Pseudotsuga menziesii

Douglas-Fir

Douglas-fir (*Pseudotsuga menziesii*) has the largest north-to-south distribution of any commercial conifer in North America. It is the predominant species west of the Cascades in Washington. Douglas-fir is also found along the east slope of the Cascades, in the northeastern section of the state, and in a small area in the southeastern part of the state (Hermann and Lavender, 1990).

Two taxonomic varieties of Douglas-fir are recognized, the coastal form (*P. menziesii* var. *menziesii*) and the Rocky Mountain form (*P. menziesii* var. *glauca*), and both are found in Washington. The varieties differ in a number of important traits. The coastal variety grows faster and gets considerably larger than the Rocky Mountain variety, which tends to be more shade tolerant and more cold hardy. Coastal Douglas-fir is a seral or early successional species, while Rocky Mountain Douglas-fir can be both a seral and a climax species (Hermann and Lavender, 1990). In Washington, the division between the two varieties is generally thought to occur at the break in the natural distribution of Douglas-fir in the Okanogan Valley (Little 1971). Sorensen (1979) notes that an area of intermediate types exists along the transition zone between the two varieties. In that area, trees that resemble the coastal variety tend to be found on wetter sites, while ones that resemble the Rocky Mountain variety tend to be found on drier sites (Frank Sorensen, personal communication, 1999).

To the west of the Cascades at low elevations, Douglas-fir has three primary associates: Sitka spruce, western hemlock, and western redcedar. Hardwood species are rare throughout this area; conifers outnumber them 1000 to 1 (Kuchler 1946). At higher elevations, Pacific silver fir, Engelmann spruce, and noble fir are found with Douglas-fir. In eastern Washington, where it is drier and cooler, associates include ponderosa pine, lodgepole pine, and western larch.

In Washington, Douglas-fir is found from sea level to about 5000 feet in elevation. Along the coast, temperatures are mild and relatively uniform, both diurnally and annually as well as north to south. The average annual temperatures, both for January minimums and July maximums, are similar between Bellingham and the Columbia River. Temperatures decrease with elevation as one moves up the Olympic Mountains or up the west slope of the Cascades. Minimum temperatures are considerably lower on the east side of the Cascades, particularly in the northeastern section of the state. Temperatures tend to fluctuate more on the east side of the Cascades as well, both on a diurnal and an annual basis. There can be as much as 70 inches of annual precipitation in the coastal lowlands and considerably more in the Olympic Mountains and along the west slope of the Cascades. Annual precipitation decreases greatly east of the Cascades; some parts of the range of Rocky Mountain Douglas-fir receive as little as 20 inches a year. Growing seasons tend to be long near the coast with as many as 200 frost-free days around Grays Harbor and the Puget Sound. The number of frost-free days decreases at higher elevations and on the east side of the Cascades, with some areas in the northeastern section of the state having as few as 50 frost-free days (Franklin and Dyrness, 1973; St. Clair and Vance-Boreland, 1998).

A species that occupies such a large geographic area with contrasting climatic conditions might be expected to possess enormous genetic variation. Researchers working with allozymes have found that Douglas-fir has an enormous amount of genetic diversity, and that more than 95% of it resides within local populations and not among them (Yeh and O'Malley, 1980). This pattern is similar to the outward appearance of Douglas-fir; there are large differences in appearance among trees within a single stand, but the average Douglas-fir from one location looks very similar to the average Douglas-fir from another location. Allozyme studies have also shown there is a sharp difference between the coastal and Rocky Mountain varieties of the species, in fact over 75% of the variation in allozymes among populations is accounted for by differences among the varieties (Li and Adams, 1989). Allozymes also show variation within varieties of Douglas-fir as well. Yeh and O'Malley (1980) found evidence of clinal variation within the coastal variety in British Columbia, and Li and Adams (1989) found evidence of a north to south trend in the Rocky Mountains.

Although molecular evidence proves that genetic variation exists, studies of adaptive traits are needed to develop recommendations for seed zones. In spite of the fact that most of the genetic variation within Douglas-fir is allocated to differences within populations, researchers who study adaptive variation in both the coastal variety (Campbell 1979) and the Rocky Mountain variety (Rehfeldt 1993) consider this species an environmental specialist. This is because there is a much stronger association between variation in adaptive traits and variation in the environmental parameters that control them in Douglas-fir than in most other tree species.

Growth is an important adaptive trait, particularly in a species that will tolerate little or no shade. Numerous researchers have shown that variation in growth is associated with environmental parameters. In their work with coastal Douglas-fir in northwest Oregon, Silen and Mandel (1983) found that the potential for height growth increased with decreased elevation, decreased latitude, or increased longitude. Similarly, in his work with Rocky Mountain Douglas-fir in northern Idaho and northeast Washington, Rehfeldt (1979a) found differences in growth that were associated with elevation, latitude and longitude. Summaries of seed source studies done in Germany (Kleinschmit *et al.*,1985) and France (Breidenstein 1990) indicate that growth can vary from north to south and elevationally along the west slope of the Washington Cascades. A number of authors have generalized their findings by pointing out that the best growth potential tends to be found in families from the best environments (Rehfeldt 1979a and 1983a, and Silen and Mandel, 1983).

The timing of bud burst in the spring and bud set in the fall are important adaptive traits because they determine the length of the growing season and susceptibility to frost damage. Research with the Rocky Mountain (Rehfeldt 1983) and coastal (Campbell and Sorensen, 1973) varieties of Douglas-fir has shown that a delay in bud set of just one week can increase the susceptibility to fall frost injury by 18% and 25%, respectively. The timing of bud burst and bud set has been shown to be related to elevation, latitude, longitude, and distance from the ocean (Campbell 1974, Campbell and Sorensen, 1973, and Rehfeldt 1979a). Laboratory freezing tests have shown that during the fall acclimation process, the coastal variety of Douglas-fir is much less cold hardy than the Rocky Mountain variety (Rehfeldt 1977), that within the coastal variety, trees from the coastal areas are less cold hardy than trees from the west slope of the Cascades (Aitken *et al*., 1996), and that within the Rocky Mountain variety, cold hardiness is related to elevation and geographic location (Rehfeldt 1986c).

The fact that variation in growth and variation in bud phenology are related to many of the same environmental parameters has resulted in some controversy.

Rehfeldt (1979a and 1983a) has repeatedly demonstrated with Rocky Mountain Douglas-fir that increased growth is associated, in general, with increased susceptibility to frost damage. However, Stonecypher *et al.* (1996) failed to find any relationship between growth and either bud phenology or frost damage in coastal Douglas-fir from near Grays Harbor. Work with coastal Douglas-fir in Oregon (Aitken *et al*. 1996) showed a weak relationship between cold hardiness and growth for trees from the west slope of the Cascades and no relationship for trees from near the coast, suggesting that the degree of association between these variables varies across the range of this species.

Researchers seeking to develop seed movement guidelines with nursery studies typically measure dozens of adaptive traits and environmental parameters. To simplify the analysis of these complex data sets they sometimes combine these traits into a few somewhat abstract variables that summarize most of the variation. Recommendations for seed transfer are then made based on differences among native populations in these synthetic variables. Thus, some recommendations may be made without demonstrating that genetic variation in a particular trait is associated with variation in a particular environmental variable (Campbell 1986). These recommendations are sometimes expressed as complex formulas that may include the latitude, longitude, elevation, slope and aspect of both the seed source and the planting site. In some cases, the genetic variation in Douglas-fir is so specialized and so complex that use of these formulas may be more logical than the use of traditional seed zones.

Very little research designed specifically to develop Douglas-fir seed zones for the state of Washington has been completed to date. However, general conclusions can be drawn from the large amount of seed movement research done with this species in other areas. Preliminary results from a large seed movement study that includes many seed sources from Washington generally support these generalizations (personal communication, Brad St. Clair, September 1999). Land managers are encouraged to check periodically for publications that will result from this study.

Past recommendations for geographic limits to seed movement.

For interior southern British Columbia, transfer limits are 2° north, 1° south, 3° west, and 2° east (British Columbia Ministry of Forests, 1995).

For maritime British Columbia, transfer limits are 3° north and 2° south (British Columbia Ministry of Forests, 1995).

For submaritime British Columbia, transfer limits are 2° north and 1° south (British Columbia Ministry of Forests, 1995).

Within the southern half of Washington, seed that has been shown to be widely adapted in field tests can be moved within the Puget Trough and coastal areas (Stonecypher *et al.* 1996).

In northeastern Washington and northern Idaho, seed should not be moved more than 1.6° north or south, or more than 2.7° east or west (Rehfeldt 1979).

The distance seed can be transferred varies in central Idaho, but can be as short as 40 miles under the most limiting conditions (Rehfeldt 1983).

In southwestern Oregon, seed can be moved relatively far north or south. The distance it can be moved east to west varies, but can be as short as 30 miles (Campbell 1986).

At the junction between the coastal and Rocky Mountain varieties in central Oregon, east to west transfers of as little as 17 miles were the equivalent of a 980 foot elevation change (Sorensen 1979).

Past recommendations of elevation limits to seed movement.

For interior British Columbia, transfer limits are 1000 feet up or 650 feet down. (British Columbia Ministry of Forests, 1995).

For maritime and submaritime British Columbia, transfer limits are 1150 feet up or down. (British Columbia Ministry of Forests, 1995).

In the Grays Harbor and Willapa Bay area, seed that has been shown to be widely adapted can be moved up and down within a 2000 foot elevation band (Stonecypher *et al*. 1996).

In northeastern Washington and northern Idaho, seed should not be moved more than 460 feet up or down (Rehfeldt 1979a).

In central Idaho, seed should not be moved more than 330 feet up or down (Rehfeldt 1983a).

In southwestern Oregon, moving seed up or down in elevation is less risky than moving seed from east to west (Campbell 1986).

New recommendations for seed transfer zone boundaries

HOH (Zone 1): Northern boundary is coast from Cape Flattery to Angeles Point; eastern boundary is from Angeles Point south to Elwha, Aurora Peak and Sugarloaf Mountain, and then along 4000 foot contour to Kimta Peak, and on to Quinault Ridge; southern boundary is from Quinault Ridge west along the old 012 seed zone line to Macafee Hill and Point Grenville. West boundary is the Pacific Ocean. Consists of the old seed zone 011, and the western portion of 012.

ELWHA (Zone 2): Northern boundary is from Aurora Peak to Mount Pleasant and along the 4000 foot contour east to Mount Zion; eastern boundary follows 4000 foot contour south to Mount Jupiter and Mount Washington; southern boundary continues along 4000 foot contour westward to Mount Tebo, Colonel Bob, and Quinault Ridge; western boundary continues along 4000 foot contour north toward Kimta Peak, Sugarloaf Mountain, and Aurora Peak. Consists of the eastern portion of old seed zone 012, and portions of 221 and 222.

TWIN HARBORS (Zone 3): Northern boundary is from Point Grenville east along the old 030 seed zone boundary to Macafee Hill, Quinault Ridge, Colonel Bob, and Capitol Peak in the Olympic Mountains; eastern boundary follows the old 030 seed zone from Capitol Peak southeast to South Mountain, south to Elma, Weikswood, southeast along Doty Hills to Doty, Pe Ell, junction of Huckleberry Ridge and Long Ridge, southeast to headwaters of Elochoman River and down Elochoman River to Cathlamet on the Columbia River; southern boundary is Columbia River west to the coast; western boundary is the Pacific Ocean. Consists of old seed zone 030, and the western portion of 041.

ISLANDS (Zone 4): Northern boundary is Washington state line from Point Roberts east to near Sumas; eastern boundary follows the approximate 2000 foot contour from a point on the Canadian border near Sumas south to three

miles east of Granite Falls; southern boundary is from a point three miles east of Granite Falls west to Interstate 5 at the northern side of Tulalip Indian Reservation, south around Whidbey Island to Port Ludlow, Uncas, Mount Zion, Mount Pleasant, Elwha, and Angeles Point; western boundary is the west coast of the western coastal islands. Consists of old seed zone 211, and portions of 201, 202, 212, and 221.

KITSAP (Zone 5): Northern boundary is Mount Zion east to Uncas, Port Ludlow, south end of Whidbey Island, Interstate 5 at northern edge of Tulalip Indian Reservation (the southern edge of the old 202 seed zone) to a point three miles east of Granite Falls; eastern and southern boundaries start at a point three miles east of Granite Falls and follows the approximate 2000 foot contour south along the Cascades through Fall City and Spar Pole Hill to Clay City, then follows the southern border of the old 232 seed zone through Porcupine Ridge, Crawford Mountain and Grand Mound, then along Highway 12 to Oakville and Elma; western boundary starts at Elma and goes north along the western edge of the old 030 seed zone to South Mountain and Capitol Peak in the Olympic Mountains. Consists of old seed zones 231, and 232, the western parts of 411, 412, 421 and 422, the northern one-third of 241, the eastern half of 222, and that portion of 212 south of Whidbey Island.

LOWER COLUMBIA (Zone 6): Northern boundary is from Elma to Oakville, Grand Mound, Crawford Mountain, and Porcupine Ridge; eastern boundary follows 2000 foot contour south from Porcupine Ridge through Windy Knob and Crazy Man Mountain, to Wolf Point, then along the northern edge of the old 042 seed zone through Green Knob, Gumboat Mountain, Stabler, and Big Huckleberry Mountain to Cook on the Columbia River; southern boundary is Columbia River from Cook west to Cathlamet; western boundary is from Cathlamet northward along the Elochoman River, then along the western edge of the old 241 seed zone through Long Ridge, Huckleberry Ridge, Pe Ell, Doty, Doty Hills, Blue Mountain, Weikswood, and Elma. Consists of old seed zone 042, the eastern half of 041, the western half of 430, the southern two-thirds of 241, and the western two-thirds of 242.

SKAGIT (Zone 7): Northern boundary is Canadian border from near Sumas (2000 foot contour) east to Cascade Crest; eastern boundary is Cascade Crest south from Canadian border to half-way between White Mountain and Bench Mark Mountain; southern boundary is from Cascade Crest between White Mountain, and Bench Mark Mountain west along the southern boundary of the old 403 seed zone through Monte Cristo and Vesper Peak to a point 3 miles east of Granite Falls; western boundary is north from a point three miles east of Granite Falls along the approximate 2000 foot contour to a point on the Canadian border near Sumas. Consists of old seed zones 401, 402, 403, and the eastern portions of both 201 and 202.

SNOQUALMIE (Zone 8): Northern boundary is 2000 foot contour three miles east of Granite Falls west along the southern boundary of the old 403 seed zone through Vesper Peak and Monte Cristo to the Cascade Crest between White and Bench Mark Mountain; western boundary is Cascade Crest south to Highway 410; southern boundary is west from Highway 410 at Cascade Crest to Mount Rainier, Mount Wow, to three miles east of Ohop at 2000 foot contour; western boundary follows 2000 foot contour northward through Spar Pole Hill and Fall City to a point three miles east of Granite City. Consists of the eastern portions of old seed zones 411, 412, and 421.

TOUTLE (Zone 9): Northern boundary is from three miles east of Ohop at 2000 foot contour to Mount Wow, Mount Rainier, Highway 410 at Cascade Crest; eastern boundary is Cascade Crest from Highway 410 south to Big Huckleberry

Mountain, southern boundary goes west along the southern edge of the old 440 seed zone through Gumboat Mountain to Wolf Point; western boundary follows approximate 2000 foot contour from Wolf Point north to Crazy Man Mountain, Windy Knob, Porcupine Ridge, to a point three miles east of Ohop. Consists of old seed zones 440, 422 above 2000 feet, and the eastern two-thirds of 430.

CHELAN (Zone 10): Northern boundary is Canadian border from Cascade Crest east to the limit of interrupted Douglas-fir range about nine miles west of Highway 97; eastern boundary starts about nine miles west of Highway 97 at the Canadian border and follows the eastern limit of the Douglas-fir range south to the Columbia River and along the Columbia River to a point east of Wenatchee on the Columbia River; southern boundary starts at a point east of Wenatchee on the Columbia River and follows the southern border of the old 621 seed zone boundary through Sugarloaf Peak and Seven-Fingered Jack to the Cascade Crest; western boundary follows Cascade Crest northward to Canadian border. Consists of old seed zones 600, 621, and western portions of 611 and 613.

YAKIMA (Zone 11): Northern boundary is Fortress Mountain at Cascade Crest, east along the southern border of the old 621 seed zone through Seven-Fingered Jack, Sugarloaf Peak and Burch Mountain to the edge of the species range west of Wenatchee; eastern boundary follows the edge of the species range to near Cowiche Mountain; southern boundary starts at edge of the species range near Cowiche Mountain and goes west along the southern border of the old 641 seed zone through Darland Mountain to Cascade Crest near Tieton Peak; western boundary follows Cascade Crest northward to Fortress Mountain. Consists of old seed zones 622, 631, 641, and western portion of 632.

WHITE SALMON (Zone 12): Northern boundary starts at the Cascade Crest at Tieton Peak and goes east along the southern boundary of the old 641 seed zone through Darland Mountain until it reaches the edge of the species range near Cowiche Mountain; eastern boundary follows the edge of the species range south from Cowiche Mountain to the Columbia River near Burdoin Mountain; southern boundary follows the Columbia River from near Burdoin Mountain west to the Cascade Crest at Cook; western boundary is Cascade Crest north from Cook at the Columbia River to Tieton Peak. Consists of old seed zones 651, 652, and the western portions of 642 and 653.

KETTLE (Zone 13): Northern boundary is Canadian border from the western edge of the interrupted Douglas-fir range east to the Columbia River. Eastern boundary is the Columbia River from the Canadian border south to the southern edge of the Douglas-fir range. Southern and western boundaries are the southern and western limits of the interrupted Douglas-fir range northward to the Canadian border.

PEND OREILLE (Zone 14): Northern boundary is Canadian border from Columbia River east to the Washington state line. Eastern boundary follows the Washington state line from the Canadian border to the southern limit of the interrupted Douglas-fir range south of Spokane. Southern boundary is southern limit of the interrupted Douglas-fir range from Washington state line to the Columbia River. Western boundary is the Columbia River.

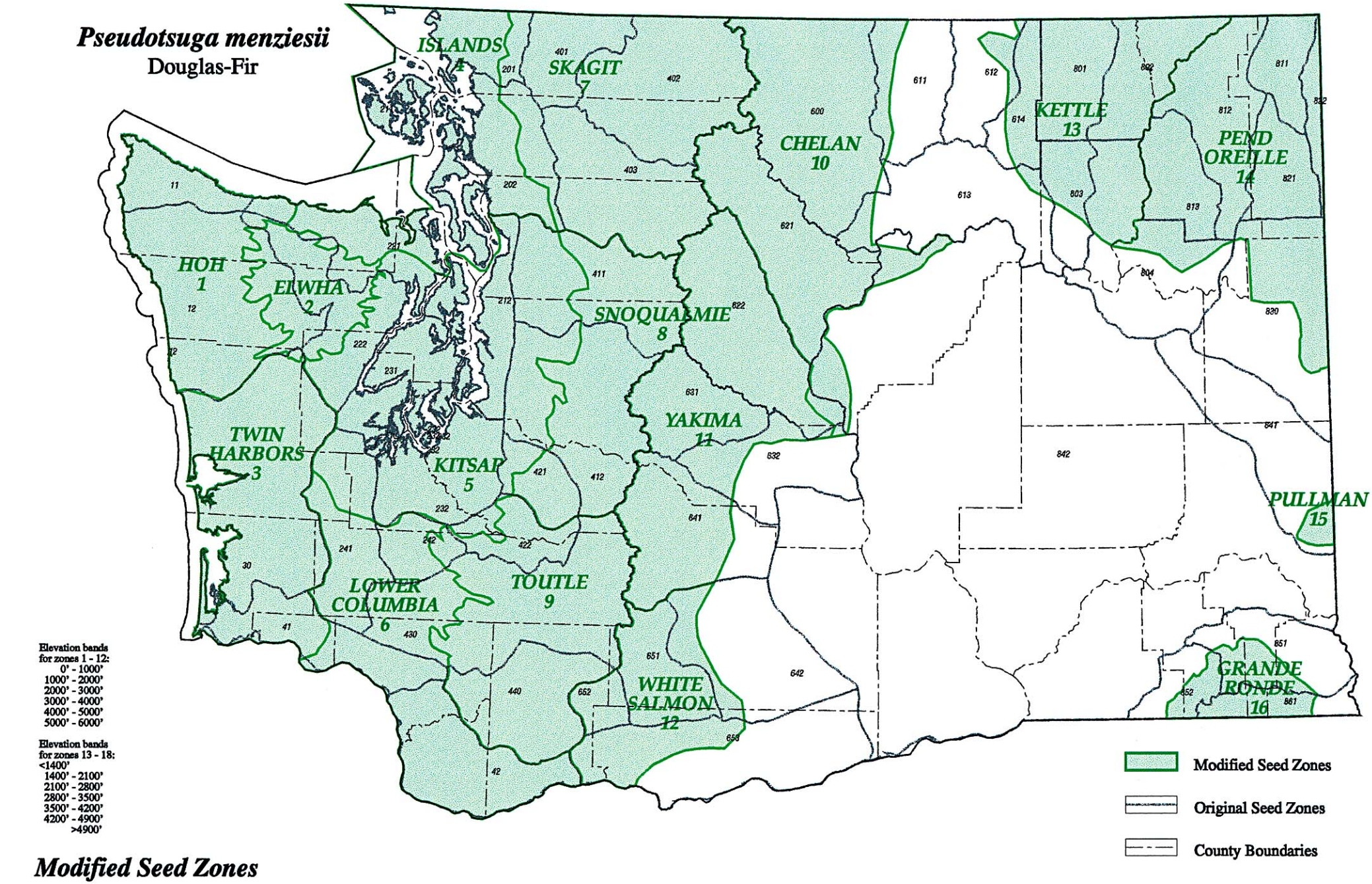
PULLMAN (Zone 15): The isolated population of Douglas-fir occurring near Pullman. If local seed is not available, use seed from nearby parts of Idaho. Consists of the southern tip of old seed zone 841.

GRANDE RONDE (Zone 16): This zone generally conforms to the Umatilla National Forest in Washington. The southern boundary follows the Oregon border from near Route 3 to near Mill Creek. The western, northern, and eastern boundaries follow the species range in the Blue Mountains. Includes the southern portions of 851, western half of 861, and eastern one-quarter of 852 of the old Washington seed zones. If Washington seed is not available, seed from nearby parts of Oregon may be used.

Elevation bands within geographic seed transfer zones

Zones 1-12(Hoh, Twin Harbors, Elwha, Islands, Kitsap, Lower Columbia, Skagit, Snoqualmie, Cowlitz, Chelan, Yakima, White Salmon): Establish 1000-foot elevation bands in these seed movement zones.

Zones 13-18(Kettle, Upper Columbia, Pend Oreille, Spokane, Pullman, Grande Ronde): Lowest elevational band will be areas below 1400 feet, use 700-foot elevational bands above that point.


Pseudotsuga menziesii
Douglas-Fir
ISLANDS
4
SKAGIT
7
CHELAN
10
KETTLE
13
PEND
OREILLE
14
HOH
1
ELWHA
2
SNOQUALMIE
8
TWIN
HARBORS
3
KITSAP
5
YAKIMA
11
PULLMAN
15
LOWER
COLUMBIA
6
TOUTLE
9
WHITE
SALMON
12
GRANDE
RONDE
16
Elevation bands
for zones 1 - 12:
0' - 1000'
1000' - 2000'
2000' - 3000'
3000' - 4000'
4000' - 5000'
5000' - 6000'
Elevation bands
for zones 13 - 18:
<1400'
1400' - 2100'
2100' - 2800'
2800' - 3500'
3500' - 4200'
4200' - 4900'
>4900'
Modified Seed Zones
Original Seed Zones
County Boundaries
Modified Seed Zones