with a very small root wad — a sign of root rot. Lower images are of trees shattering near the base due to heart rot. The lower left is of a 323 cm diameter tree, near Lake Crescent and to the right is a 408 cm diameter tree at Quinault Lake — both on the Olympic Peninsula. Both show the classic ***barber chair*** stump — healthy sapwood splintering around the decayed heartwood.