Moritani Preserve Forest Restoration Plan

Prepared For Bainbridge Island Metropolitan Parks and Recreation District
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GENERAL INFORMATION

Site Details

Parcel Number:	272502-4-003-2003
Location:	Section 27, Township 25, Range 2E (SE/4)
Total Acres:	8.58 acres
Lat, Long:	47.62589746, -122.52779230

Overview & History

The Moritani Preserve is an 8.5 acre open-space passive park in downtown Winslow donated to the Bainbridge Island Metropolitan Parks and Recreation District ("BIMPRD") by the Fletcher Bay Foundation in September of 2017. The Preserve was for many years a working strawberry farm and then unoccupied. Due to the many decades of farming on the property all of the forested areas of the property were planted by the Moritani family starting in the 1970s. Prior to transfer to BIMPRD significant tonnage of surplus materials and hazardous structures were removed from the property. The BIMPRD in collaboration with the Bainbridge Island Parks Foundation has created a project known as the Friends of Moritani Preserve. The purpose of this project is to restore the ecological balance of the property by systematically removing invasive plants and replacing them with native vegetation over time. The primary project activities will be the development and implementation of a multi-year management plan for the Preserve under the supervision of the District and fundraising to help finance the costs of the ecological restoration under the supervision of the Foundation.

Purpose

The management of the Moritani Preserve by BIMPRD is currently guided by a management plan (hereinafter, the "Management Plan"), which evaluates and inventories the invasive and other vegetation on the property and provides options to restore the ecological health of the property consistent with its use as a passive park and natural open space. The Management Plan, however, does not evaluate or inventory precisely the forested portions of the Preserve. The Moritani Preserve Forest Restoration Plan created under this initiative (hereinafter, the "Forest Restoration Plan") will complete the evaluation of and inventory the forest areas of the Moritani Preserve. The Forest Restoration Plan will include long-term management recommendations, forestry techniques, and propose restoration options to increase the health and resiliency of the forested areas of the Moritani Preserve. It is envisioned that the Forest Restoration Plan will be incorporated into and become a key component of the existing Management Plan.

Management Objectives

1. To supplement the existing Management Plan of Moritani Preserve as described in Section 2.2 of the Agreement Regarding Donation of Park Property dated 9/13/17.
2. To improve overall forest and ecological health of Moritani Preserve through:
    a. Reducing risks of fire, disease, and mortality in forest

    b. Removing noxious weeds
    c. Restoring biological diversity with appropriate native plants
    d. Provide habitat to support pollinators and wildlife
    e. Establishing an understory and structural diversity in forest
3. To preserve the existing quiet and private feeling of Moritani Preserve by maintaining as much as possible of the existing forest and vegetation on the lines of sight looking into the Preserve from the outside perimeter, and from inside the Preserve looking out to the adjoining properties.
4. To preserve the existing trees relating to the cultural heritage of Moritani Preserve.
5. To consider an adaptive response to the effect of climate change on the forest and ecological health of Moritani Preserve.

SITE CHARACTERISTICS

Soils & Geology

Kapowsin Gravelly Ashy Loam (Andisol)

- The Kapowsin soil series is moderately well drained soil in glacial marine deposits with an influence of volcanic ash in the surface layers. Presence of volcanic ash in soil can help retain nutrients and water for plants, making it a more productive soil.
- This soil has a xeric moisture regime, meaning "dry", where winters are moist and cool and summers are warm and dry. In a xeric moisture regime the soil can remain dry in all parts for 45 or more consecutive days in the 4 months during the summer, and moist in all parts for 45 or more consecutive days in the 4 months during the winter.

NRCS (Natural Resource Conservation Service) classifies this site as Site Index II, which typically means high productivity for plants, likely due to the presence of volcanic ash. However NRCS provides more general classifications and a review of the native plants present on site combined with the presence of glacial till and the likelihood of soil compaction from past land management all indicate a lower site productivity.

Historic Vegetation & Disturbance Patterns

Historic native vegetation of this area of Washington State is forest intermixed with upland and wet prairies. (Source NRCS)

- Douglas-fir, western hemlock, and red alder are the most common tree species with lesser amounts of western red cedar, bigleaf maple, grand fir, and garry oak in open areas.
- Typical forest understory species include huckleberry, salal, blackberry, twinflower, vine maple, Pacific yew, thimbleberry, rhododendron, Oregon-grape, salmonberry, violet, trillium, and swordfern.
- Typical prairie species include blue wildrye, Roemer's fescue, tufted hairgrass, camas, and biscuitroot.

Forests and prairies were managed by natural disturbances such as fire and windthrow. Douglas-fir stands are somewhat fire dependent and major fires occurred every 400-800 years roughly. Smaller more frequent fires happened every 1-20 years that were lower intensity and helped turn over prairies. Windthrow happens at any stage and gaps and edges of forests are most vulnerable. Today, native pathogens such as laminated root rot continue to help create disturbance regimes in forests.

MORITANI FOREST STANDS

Moritani Forest Stands

(See appendix for full size map.)

There are three distinct Douglas Fir plantations (F1-3) that border the site on the south, west and north sides that make up 4.8 acres, not including the ornamental stands in open areas. Approximately 40% of the preserve is still in open areas with stands of mixed ornamental tree species mixed in. At a high level each of the three stands are overstocked, even aged plantations from roughly 1975. However there are distinct differences between the stands that will help inform management decisions. Sample inventories were conducted on 1/60th acre fixed plots in each stand to obtain baseline data.

Stand F1

Total area: 1.8 acres

Oldest of the three stands with age of trees varying from roughly 40-50 years planted between 1970-1980. Aerial photos show that some of these trees were already well established before any of the other plantations were visible on the map. Also this is the most biologically diverse stand with less than 10 Western white pines and Grand firs mixed in. This stand is perhaps the healthiest overall of the three.

Stand is generally even aged and variations in tree sizes are more likely due to suppression than age across the stand, as evidenced from sampling ages within plots. Live tree crown ratios are low here and average around 20%, except on edges of stands where outer trees had live crown ratios closer to 50% due to sunlight and favorable growing conditions. Canopy closure was approximately 90% across the stand. No new seedlings or young trees were visible in the stand. The forest relative density is at 70, indicating it is severely stressed from competition. However, this stand could be further divided into two stands based on stocking and competition signs. Much of the furthest west part of this stand is better spaced compared to the rest of the forest in the Preserve overall, however there is a portion of the stand on the furthest SE corner on the E side of the trail that is extremely overstocked and skews the numbers for this stand to some degree.

Understory in this stand is about 75% bare ground with 15% cover of Sword fern. Annual herbs, noxious weeds (including Herb robert, English ivy, and English holly), and Oregon grape make up the rest of the understory population. Grasses are encroaching along edges from meadow as well.

	Size Class	**Height**	**Live Crown %**	**Age**	**Spacing**
Average	12”	75’	18%	45 years	12’
Range	8-27”	30’-90’	10-40%	40-50 years	6’-20’

Stocking: 300 trees per acre
Relative Density: 70

Target Stocking: 175-200 trees per acre (approximately 15’ average spacing)
Target Relative Density: 45

(This would mean a reduction of approximately 30-40% of the trees to achieve an average spacing of 15’ between trees.)

Tree core samples from different DBH sizes shows the difference between a dominant and suppressed tree of the same age.

Stand F2

Total area: 1.5 acres

This stand is in the poorest condition on the Preserve and a pure Douglas-fir stand. Dense stocking rates mean smaller tree sizes and lower crown ratios. Mortality through self thinning is starting to occur here as well. Spatially the stand shows some signs of plantation rows, but also shows random distribution patterns and a couple of small gaps. Stand is generally even aged and variations in size are due to suppression. Timber in this stand is the least marketable due to size and could mainly only be sold as pulp or a niche market, including poles for example. Canopy closure is around 95%, but crown ratios are smaller and tree crowns in general are slightly thinner and weaker than in either of the other stands. No new seedlings or young trees were visible in the stand. A tree core sample from this stand showed the most suppression in the last 20 years, indicating it was overstock

Most of the understory is bare (90-100%) in highest stocked areas, but shrubs and forbs are present in small patches and along edges. Understory species diversity is higher in this stand than others and includes Sword fern, Oregon grape, Snowberry, Red elderberry, and somewhat surprisingly, Twinberry. This stand also has the highest concentrations of noxious weeds, possibly partly due to proximity to homes and/or due to less restoration work focused in this stand so far.

	Size Class	Height	Live Crown %	Age	Spacing
Average	9”	55’	12%	37 years	8’
Range	5-15”	20’-75’	0-40%	30-45 years	4’-14’

Stocking: 600+ trees per acre

Relative Density: 100+

Target Stocking: 300 trees per acre (approximately 12' average spacing)
Target Relative Density: 45

(This would mean a reduction of approximately 50% of the trees to achieve an average spacing of 12' between trees.)

Stand F3

<u>Total area</u>: 1.5 acres
This stand is the most obvious plantation on the Preserve and is still mostly in easily identified rows. The north and south edges of this stand (south in particular) have higher crown ratios (up to 70%) due to favorable southern exposure, especially on a south facing slope. However the interior of the stand is severely suppressed and has a small number of dead suppressed trees, which is a sign of self thinning. Trees along the north edge are planted particularly close for their growth rate. A large Western white pine has a broken top on the northeast portion of the stand, but will serve as useful habitat, structural, and biological diversity in this otherwise uniform Douglas-firs stand. A large diameter log has also fallen recently and adds structural diversity and habitat for this stand. Canopy closure around 90% throughout the stand. No seedlings or young trees were visible in the stand.

Understory is mostly bare with 10% vegetation cover made up of Sword fern, Oregon grape, and occasional noxious weed Spurge laurel. Disturbed area along trail to north of stand is a potential vector for new weeds coming in especially if the canopy opens.

	Size Class	Height	Live Crown %	Age	Spacing
Average	11"	68'	15%	37 years	8'
Range	7-16"	20'-85'	0-70%	30-45 years	5'-12'

Stocking: 600+ trees per acre
Relative Density: 100+

Target Stocking: 225 trees per acre (approximately 14' average spacing)
Target Relative Density: 45

(This would mean a reduction of approximately 60% of the trees to achieve an average spacing of 14' between trees.)

Meadows & Open Areas

Much of the interior of the site includes a mosaic of meadow and pasture grass areas. Because of the history of farming and homestead on the property, these areas have been heavily influenced by human management and have fewer native species. Meadows and prairies are typically the most vulnerable ecosystems to be impacted, and this site is no exception. Scotch broom and non-native pasture grasses are aggressive in these areas and tend to outcompete native vegetation. However, non-native pasture grasses still provide habitat for pollinators and native wildflowers such as Yarrow and Wild carrot were prolific in certain areas as well.

A small stand of young Douglas-firs is establishing in meadow on the south side of stand F3, which should be hand thinned or completely removed to maintain open space.
Otherwise ornamental trees growing in open areas of the preserve look healthy and vigorous overall, but should continue to be monitored for signs of concern including sudden needle or leaf loss, wounds on trunks, large patches of discoloration, sudden mortality, or other sudden changes.

MANAGEMENT RECOMMENDATIONS

Forest objectives:

1. **Improve overall ecological health**
2. **Protect privacy and quiet feeling by protecting lines of sight into park**
3. **Adaptive response to climate change for ecological health**

Restoration Thinning

Relative Density: "Indicates how fully the trees occupy a site. Relative stand density is a measure of the number and average size of trees growing in a stand compared to the maximum possible number of trees of the same average size that the site could support (a biological limitation). It tells us how crowded the trees are and measures the intensity of competition. RD is expressed on a scale of 0–100 percent, where 0 is an unoccupied site and 100 represents the potential maximum density for that species." - *Source: OSU Extension, Competition and Density in Woodland Stands*

Relative densities of the forest stands in the Preserve are high - ranked at 70-100% stocked. These levels are technically beyond the point of thinning, however the stands are already beginning to self thin due to poor conditions and will continue to survive in a weakened state if left alone. In this case, relative density should be used as a tool and indicator, not an absolute. These conditions are normal for plantations of young forests that were never thinned, the management decisions now depend on the long term goals for the forest.

Recommended Treatment:
Traditional thinning is done in one harvest across the stand and is not recommended here as it will leave these forests, which are already vulnerable from competition, at high risk. Thinning the forest stands when the competition is so high is higher risk due to thinning shock and the vulnerability of remaining trees. When trees in the stand are already in such a weakened state with tall, thin trunks that may not be structurally able to handle winds or recover crown coverage.

Instead, a staged thinning program is recommended as part of an adaptive management strategy. Initially only a small percentage of each stand would be thinned to create a gap and lower the density of a surrounding area (less than ⅓ acre) be impacted initially to assess the response and effectiveness of the method. A weak part of each stand should be selected for the initial thinning to create a small gap or thinned area to allow for understory regeneration.

Although the relative densities stocking rates recommend high reductions (30-60% depending on stand) to achieve healthy stocking rates, this should be a long term goal rather than short term.

Harvest Methods:
Thinning by hand is recommended for these stands. Trees are growing too densely for machinery and machinery will be more disruptive to the quiet nature of the park. Hand thinning is also important trees will be difficult to fell and will get caught in the canopy most likely and may need to be pulled down with ropes.

Some slash should be left on the ground for structural down woody debris, which breaks down more slowly and provides habitat for insects and small wildlife. Chipping some of the wood may also be an option, but is generally more expensive.

Cost and Wood Value:
Harvests this small are more difficult to market, which makes them more costly. However, the small size of harvests and low frequency also makes it more flexible of an opportunity for the right logger. Seeking qualified professionals who are willing to volunteer their time occasionally will be beneficial and likely more feasible given the small size of the projects.

Local opportunities for selling logs should be investigated. Local milling or niche products, such as woodworking, poles, high school wood shops, or other specialty wood products may be local opportunities to ensure that trees have continuing value.

Permitting:
Harvest permits will need to be obtained at both the local and state level. The state level will include a complete an environmental assessment on the harvest area. A certified forester can prepare these permits and help hire loggers or other contractors if staff and board desire outside assistance. Both offices have free assistance and can be contacted through the information below:

- Bainbridge Island Government
  Tree Removal Permits
  pcd@bainbridgewa.gov
  (206) 780-3750

- Washington Dept of Natural Resources, South Puget Sound
  Forest Practices Application (FPA) - Single fee of $100, lasts for 3 years
  southpuget.forestpractices@dnr.wa.gov
  (360) 825-1631

Ecological Restoration

Ecological restoration principles and climate change adaptation principles are well in line. Predictions on how climate change will continue to impact forests in the Pacific Northwest are not guarantees, however it is in the best interest of land managers to help prepare lands for more extreme weather conditions (more wet, more drought), more potential infestations from pests, and temperature fluctuations. The best way to mitigate these risks is to restore overall ecological diversity and health of forest stands to improve resiliency.

Restoration of the forest stands is a long term goal and will not happen with one application. An ecological restoration long-term strategy is laid out here to help achieve the goals outlined that happen concurrently with thinning. The overall aims for restoring forests under these considerations are outlined below.

Three Layers (Structural Diversity):

The long term goal of these forests is to have a minimum of three distinct layers: canopy, mid canopy, and seedling/shrub layer in the understory. The canopy trees should have at least two age classes and there should be a mix of understory shrubs and groundcover. Currently there is generally one layer in each of the stands consisting of dominant, codominant, and suppressed trees. These forests are generally even-aged as a result of a plantation.

Having a mix of ages of trees and shrubs helps create visual barriers and helps ensure that the life cycle of the forest will continue over time as the next layer of trees will grow to replace the previous layer.

Dead wood is also key to structural diversity. Standing dead trees (snags) for woodpecker habitat and downed logs for water retention, insect habitat, and nurse logs.

Forest stands should also preserve some level of spacing over time. Monitoring should continue to evaluate when tree crowns begin to touch and/or when spacing becomes too dense and starts to compromise tree health. Relative density can be used as a tool indefinitely to help determine when further thinning is needed.

Biological Diversity and Plant Selection:

Currently each of the stands are either pure or mostly pure Douglas-fir stands. Introducing site appropriate native species will be key to restoration of the forests ecological functions. Naturally occurring plant diversity already existing on site combined with soil data and historic vegetation patterns indicates a fairly productive soil with moderate nitrogen levels.

This is somewhat contradictory to reported accounts from Moritani family and evidence on site that shows some restrictive properties for plants, but this is likely due to soil compaction over time from farming activities and overstocked plantations.

Native plants with local genetics should be prioritized whenever possible. Salvaging local plants from site that have planned development is one easy and affordable way to preserve local genetics. When purchasing from Conservation District or other native plant sources information should be requested on where the plants originate from. Often the genetics are from Eastern Washington or Skagit Valley and are not as appropriate for local site conditions. Treating plants with mycorrhizae inoculation when planting will also aid restoration efforts.

A list of recommended plant species specifically for Moritani Preserve can be found in the appendix. Highlighted species are perhaps best on the list for this location. In addition, a list of native plants at a site called Dolphin Place on Bainbridge Island, compiled by the Washington Native Plant Society, has also been attached as an additional plant list reference for further reading.

Resources:

- WSU Extension Grow Your Own Native Landscape
  Excellent guide to use for restoration purposes. Can be found online or for purchase.

- Sound Native Plants
  Local nursery with extensive online tools for finding the right plants for restoration as well as planting densities, mixes, and guides to maintaining plantings. This is the best source for understory restoration information.

- Native Plant Salvage
  Olympia based organization focused on salvaging native plants from construction sites.

- Kitsap County Conservation District Native Plant Sale
  Affordable bareroot plant sale that takes place annually in January/February

Maintaining Privacy:
Maintaining privacy and restoration is a bit of a juggling act. Thinning to reduce crowding can open up gaps temporarily, but prioritizing reestablishment of shrubs and small trees along borders will be the best route to maintaining privacy.

- Nootka rose and other fast establishing shrubs should be planted along edges to maintain privacy and prevent invasion from non-native plants from neighboring properties. See plant list for recommended species.
- Small, shade tolerant trees such as Beaked hazelnut, Western yew, Vine maple, and even Oceanspray because it grows so tall, will be ideal additions to help fill in mid- level sight gaps.

Monitoring and Adapting:
Annual monitoring for a number of characteristics will be the greatest guide in determining how long term management proceeds and will be a useful resource locally for other restoration projects. Adaptive management simply means to have a general strategy of restoration, but adapt plans as the environment changes. Climate change will bring new circumstances that may be difficult to prepare for, but monitoring and adapting management strategies will provide the greatest chances of long term restoration success.

Monitoring Strategy

- Choose two plots in each stand to establish as permanent monitoring plots. Place markers on ground or tree to identify plot in later years.
- In each stand, one plot will be a control (left untouched) plot, and one will be a treatment (thinning, replanting, etc) to monitor the response and effectiveness of treatments over time.
- Custom data sheet has been provided for citizens to conduct annual monitoring. Monitoring should be done at generally the same time each year and is best during the summer or when leaves are out to measure ground cover accurately. Photo points should be taken each year as well from the same angle.

MANAGEMENT TIMELINE

Phase 1: 2020-2025

- Continue removal of noxious weeds from stands
- Select 1-2 pilot areas per stand, each a ⅓ acre or less, to conduct thinning harvest
    - Harvest target to reduce the number of trees by 30% and/or create small gap for replanting new trees
    - Review site selection with forester to identify ideal areas and write prescription
    - Acquire permits from both Bainbridge Island and DNR
    - Select appropriate logger/contractor
    - Identify market for wood
    - Begin to replant in opened areas with mix of light appropriate species from list in spring or fall, whichever is closest season following harvest
- Begin to plant shade tolerant shrub and tree species in areas where no thinning will occur initially and to help establish privacy along borders
- Annually monitor stands and take data including photo point (see monitoring sheet in appendix) to inform future management decisions

Phase 2: 2025-2030

- Evaluate success of initial pilot harvest areas for survival of neighboring trees and restored vegetation
- If thinning areas are succeeding then select next target area for harvest, again ⅓ acre approximately but may go up to ½ acre if no issues have arisen from pilot harvests. Target is to reduce trees per acre by 30% and aim for spacing outlined in forest descriptions.
    - If problems persist from original pilot harvests, plan remediation and continue restoration efforts. Consult with forester if causes are unknown.
- Continue to replant in fall and spring with native plants in bare areas. Use mixes of plants that have proven to be successful.
- Continue monitoring forest health for any issues arise. Start to identify what has been working and what hasn't.

Phase 3: Ongoing

- Monitor forest stands and open areas annually for changes and continue collecting photo points.
- Continue to evaluate the success of thinnings and restoration and adapt as necessary.
- Continue to monitor for forest health issues as well as spacing and determine continuing harvests through health concerns, Relative Density calculations, and intuition using adaptive management strategies.
- Once ideal spacing and structural diversity are established thinnings are less necessary, but until then thinnings will likely need to occur every 20-40 years to mimic natural disturbance patterns.

Appendix

Forest Stand Map
Soils Map
Annual Monitoring Sheet Template
Moritani Preserve Recommended Native Plant List
Washington Native Plant Society Native Plant List: Dolphin Place
Oregon State University Thinning/Competition Guide

Moritani Preserve Forest Stand Map

MAP LEGEND

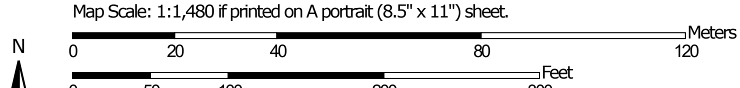
Property Boundary

Stand Boundary

Trails

Soil Map—Kitsap County Area, Washington
(Moritani Preserve Soils Map)

Map Scale: 1:1,480 if printed on A portrait (8.5" x 11") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Kitsap County Area, Washington
Survey Area Data: Version 15, Sep 16, 2019

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 9, 2018—May 23, 2019

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
22	Kapowsin gravelly ashy loam, 0 to 6 percent slopes	4.9	53.1%
23	Kapowsin gravelly ashy loam, 6 to 15 percent slopes	4.3	46.9%
Totals for Area of Interest		**9.2**	**100.0%**

Moritani Annual Monitoring Sheet

Plot ID: ____________________ *(indicate stand and plot number)*
Observers: ____________________
Date: ____________________

Plot Size: 1/10th acre (37.2’ radius) Photo Point Taken? Yes No

Equipment		***Optional***
Data sheet	Compass	*Clinometer*
Clip board	DBH tape	*Increment borer*
Pen/pencil	50' Measuring tape	*Laser rangefinder*

Instructions: Start from established plot center. Start by facing N from plot center and pull measuring tape out 37.2’ from plot center. Measure each tree within the 37.2’ radius, moving around plot center to measure all trees within the full plot circle. Collecting height is optional, but useful if clinometer is available.* Once completed, start back from plot center and measure shrubs and groundcover percentages across plot. May help to divide plot into quadrants (between N/S/E/W) to measure. Complete plot with canopy closure and additional observations.

Vegetation

TREES

Species	DBH (in)	Height* (ft)	Crown Ratio (%)	Alive? (Y/N)	Notes

SHRUBS & GROUNDCOVER

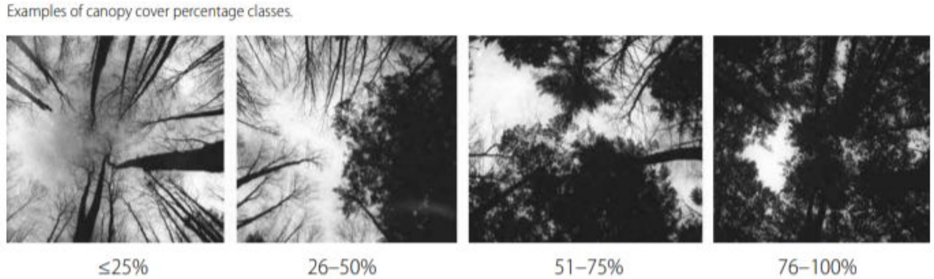
% Bare ground: ________

Species	% Cover	Nox Weed? (Y/N)	Notes

Canopy Closure

Estimate across plot: ________________%

Examples of canopy cover percentage classes.



Additional Observations

Noxious weeds, down woody debris, wildlife, overall impressions, etc. Anything noteworthy about plot here.

Moritani Preserve Forest Restoration Plant List

Plant Name/Type	Sun/Shade	Moisture	Success Rate	Spreading Rate	Notes
Trees					
Douglas-fir *(Pseudotsuga menziesii)*	full sun/part shade	moist/dry	high	moderate	
Grand fir *(Abies grandis)*	full sun/part shade	moist/dry	high	moderate	
Western white pine *(Pinus monticola)*	full sun/part shade	moist/dry	medium	moderate	Do not plant next to Ribes spp (Currants) to avoid Blister rust
Western redcedar *(Thuja plicata)*	part shade/deep shade	wet/moist	medium	moderate	
Western yew *(Taxus brevifolia)*	part/full shade	moist/dry	medium	moderate	
Garry oak *(Quercus garryana)*	full sun/part shade	moist/dry	medium	slow	Typical of well-drained, rocky prairie soil in Puget Trough and flood plains
Scouler willow *(Salix scouleriana)*	full sun/part shade	moist/dry	high	rapid	Only native Willow that is drought tolerant
Shore pine *(Pinus contorta)*	full sun/part shade	wet/dry	high	rapid	Tolerant of wide variety of site conditions
Small Trees/Shrubs					
Vine maple *(Acer circinatum)*	part/full shade	moist/dry	high	moderate	
Beaked hazelnut *(Corylus cornuta)*	full sun/shade	moist/dry	high	moderate	Prefers well drained sites
Pacific dogwood (Cornus nuttallii)	part/full shade	moist	medium	moderate	
Red elderberry *(Sambucus racemosa)*	full sun/shade	moist/dry	medium	rapid	
Serviceberry *(Amelanchier alnifolia)*	full sun/shade	moist/dry	medium	moderate	
Osoberry *(Oemleria cerasiformis)*	part/full shade	moist/dry	high	moderate	
Mock orange *(Philadelphus lewisii)*	full sun/part shade	moist/dry	medium	rapid	
Nootka rose *(Rosa nutkana)*	full sun/part shade	wet/moist	high	rapid	Forms thickets, great for privacy along edges
Red-flowering currant *(Ribes sanguineum)*	full sun/part shade	dry	medium	moderate	
Pacific rhododendron *(Rhododendron macrophy*	part/full shade	moist/dry	low/med	slow	
Oceanspray *(Holodiscus discolor)*	full sun/shade	moist/dry	high	rapid	
Twinberry *(Lonicera involucrata)*	full sun/part shade	moist	high	rapid	
Snowberry (*Symphoricarpos albus)*	full sun/shade	moist/dry	high	rapid	
Cascara (*Frangula purshiana)*	full sun/shade	wet/dry	high	rapid	
Tall Oregon grape *(Mahonia aquifolium)*	full sun/part shade	moist/dry	high	moderate	
Low Oregon grape *(Mahonia nervosa)*	shade	moist/dry	medium	slow	
Salal *(Gaultheria shallon)*	partial/deep shade	moist/dry	medium	slow	Higher success rate if growing in shade
Evergreen huckleberry *(Vaccinium ovatum)*	part/full shade	moist/dry	medium	slow	
Groundcovers					
False lily-of-the-valley (Maianthemum dilatatum)	part/full shade	moist/dry	high	rapid	Great common ground cover in Kitsap/East Olympic
Twinflower (Linnaea borealis)	part/full shade	moist	low/med	moderate	
Bunchberry (Cornus unalaschkensis)	part/full shade	moist	moderate	slow	
Goat's beard (Aruncus dioicus)	part/full shade	moist	high	rapid	
Wild-ginger (Asarum caudatum)	part/full shade	moist	medium	slow	
Vanilla leaf (Achlys triphylla)	part/full shade	moist	high	moderate	Great common ground cover in Kitsap/East Olympic
Deer fern (Blechnum spicant)	shade	wet/moist	high	moderate	
Kinnickinnick (Arctostaphylos uva-ursi)	full sun/part shade	moist/dry	medium	slow	
Fringecup (Tellima grandiflora)	part/full shade	moist	high	moderate	These three species often found together in local forests, great planting mix and ground cover
Piggyback plant *(Tolmiea menziesii)*	part/full shade	moist/wet	high	rapid	
Foamflower (Tiarella trifoliata)	part/full shade	moist	high	moderate	
Strawberry (Fragaria vesca or chiloensis)	full sun/part shade	moist	high	rapid	
Sword fern (Polystichum munitum)	part/full shade	moist/dry	high	moderate	

Resources

Sound Native Plants	Restoration focused, local genetics from Puget Sound on all plants, plenty of resources/guidance on planting
WSU Grow Your Own Native Garden	Very useful guide to salvaging, growing, and planting native species in Western Washington
Washington Native Plant Society	Useful guide filled with local plant lists to get ideas for mixes/planting
Kitsap Conservation District Plant Sale	Low cost way to buy large quantities of bare root plants, not as local as Sound Native Plants, but more affordable

Vascular Plant List:

Dolphin Place

Kitsap County, Washington

Kitsap County, WA. List covers plants found in Dolphin Place, property of Al Philips, on Bainbridge Island. List by Al Philips, 2003.

103 species (102 native, 1 introduced)

Coordinates: 47.671695°, -122.559345°

Key to symbols:

* = Introduced species.

+ = Species is represented by two or more subspecies or varieties in Washington; the species in this list has not been identified to subspecies or variety.

! = Species is not known to occur near this location based on specimen records in the PNW Herbaria database, and may be misidentified.

Numeric superscripts after a scientific name indicates the name was more broadly circumscribed in the past, and has since been split into two or more accepted taxa in Washington. The possible accepted taxa names for Washington are provided after the species list, keyed by superscript.

Accepted names and family classifications are obtained from the Washington Flora Checklist and the Revised Flora of the Pacific Northwest, managed by the University of Washington Herbarium at the Burke Museum. Relevant synonyms are indicated in parentheses.

An online version of this plant list with more information and additional formatting options is available on the WNPS web site: http://www.wnps.org/plant-lists/list?Dolphin_Place

FERNS AND LYCOPHYTES:

Accepted Name (Synonym)	Common Name	Family
Adiantum aleuticum var. aleuticum (Adiantum pedatum)	Maidenhair fern	Pteridaceae
Athyrium filix-femina ssp. cyclosorum	Lady fern	Athyriaceae
Dryopteris carthusiana	Wood-fern	Dryopteridaceae
Dryopteris expansa (Dryopteris austriaca)	Spreading wood-fern	Dryopteridaceae
Equisetum arvense	Common horsetail	Equisetaceae
Equisetum hyemale ssp. affine	Scouring rush	Equisetaceae
Parathelypteris nevadensis ! (Thelypteris nevadensis)	Sierra wood-fern	Thelypteridaceae
Polypodium glycyrrhiza	Licorice fern	Polypodiaceae
Polypodium scouleri	Leathery polypody	Polypodiaceae
Polystichum andersonii !	Anderson's sword-fern	Dryopteridaceae
Polystichum munitum [1]	Sword fern	Dryopteridaceae
Struthiopteris spicant (Blechnum spicant)	Deer fern	Blechnaceae
Woodwardia fimbriata	Chain fern	Blechnaceae

GYMNOSPERMS:

Accepted Name (Synonym)	Common Name	Family
Abies grandis	Grand fir	Pinaceae
Juniperus communis +	Mountain juniper	Cupressaceae

Accepted Name (Synonym)	Common Name	Family
Picea sitchensis	Sitka spruce	Pinaceae
Pinus contorta +	Lodgepole pine	Pinaceae
Pinus monticola	Western white pine	Pinaceae
Pseudotsuga menziesii +	Douglas fir	Pinaceae
Taxus brevifolia	Western yew	Taxaceae
Thuja plicata	Western red cedar	Cupressaceae

DICOTS:

Accepted Name (Synonym)	Common Name	Family
Acer circinatum	Vine maple	Sapindaceae
Acer glabrum var. douglasii	Douglas maple	Sapindaceae
Acer macrophyllum	Big-leaf maple	Sapindaceae
Achlys triphylla [2]	Vanilla leaf	Berberidaceae
Alnus rubra	Red alder	Betulaceae
Arbutus menziesii	Pacific madrone	Ericaceae
Arctostaphylos uva-ursi	Bearberry	Ericaceae
Asarum caudatum	Wild ginger	Aristolochiaceae
Berberis aquifolium !	Tall Oregongrape	Berberidaceae
Berberis nervosa	Cascade Oregongrape	Berberidaceae
Betula papyrifera [3]	Paper birch	Betulaceae
Cardamine oligosperma [4]	Little Western bittercress	Brassicaceae
Chamaenerion angustifolium (Epilobium angustifolium)	Fireweed	Onagraceae
Circaea alpina +	Enchanter's nightshade	Onagraceae
Claytonia perfoliata [5]	Miner's lettuce	Montiaceae
Claytonia sibirica (Montia sibirica)	Candyflower	Montiaceae
Cornus canadensis [6]	Bunchberry	Cornaceae
Cornus nuttallii	Pacific dogwood	Cornaceae
Cornus stolonifera [7]	Red-osier dogwood	Cornaceae
Corylus cornuta +	Hazelnut	Betulaceae
Crataegus douglasii [8]	Black hawthorn	Rosaceae
Dicentra formosa ssp. formosa	Bleeding heart	Papaveraceae
Fragaria chiloensis ssp. pacifica	Coastal strawberry	Rosaceae
Fragaria vesca +	Wild strawberry	Rosaceae
Frangula purshiana (Rhamnus purshiana)	Cascara	Rhamnaceae
Fraxinus latifolia	Oregon ash	Oleaceae
Gaultheria shallon	Salal	Ericaceae
Geum macrophyllum	Large-leaved avens	Rosaceae
Heuchera sp.	Alumroot	Saxifragaceae
Holodiscus discolor var. discolor	Ocean spray	Rosaceae
Linnaea borealis ssp. longiflora	Twinflower	Linnaeaceae
Lonicera ciliosa	Orange honeysuckle	Caprifoliaceae
Lonicera hispidula	California honeysuckle	Caprifoliaceae
Lonicera involucrata var. involucrata	Black twinberry	Caprifoliaceae
Lysimachia latifolia (Trientalis latifolia)	Broadleaved starflower	Primulaceae
Malus pumila * (Pyrus malus)	Apple	Rosaceae
Oemleria cerasiformis	Indian plum	Rosaceae
Oplopanax horridus (Oplopanax horridum)	Devil's club	Araliaceae
Oxalis suksdorfii !	Western yellow oxalis	Oxalidaceae
Philadelphus lewisii	Mock-orange	Hydrangeaceae

Accepted Name (Synonym)	Common Name	Family
Physocarpus capitatus	Pacific ninebark	Rosaceae
Populus tremuloides	Quaking aspen	Salicaceae
Populus trichocarpa	Black cottonwood	Salicaceae
Prunus emarginata	Bitter cherry	Rosaceae
Prunus virginiana	Chokecherry	Rosaceae
Quercus garryana var. garryana	Oregon white oak	Fagaceae
Rhododendron groenlandicum (Ledum groenlandicum)	Labrador tea	Ericaceae
Rhododendron macrophyllum	Western rhododendron	Ericaceae
Ribes sanguineum var. sanguineum	Red-flowered currant	Grossulariaceae
Rosa nutkana +	Nootka rose	Rosaceae
Rosa pisocarpa var. pisocarpa	Clustered wild rose	Rosaceae
Rubus nutkanus (Rubus parviflorus)	Thimbleberry	Rosaceae
Rubus spectabilis	Salmonberry	Rosaceae
Rubus ursinus (Rubus ursinus var. macropetalus)	Wild blackberry	Rosaceae
Salix lasiandra +	Pacific willow	Salicaceae
Salix scouleriana	Scouler willow	Salicaceae
Salix sitchensis var. sitchensis	Sitka willow	Salicaceae
Sambucus cerulea	Blue elderberry	Adoxaceae
Sambucus racemosa +	Red elderberry	Adoxaceae
Spiraea douglasii +	Hardhack	Rosaceae
Symphoricarpos albus +	Common snowberry	Caprifoliaceae
Synthyris reniformis !	Snow-queen	Plantaginaceae
Tellima grandiflora	Fringecup	Saxifragaceae
Tiarella trifoliata +	Foamflower	Saxifragaceae
Tolmiea menziesii	Youth-on-age	Saxifragaceae
Vaccinium ovatum	Evergreen huckleberry	Ericaceae
Vaccinium parvifolium	Red huckleberry	Ericaceae
Veronica americana	American brooklime	Plantaginaceae
Vicia sp.	Vetch	Fabaceae
Viola adunca	Early blue violet	Violaceae
Viola sempervirens	Evergreen violet	Violaceae

MONOCOTS:

Accepted Name (Synonym)	Common Name	Family
Calypso bulbosa +	Fairy slipper	Orchidaceae
Camassia quamash +	Common camas	Asparagaceae
Carex sp.	Sedge	Cyperaceae
Juncus ensifolius [9]	Daggerleaf rush	Juncaceae
Lysichiton americanus (Lysichitum americanum)	Skunk cabbage	Araceae
Maianthemum dilatatum	False lily-of-the-valley	Asparagaceae
Maianthemum racemosum ssp. amplexicaule (Smilacina racemosa)	False Solomon's seal	Asparagaceae
Scirpus microcarpus	Small-flowered bulrush	Cyperaceae
Streptopus amplexifolius	Clasping-leaved twisted-stalk	Liliaceae
Trillium ovatum var. ovatum	White trillium	Melanthiaceae
Typha latifolia	Common cattail	Typhaceae

Key to potential accepted names for ambiguous species:

The following underlined names were more broadly circumscribed in the past, and have since been split into two or more accepted taxa in Washington. For each, the possible accepted names in Washington are provided; one or more of these may occur at this site.

1 Polystichum munitum: Polystichum imbricans, Polystichum munitum
2 Achlys triphylla: Achlys californica, Achlys triphylla
3 Betula papyrifera: Betula papyrifera, Betula utahensis
4 Cardamine oligosperma: Cardamine oligosperma, Cardamine umbellata
5 Claytonia perfoliata: Claytonia parviflora, Claytonia perfoliata, Claytonia rubra
6 Cornus canadensis: Cornus canadensis, Cornus unalaschkensis
7 Cornus stolonifera: Cornus occidentalis, Cornus stolonifera
8 Crataegus douglasii: Crataegus chrysocarpa, Crataegus douglasii
9 Juncus ensifolius: Juncus ensifolius, Juncus saximontanus

OREGON STATE UNIVERSITY EXTENSION SERVICE

Competition and Density in Woodland Stands

Photo: Lynn Ketchum, © Oregon State University

OSU Extension Forestry and Natural Resources faculty member Valerie Grant measures a tree's diameter. Forest landowners can learn to manage stands to meet their objectives by looking closely at average stand diameter, trees per acre, and stand density tables.

Brad Withrow-Robinson and Doug Maguire

The number of trees growing in a forest at any point in time shapes the look and character of a woodland and determines the benefits woodland owners may reap from it. A thorough look at competition and stand density can help landowners get the most out of their woods.

Family forest landowners have many aims and expectations for their property. The objectives of small woodland owners are generally quite different from those of their neighbors who manage industry or government land.

Many people want an attractive, peaceful place to live or play in privacy, as well as a place that is diverse and welcoming to wildlife and human visitors. They view it as a personal and economic investment, and a legacy that they hope to leave for heirs. Although timber production is not a primary motivation for most family landowners, it is important for some, and periodic income from property is often seen as a way to help pay the bills or make desired improvements.

The main strategy for meeting many family landowners' objectives is to grow older forests. Both stand age and disturbances, such as thinning to reduce density and competition, can enhance development of many desired stand characteristics.

Brad Withrow-Robinson, Forestry & Natural Resources Extension; and Doug Maguire, Giustina professor of forest management and director, Center for Intensive Planted-forest Silviculture, Oregon State University

Oregon State University

EM 9206
June 2018

Defining some terms

- **Competition** occurs among trees because the amount of resources needed to support plant growth (light, moisture, or nutrients) is limited. Each tree needs more of those resources as it grows larger. This increasing demand means that as the trees grow, resources will eventually run short. Competition increases among trees as they struggle to get what they need from the site.
- **Stand density** is a measure of the number of trees and how fully the trees occupy a site. We can think about density in either absolute or relative terms.
- **Absolute stand density** is the number of trees per unit area (typically the number of trees per acre, or TPA).
- **Relative stand density** (RD) indicates how fully the trees occupy a site. Relative stand density is a measure of the number and average size of trees growing in a stand compared to the maximum possible number of trees of the same average size that the site could support (a biological limitation). It tells us how crowded the trees are and measures the intensity of competition. RD is expressed on a scale of 0–100 percent, where 0 is an unoccupied site and 100 represents the potential maximum density for that species. Maximum density levels vary dramatically between species, but only slightly by location and site for a given species.

Both absolute and relative stand density can change dramatically over time. Absolute density changes when the number of trees changes, for example, as new trees seed in or as established trees die. Relative density increases or decreases along with corresponding changes in absolute density, and also when a fixed number of live trees grow bigger.

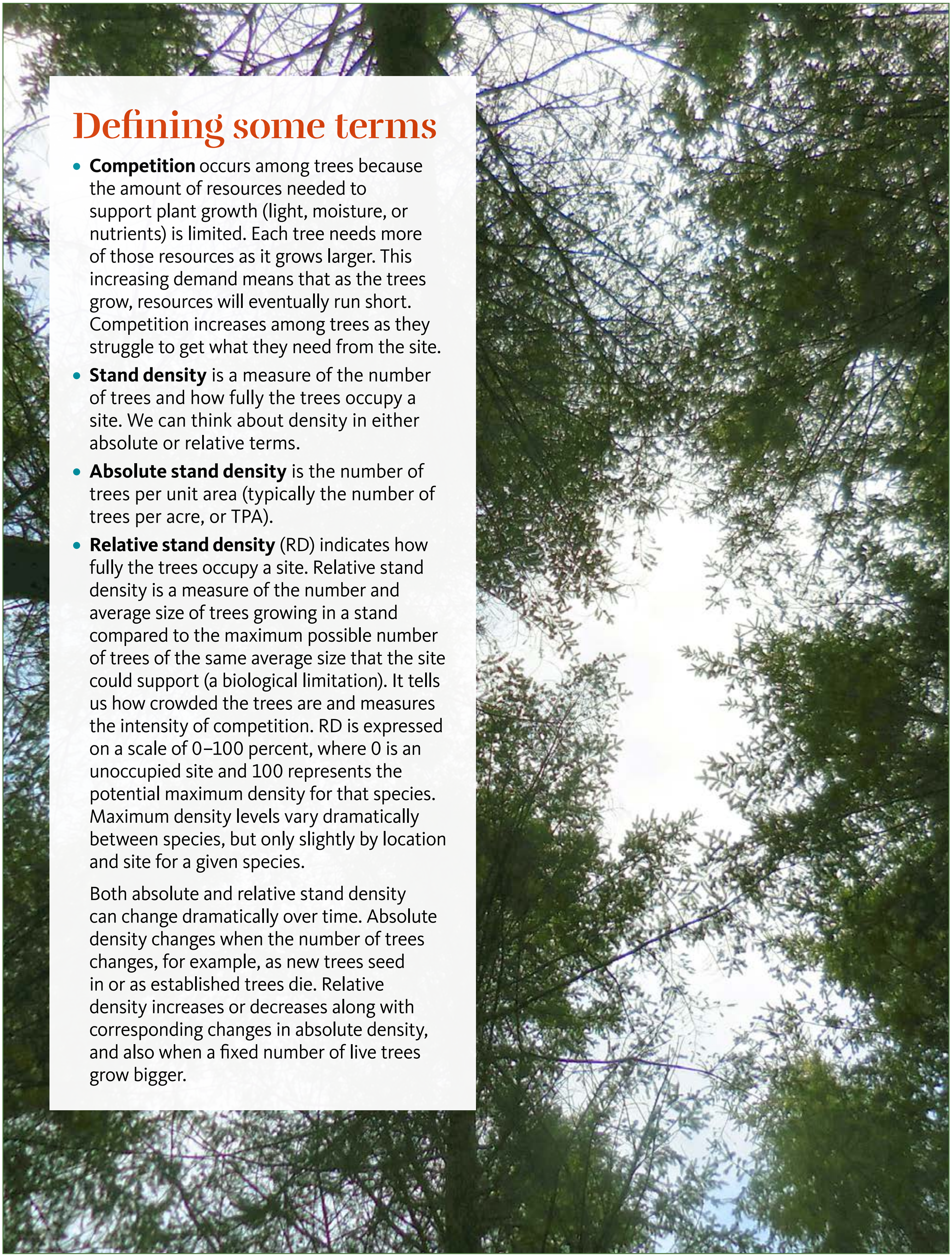


Photo: Brad Withrow-Robinson, © Oregon State University

Relative density as an indicator of competition

RD is our best measure of crowding and competition in a stand of trees. It relates well to other common indicators such as tree growth rates, crown depth, and self-thinning. Those other indicators are useful in the present but less helpful predicting the future. Because we can quantify and predict future RDs, we can use RD to anticipate future competition and determine when to take future management actions.

How this applies to your woods

Competition among trees has a powerful effect on the growth, health, resiliency, and character of a woodland. It affects trees individually, but also as a group or "stand" of which each is a part. Therefore, it is important for woodland owners to be aware of the degree of competition influencing trees within a stand.

Competition affects an individual tree's growth rate, and therefore diameter, taper, maximum branch size, and the width of annual growth rings. Competition also affects a tree's vigor and its ability to tolerate or resist insects, diseases, and storms.

Competition shapes the development of a stand and of stand-level characteristics, including the size of trees, the size of the green crown (crown length or depth), the forest structure (for example, size variability), stand volume, and both the type and amount of other plants growing on the forest floor and beneath the main forest canopy (the understory).

Stand density management is not just academic. These different tree and stand characteristics that result from changes in stand density are important in determining how well a stand meets a landowner's specific management objective, such as habitat diversity or optimal timber quality or yield. It is up to landowners to choose the right degree of competition during the life of the stand to get the results they want.

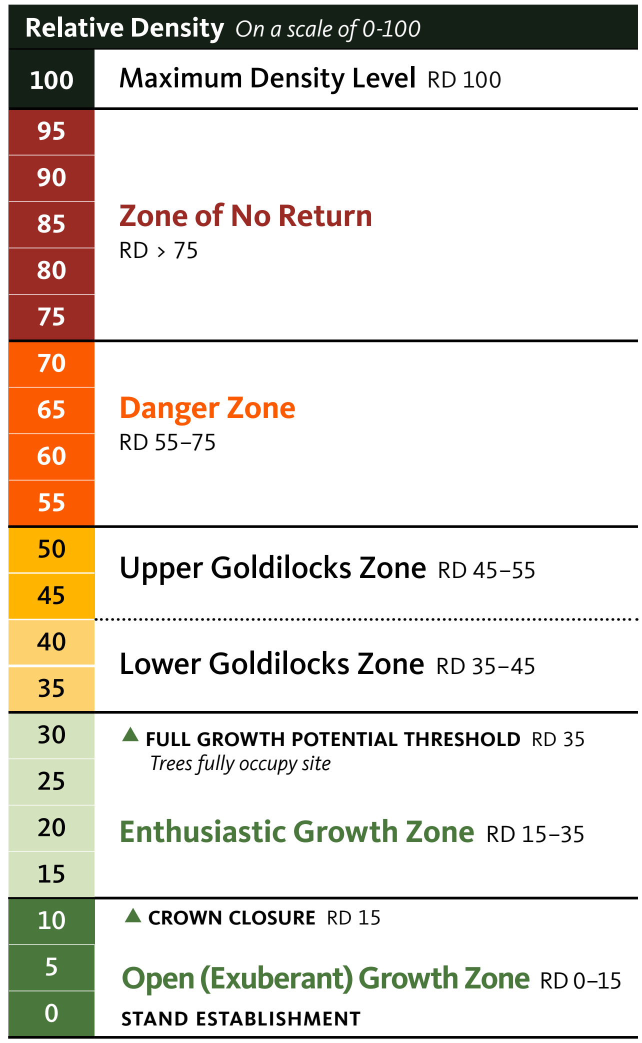
Stages of competition

As trees grow from uncrowded seedlings toward a group of larger trees approaching maximum density level (RD 100) without a major disturbance, the stand passes through certain stages along the way. These stages correspond with predictable levels of competition at anticipated RDs that have been identified through years of forestry research. It is important to be familiar with these stages, the amount of competition occurring, and its impact on tree and stand characteristics. See Figure 1.

Let's look at the key stages of competition, including approximate RDs at which they occur. These descriptions apply best to development in undisturbed, even-aged stands of a single species, but can also reflect competition levels following a disturbance or give insight into competition pressure when managing mixed

Figure 1. Relative density scale

This simplified illustration shows a gradual progression of stages, from bottom to top, that occur in absence of any major disturbance as a stand of trees develops from the seedling stage. It also relates to competition levels in older stands following a disturbance, such as wind throw or a thinning. As tree size increases, so does competition.



species. Disturbances that kill trees may be natural occurences (such as wind throw) or intentional human activities (such as harvesting trees in a thinning or when creating an opening).

Either type of disturbance temporarily frees up growing space, lowers stand RD, and delays progression to the next stage. Large disturbances may change the RD enough to shift a stand back into an earlier and less intense stage of competition.

By lowering the RD and the level of competition, the disturbance changes not just the timeline but also the look and character of the stand and the trees within it.

Stages of increasing stand competition

OPEN (EXUBERANT) GROWTH ZONE RD 0-15

Although seedlings or young trees may compete with leafy (herbaceous) or woody (shrub and tree) vegetation during the establishment stage, they are not yet competing with each other and should have lots of room to grow. **Crown closure** occurs for a young stand around RD 15.

ENTHUSIASTIC GROWTH ZONE RD 15-35

Usually seen in young stands following crown closure when trees still have plenty of room and resources (water, nutrients and light) but are beginning to compete with each other and with any other woody plants in the stand. Lower branches begin to decline and die as they become increasingly shaded (a process called "self-pruning"). The bottom of the live crown begins to move up the stem in what is called "crown lift" or "crown recession." The understory becomes sparse. Understory plants shift to shade-tolerant species. **Full growth potential threshold** is reached as trees fully capture the site (around RD 35).

THE GOLDILOCKS ZONE RD 35-55

Traditionally thought of as the "optimum growth zone" by foresters, we call this the Goldilocks Zone because it is seen as "just right": not too open, not too crowded. It is a zone of robust growth and the zone in which many managers often try to maintain stands for decades with repeated thinning. Individual trees are generally robust, so stands are vigorous and resilient to stress and pests. Stands in this zone are conducive to thinning. Trees typically respond well in growth and remain stable afterwards. Thinning intensity is geared for a return to the pre-thinning RD within 10 or so years. Managers can achieve many different objectives—ecological, economic and social—from stands in this zone.

LOWER GOLDILOCKS ZONE RD 35-45

In young stands, trees fully control the site and most of its resources. Competition between trees intensifies. The trees begin to separate into different into "crown classes" (See *Thinning: An Important Timber Management Tool*, PNW 184), but crowns are generally deep enough (40 to 60 percent crown ratio) to support robust tree growth. With repeated thinning, older stands can be maintained to meet non-timber objectives without too adversely reducing stand growth. Stands are spaced widely (open) enough to allow light to penetrate the canopy. This helps maintain deep crowns and supports understory growth, which is important to providing habitat for many species. To meet certain habitat objectives, it may be desirable to reduce competition below the Goldilocks Zone for some period, perhaps to as low as RD 25.

UPPER GOLDILOCKS ZONE RD 45-55

Competition is more intense in the upper parts of the Goldilocks Zone. Here we see continued crown lift and further differentiation of individual trees into crown classes in young stands. Average crown depth decreases (30 to 50 percent). This keeps maximum branch size small and stem-form more cylindrical (meaning, less taper). Dense shade limits the type and growth of understory vegetation. Individual tree growth is strong, although decreasing, especially among lower crown classes, but volume growth of the stand is high. The Upper Goldilocks Zone is generally seen as "just right" when it comes to optimizing timber quality and quantity.

DANGER ZONE RD 55-75

Trees compete intensely for resources. We see rapid and continued crown lift and wider differentiation into crown classes. This means the average crown lengths become dangerously small—especially the smallest overtopped trees. Some trees fail to get the resources needed. Weaker trees die, freeing up resources that allow surviving trees to grow. When trees die because of competition, we say the stand is "self-thinning." Foresters call this "competition mortality," or "suppression mortality" and call the area above RD 55 the "Zone of Imminent Competition Mortality."

Trees in the Danger Zone tend to be skinny for their height, with small, narrow crowns. The proportion of the tree length with live branches continues to decline, and trees become steadily more stressed. They tend to have little taper, small branches and tight growth rings. Stand-level volume growth can remain high. The understory tends to be sparse. This is an acceptable condition near the end of a rotation prior to final harvest. But it is not a good condition if the landowner wants to keep the stand longer, to harvest some trees in late thinnings, or to develop different stand conditions.

We call this the Danger Zone to highlight the rapid loss of options, rather than the natural loss of trees. The longer a stand remains in this zone, the more poorly it will respond to thinning with renewed growth, and the more likely the stand will be unstable and easily damaged by wind or wet snow. The window of opportunity to thin the stand narrows, depending on how much the crowns have differentiated. If the stand stays in this zone for long, the landowner has, in many cases, missed the opportunity to manage for different stand conditions.

ZONE OF NO RETURN RD 75

This zone is characterized by many small, skinny, and stressed trees with small crowns and active self-thinning. Even the dominant trees may have small, weak crowns. For many stands arriving at this point, it is too late to thin. Stability of residual trees is frequently poor if the stand is opened up. Once a stand reaches this stage, the best option is often to leave it alone until the time arrives for a regeneration harvest (a clearcut or shelterwood cut) to start a new stand.

Taking stock of stand diameter

An individual tree's diameter is measured at breast height (DBH), or 4.5 feet above the ground on the uphill side of the tree. But there are several ways to calculate the average diameter of the trees in a stand, or stand diameter.

Foresters generally use the **Quadratic Mean Diameter** (QMD) to calculate stand diameter. The QMD is the diameter of the tree of average basal area (BA) for a stand. Growth models, density management diagrams, and stand density tables are developed based on the QMD.

The QMD is used for calculating stand density because it accounts for variability in a stand better than the average DBH does, and it is readily converted into stand basal area. This is important because there is sometimes a great deal of variation in the size of individual trees within a stand. A simple average tends to underestimate the effect of the larger trees in those situations.

Most people would rather calculate the **average stand DBH** to make their decisions. Although this creates some room for error, it is probably a reasonable practice for family landowners in many circumstances.

For instance, the difference between the average DBH and QMD tends to be quite small in uniform stands, with small differences in tree sizes. For many young, planted forests growing on private lands, particularly in western Oregon, the difference between the two measures would probably be unimportant for most management decisions.

The difference between the two measures becomes greater as the stands become less uniform. A simple stand average DBH would become less accurate (underestimating the larger trees) in older or uneven aged stands, as is more typical of managed stands in central and eastern Oregon. In these situations, it may be prudent to calculate the stand QMD, or perhaps hire a consulting forester to cruise your stand.

See *Measuring Your Trees* (EM 9058) for information on forest inventory measurements and calculations. This publication covers plot layout, measurements and calculation of QMD.

Stand density tables

Woodland owners can learn to visualize and apply these competitive forces and biological limitations with the use of relative stand density tables. These tables provide information about three interdependent factors: stand density (TPA), tree size (average DBH) and level of competition (RD). We use these tables to estimate current levels or predict future levels of one of these factors, based on the other two.

Stand density tables come in a variety of configurations. We have arranged our tables in a new way, according to stand density and competition level to reveal tree size. In Figure 2, columns are arranged by increasing density (trees per acre)—from a few trees to many trees—from left to right. The rows are arranged by

Figure 2. Stand density table, abbreviated

An example of a part of a relative stand density table. Average tree diameters (DBH in inches) are shown arranged in columns by tree density (TPA) and approximate average spacing, and in rows by competition level (RD). *From Appendix F, western redcedar stand density table.*

Zones and thresholds ▼	Relative density ▼	Trees per acre ▶	100	125	150
		Spacing ▶	21'	19'	17'
Maximum	100	▶ Average diameter at breast height (DBH) ▶	34"	30"	27"
Zone of No Return	75		29	25	22
	70		27	24	21
Danger Zone	65		26	23	20
	60		25	22	19
	55		24	21	18
Upper Goldilocks Zone	50		22	19	17
	45		21	18	16
Lower Goldilocks Zone	40		19	17	15
	35		18	16	14
Enthusiastic Growth Zone	30		16	14	13
	25		14	13	11
	20		13	11	10
Crown Closure	15		11	9	8

increasing competition and RD (see the second column), from less competition to more competition, from bottom to top, as illustrated in Figure 1 (page 3).

The intersection of a column and a row reveals the average size of tree (in inches DBH) at that number of trees per acre and level of completion (RD).

This configuration of a relative stand density table allows a woodland owner to visualize and anticipate how a stand progresses through competitive stages as it develops over time, and helps predict future levels of competition that will arise in the stand as the trees grow. See the Appendices (starting at page 11) for relative stand density tables for several different species, each with density and DBH values appropriate for that species.

Understanding the stand density table

Let's look at how this table illustrates competition and stand development. Imagine a new (even-aged) stand starting off with a given number of seedling trees, about 360 trees per acre, as represented by a blue dot in Figure 3. The trees begin growing without much competition, and so survival is good and few trees die initially. As the trees grow, they gradually and increasingly crowd and compete with each other. Tree growth gradually slows. In the absence of a major disturbance, the number of trees holds steady through the green Open and Enthusiastic Growth zones and the yellow Goldilocks zones. The straight vertical portion of the dotted line in Figure 3 illustrates this period of growth. When the trees eventually become so crowded that some begin to die (or self-thin), the number of trees declines in the orange Danger Zone. This decline is illustrated by the curved section of the growth line that turns to the left in Figure 3.

As stressed trees die, the growing space vacated by the dying trees can be used by the surviving trees, allowing them to grow larger. Thus, the line representing the number and size of trees in the stand continues to drift left as the number of trees decreases

Photo: Lynn Ketchum, © Oregon State University

A stand of even-aged trees progresses through competitive stages as trees grow.

Figure 3. Development and decline of tree quantities in an even-aged stand

General pattern of stand development and decline of tree numbers in an even-aged stand, illustrated by the blue line on a relative stand density table. It starts with a large number of small seedlings before crown closure and proceeds to a smaller number of large trees near the maximum density level. *From Appendix A, Douglas-fir stand density table (page 11).*

Zones and thresholds ▼	Relative density ▼	Trees per acre ▶	175	200	225	250	275	300	360	435
		Spacing ▶	16'	15'	14'	13'	12.5'	12'	11'	n/a
Max. Stocking	100	▼ Average diameter at breast height (DBH) ▶	20	18	17	16	15	14	13	11
Zone of No Return	95		19	18	16	15	14	14	12	11
	90		18	17	16	15	14	13	12	10
	85		18	16	15	14	13	13	11	10
	80		17	16	15	14	13	12	11	10
	75		16	15	14	13	12	12	11	9
Danger Zone	70		16	15	13	13	12	11	10	9
	65		15	14	13	12	11	11	10	9
	60		14	13	12	11	11	10	9	8
	55		14	12	12	11	10	10	9	8
Upper Goldilocks	50		13	12	11	10	10	9	8	7
	45		12	11	10	10	9	9	8	7
Lower Goldilocks	40		11	10	10	9	8	8	7	6
	35		10	9	9	8	8	7	7	6
Enthusiastic Growth Zone	30		9	9	8	7	7	7	6	5
	25		8	8	7	7	6	6	5	5
	20		7	7	6	6	5	5	5	4
Open Growth Zone	15		6	6	5	5	5	4	4	3
	10		5	4	4	4	4	3	3	3
	5		3	3	3	2	2	2	2	2

and upward as the surviving trees grow gradually larger. This continues through the red Danger Zone before flattening out in the brown Zone of No Return, just below the maximum density level.

Using a stand density table to guide your actions

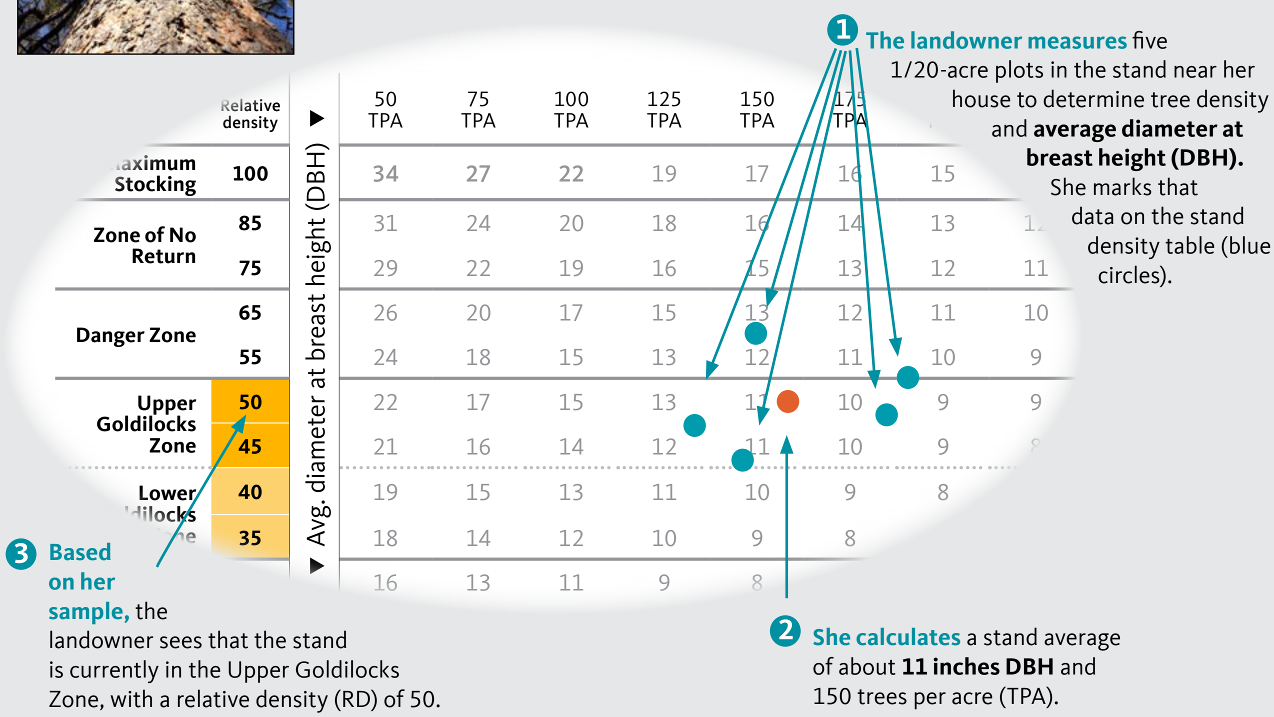
A stand density table can help you make important decisions about your woodland. A density table can tell you when and how much to thin (at what stand diameter and to what new density). This lets you keep a stand growing within a desired range of competition, which helps to develop the conditions you want. You can also use the table to decide if a young stand thinning (also called pre-commercial thinning) is needed to allow room for trees to reach a target diameter and prevent overcrowding and stress.

Let's take an example of a landowner in eastern Oregon who has several vigorous ponderosa pine stands that were thinned some years ago. She is concerned about keeping the trees vigorous and resilient to drought and insect threats, and she also seeks to produce some forage for grazing. She wants to know if it is time for a thinning harvest.

To get an idea, she goes out to the small stand nearest her house to get current information. Referring to *Measuring Your Trees* (EM 9058), she measures a sample of five 1/20-acre plots to determine tree density and average DBH for each. She then marks the data on a copy of the stand density table (blue circles, Figure 4). The plot average for tree density and DBH varies among the samples, but she calculates a stand average of about 11 inches DBH and 150 TPA (red circle A, Figure 4). Based on her sample, she sees that the stand currently has an RD around 45–50, in the Upper Goldilocks Zone.

Figure 4. Using a ponderosa pine stand density table

A landowner in eastern Oregon has several vigorous ponderosa pine stands that were thinned some years ago. She wants to know if it is time for a thinning harvest. What steps does she take to find out?



4 **What this tells her:** She wants to keep the stand resilient into the future and also allow cattle to graze the understory. She opts for a light thinning to create a more open stand. ***See Figure 5, page 8, for the next steps.***

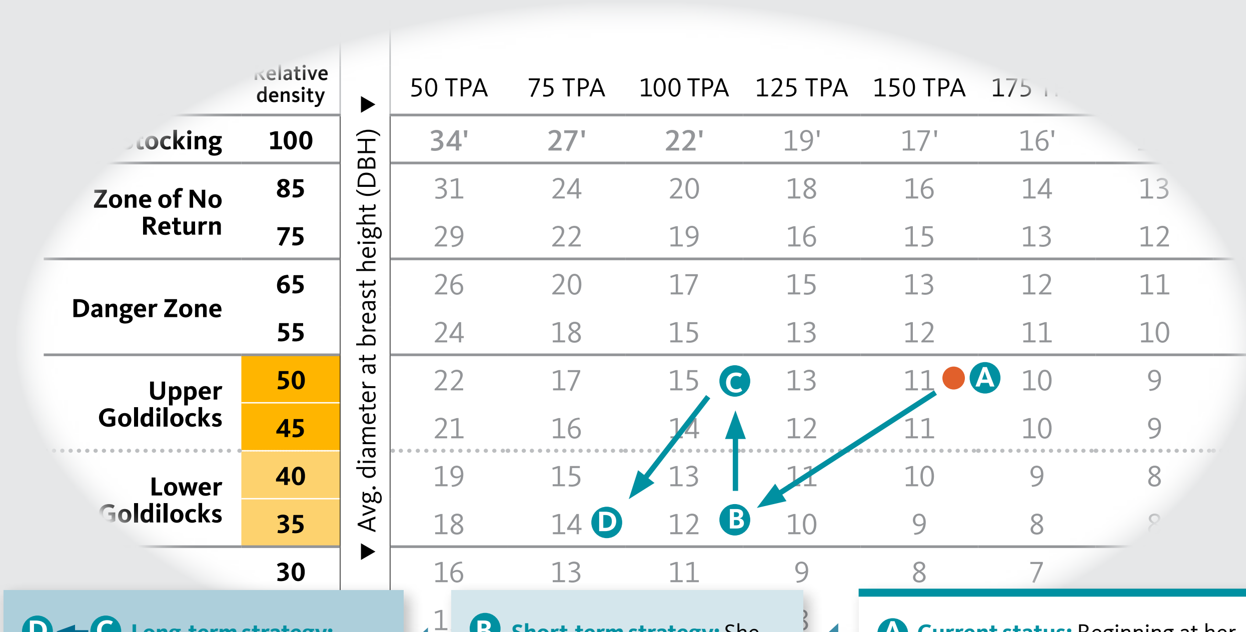
From Appendix C, ponderosa pine stand density table

She now needs to figure out what this information means to her. The stand's RD is below the point generally seen as the upper limit a stand should be allowed to reach before thinning (RD 55), so she can consider allowing it to grow longer. However, she knows that too much competition can predispose trees to damage from insects and other problems, especially in times of drought. She hopes to avoid that risk by keeping the stand vigorous and resilient to stress, and is willing to sacrifice some potential stand growth to gain that. She would also like to allow some light cattle grazing of the understory, which would benefit from a more open stand. She decides that keeping the stand's densities between RD 35 and RD 50 would best meet her objectives. This means that if her sample is representative of the rest of her stands, it is time to plan a thinning.

Now she can use the stand density table to help (Figure 5). She anticipates a "proportional thinning." This means she will take trees from across the size range, meaning the thinning will not significantly affect the stands' average diameter. Beginning at the point representing her current stand average in the discussion above (Figure 5, circle A), she looks to the columns representing lower densities to the left to find a similar average tree size (11-inch DBH). She finds this under the 125-TPA column, in the row representing RD 40 (in the yellow Lower Goldilocks Zone). She also finds 11-inch DBH in the 100-TPA column, in the row representing RD 30 (in the green Enthusiastic Growth Zone). She decides to split the difference and thin to a residual stand density of about 110–115 TPA for a RD of about 35, at the bottom of the Lower Goldilocks Zone (Figure 5, circle B).

Figure 5. Planning a thinning operation to reach objectives

A landowner wants to keep her ponderosa pine stands' relative density between RD 35 and RD 50. She will do a "proportional thinning," which will not significantly affect the stands' average diameter.



D←C Long-term strategy: Once she thins to 110–115 TPA, the trees will have room to grow about 3 inches (vertical line), to an average of 14 inches DBH (circle C), before they reach her upper competition threshold (RD 50), and be ready for another thinning. The second thinning (shown as the line sloping down from circle c) would again move the stand back to RD 35, circle D.

B Short-term strategy: She decides to split the difference and thin to a residual stand density of 110–115 TPA to hit her target density, RD 35 (circle

A Current status: Beginning at her current average stand diameter of about 11 inches DBH (red dot), she looks in the columns representing lower densities to find a similar stand average. She finds 11-inch DBH in the 125-TPA column in the row representing RD 40 and also in the 100-TPA column, at RD 30.

From Appendix C, Ponderosa pine stand density table

The table also lets her look ahead. She sees that if she thins to the target 110–115 TPA, the trees in the stands will then have room to grow about 3 inches (Figure 5, vertical line [page 8]) to an average of around 14 inches DBH (Figure 5, circle C [page 8]), before they reach her upper threshold (RD 50) at the top of her chosen target range. They would then be ready for a second thinning harvest, which would again move the stand back to the lower target density (RD 35) at Figure 5, circle D (page 8).

For our next example, a landowner with a 12-year-old Douglas-fir plantation in western Oregon had good survival at planting and is now concerned that he has too many trees and that they will become too crowded before they are large enough to be ready for a first thinning harvest at age 25 or so. He wants to cover the costs of the operation by selling the logs he thins. Based on the markets in his area, he figures he needs a stand with an average tree size of at least 10 inches DBH at the time of the first thinning harvest to “break even.” He knows he wants the stand to reach that target size before excessive competition begins (avoiding the danger zone above RD 55) and needs to estimate the stand density (TPA) that will allow that. He can use the Douglas-fir stand density table to figure this out.

He starts by finding the row for RD 55, his chosen upper competition threshold (Figure 6, circle A) and then follows that row across the columns to the right until reaching a column with his target stand size, 10 inches DBH. He finds that in two columns (Figure 6, circle B). This gives him a target density range of 275 TPA and 300 TPA (Figure 6, circle C).

Photo © Walter Siegmund

Figure 6. Estimating a target stand density based on a target size diameter

A landowner with a young Douglas-fir plantation suspects he has too many trees and wants to find out if he needs to do a young stand thinning. He wants to do a thinning harvest around age 25, but before excessive competition begins (above RD 55), and figures an average tree size of at least 10 inches DBH will let him break even. He needs to know what density will allow that.

	Relative density	250 TPA	275 TPA	300 TPA	360 TPA	435 TPA	TPA
Maximum Stocking	100	16	15	14	13	11	8
Zone of No Return	85	14	13	13	11	10	8
	75	13	12	12	11	9	7
Danger Zone	65	12	11	11	10	9	6
	60	11	11	10	9	8	6
	55 (A)	10	10 (B)	10 (B)	9	8	6
	50	10	10	9	8	7	5
Zone	45	10	9	9	8	7	

▼ Avg. DBH ▼

(D) ← (C)

A First, he finds the row for RD 55, his chosen upper competition threshold.

B Next, he follows that row across the table and finds his target stand size, 10 inches DBH, in two columns (circle B). This gives him a target density range of 275–300 TPA (circle D).

C → D Next, he estimates the number of trees in his stand. The north-facing section has about 420–480 TPA (circle C). This tells him he needs to remove 130–190 TPA (moving the stand’s density from circle C to circle D) to allow his trees the room they need to grow to his target size.

From Appendix A, Douglas fir stand density table, abridged

Next, he needs to know the density of trees (TPA) he has in his young stand. He estimates that with plots as described in *Measuring Your Trees* (EM 9058) and compares it to his target density to decide if he needs to do a young stand thinning (also known as PCT). He finds a lot of variation in his measurements, especially on the two different sides of a draw that runs through the stand. On the south-facing side, his plots range from 240 TPA to 340 TPA, but were generally around 300 TPA. Survival is higher on the north-facing side of the draw. There his plots range from around 420 TPA to 480 TPA, which is sometimes more trees than he planted due to natural seeding from the adjacent mature stand.

So what does this mean? Since his young stand on the south-facing slope generally has a similar number of trees per acre as his target density, he is on track to reach the desired average tree diameter. But the north-facing part of the stand (Figure 6, circle D [page 9]) generally has significantly more trees per acre than his target density, so he is NOT on track. He needs to consider a young stand thinning (YST) to correct that.

With this information in hand, he decides to leave the south-facing section alone and pursue a young stand thinning in the north-facing section. He will need to remove 130–190 TPA in various parts of the planting to bring the stand density down to 290 TPA, the midpoint of his target range (Figure 6, circle D to circle C ([page 9]). This will allow his trees to reach the desired average tree diameter before experiencing significant harmful competition.

Conclusion

Understanding the effects of competition on how trees grow and how forest stands develop is critical to shaping the conditions you want on your property. Managing for or restoring desired conditions is easier if you understand that competition develops in a predictable manner and that a developing forest moves predictably through zones of increasing competition.

Relative stand density (RD) is an important tool for estimating the competition within stands and understanding where a stand falls in the progression of competitive stages. Stand density tables use relative stand density to help landowners understand and manage the competition in their forest stands and shape the future of their woodland property. It is up to the landowner to control competition during the life of the stand to achieve desired goals.

Resources

OSU Extension publications

Find these and other Oregon State University Extension Service publications online at *catalog.extension.oregonstate.edu/*

- *Tools for Measuring Your Forest* (EC 1129), *catalog.extension.oregonstate.edu/ec1129*
- *Measuring Your Trees* (EM 9058), *catalog.extension.oregonstate.edu/em9058*
- *Basic Forest Inventory Techniques for Family Forest Owners* (PNW 630), *catalog.extension.oregonstate.edu/pnw630*
- *Thinning: An Important Timber Management Tool* (PNW 184), *catalog.extension.oregonstate.edu/pnw184*

Other resources

Management by Objective *http://blogs.oregonstate.edu/treetopics/2015/02/10/management-objective/*

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Appendix A. Douglas-fir stand density table

Approximate tree size in inches DBH at different absolute densities (trees per acre, or by approximate spacing [in feet]) and competition level (RD). Based on stand quadratic mean diameter and a maximum stand density index of 520.

Zones and thresholds ▼	Relative density ▼	Trees per acre ▶	50	75	100	125	150	175	200	225	250	275	300	360	435	680
		Spacing ▶	30'	24'	21'	19'	17'	16'	15'	14'	13'	12.5'	12'	11'	10'	8'
Maximum Stocking	100	▼ Average diameter at breast height (DBH) ▼	43"	33"	28"	24"	22"	20"	18"	17"	16"	15"	14"	13"	11"	8"
Zone of No Return	75		39	30	25	22	20	18	16	15	14	13	13	11	10	8
	70		36	28	23	20	18	16	15	14	13	12	12	11	9	7
Danger Zone	65		33	26	21	19	17	15	14	13	12	11	11	10	9	6
	60		31	24	20	18	16	14	13	12	11	11	10	9	8	6
	55		30	23	19	17	15	14	12	12	11	10	10	9	8	6
Upper Goldilocks Zone	50		28	22	18	16	14	13	12	11	10	10	9	8	7	5
	45		26	20	17	15	13	12	11	10	10	9	9	8	7	5
Lower Goldilocks Zone	40		24	19	16	14	12	11	10	10	9	8	8	7	6	5
	35		22	17	15	13	11	10	9	9	8	8	7	7	6	4
Enthusiastic Growth Zone	30		20	16	13	11	10	9	9	8	7	7	7	6	5	4
	25		18	14	12	10	9	8	8	7	7	6	6	5	5	4
	20		16	12	10	9	8	7	7	6	6	5	5	5	4	3
Crown Closure	15		13	10	9	7	7	6	6	5	5	5	4	4	3	3

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Appendix B. Grand fir stand density table

Approximate tree size in inches DBH at different absolute densities (trees per acre, or by approximate spacing [in feet]) and competition level (RD). Based on stand quadratic mean diameter and a maximum stand density index of 560.

Zones and thresholds ▼	Relative density ▼	Trees per acre ▶	50	75	100	125	150	175	200	225	250	275	300	360	435	680
		Spacing ▶	30'	24'	21'	19'	17'	16'	15'	14'	13'	12.5'	12'	11'	10'	8'
Maximum Stocking	100	▼ Average diameter at breast height (DBH) ▼	45"	35"	29"	25"	23"	21"	19"	18"	17"	16"	15"	13"	12"	9"
Zone of No Return	75		41	32	26	23	21	19	17	16	15	14	13	12	11	8
	70		38	29	24	21	19	17	16	15	14	13	12	11	10	7
Danger Zone	65		34	27	22	19	17	16	15	13	13	12	11	10	9	7
	60		33	25	21	19	17	15	14	13	12	11	11	10	9	6
	55		31	24	20	18	16	14	13	12	11	11	10	9	8	6
Upper Goldilocks Zone	50		29	23	19	17	15	13	12	11	11	10	10	9	8	6
	45		27	21	18	15	14	13	12	11	10	9	9	8	7	5
Lower Goldilocks Zone	40		25	20	17	14	13	12	11	10	9	9	8	7	7	5
	35		23	18	15	13	12	11	10	9	9	8	8	7	6	5
Enthusiastic Growth Zone	30		21	17	14	12	11	10	9	8	8	7	7	6	6	4
	25		19	15	12	11	10	9	8	7	7	7	6	6	5	4
	20		17	13	11	9	8	8	7	6	6	6	5	5	4	3
Crown Closure	15		14	11	9	8	7	6	6	5	5	5	5	4	4	3

Table: Withrow-Robinson and Maguire,

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Appendix C. Ponderosa pine stand density table

Approximate tree size in inches DBH at different absolute densities (trees per acre, or by approximate spacing [in feet]) and competition level (RD). Based on stand quadratic mean diameter and a maximum stand density index of 365.

Zones and thresholds ▼	Relative density ▼	Trees per acre ▶	50	75	100	125	150	175	200	225	250	275	300	360	435	680
		Spacing ▶	30'	24'	21'	19'	17'	16'	15'	14'	13'	12.5'	12'	11'	10'	8'
Maximum Stocking	100	▼ Average diameter at breast height (DBH) ▼	34"	27"	22"	19"	17"	16"	15"	14"	13"	12"	11"	10"	9"	7"
Zone of No Return	85		31	24	20	18	16	14	13	12	11	11	10	9	8	6
	75		29	22	19	16	15	13	12	11	11	10	9	8	7	6
Danger Zone	65		26	20	17	15	13	12	11	10	10	9	9	8	7	5
	60		25	19	16	14	13	12	11	10	9	9	8	7	7	5
	55		24	18	15	13	12	11	10	9	9	8	8	7	6	5
Upper Goldilocks Zone	50		22	17	15	13	11	10	9	9	8	8	7	7	6	4
	45		21	16	14	12	11	10	9	8	8	7	7	6	5	4
Lower Goldilocks Zone	40		19	15	13	11	10	9	8	8	7	7	6	6	5	4
	35		18	14	12	10	9	8	8	7	7	6	6	5	5	4
Enthusiastic Growth Zone	30		16	13	11	9	8	7	7	6	6	6	5	5	4	3
	25		15	11	9	8	7	7	6	6	5	5	5	4	4	3
	20		13	10	8	7	6	6	5	5	5	4	4	4	3	2
Crown Closure	15		11	8	7	6	5	5	4	4	4	4	3	3	3	2

Appendix D. Red alder stand density table

Approximate tree size in inches DBH at different absolute densities (trees per acre, or by approximate spacing [in feet]) and competition level (RD). Based on stand quadratic mean diameter and a maximum stand density index of 520. This table reflects the recommendations of the Hardwood Silviculture Cooperative, with competitive zones shifted down to lower RD bands than used in conifer tables.

Zones and thresholds ▼	Relative density ▼	Trees per acre ▶	50	75	100	125	150	175	200	225	250	275	300	360	435	680
		Spacing ▶	30'	24'	21'	19'	17'	16'	15'	14'	13'	12.5'	12'	11'	10'	8'
Maximum Stocking	100	▼ Average diameter at breast height (DBH) ▼	31"	26"	22"	20"	18"	17"	15"	14"	14"	13"	11"	10"	8"	5"
Zone of No Return	75		26	21	19	17	15	14	13	12	11	11	10	9	6	5
	65		23	20	17	15	14	13	12	11	10	10	9	8	6	4
Danger Zone	55		21	18	15	14	12	11	11	10	9	9	8	7	5	4
	50		20	17	14	13	12	11	10	9	9	8	7	7	5	4
	45		19	16	14	12	11	10	9	9	8	8	7	6	5	3
Upper Goldilocks Zone	40		17	14	13	11	10	9	9	8	8	7	6	6	4	3
	35		16	13	12	10	9	9	8	7	7	7	6	5	4	3
Lower Goldilocks Zone	30		14	12	10	9	9	8	7	7	6	6	5	5	4	3
	25		13	11	9	8	8	7	6	6	6	5	5	4	3	2
Enthusiastic Growth Zone	20		11	9	8	7	7	6	6	5	5	5	4	4	3	2
Crown Closure	15		9	8	7	6	6	5	5	4	4	4	4	3	2	2

Table: Withrow-Robinson and Maguire, © Oregon State University

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Appendix E. Western hemlock stand density table

Approximate tree size in inches DBH at different absolute densities (trees per acre, or by approximate spacing [in feet]) and competition level (RD). Based on stand quadratic mean diameter and a maximum stand density index of 850.

Zones and thresholds ▼	Relative density ▼	Trees per acre ▶	50	75	100	125	150	175	200	225	250	275	300	360	435	680
		Spacing ▶	30'	24'	21'	19'	17'	16'	15'	14'	13'	12.5'	12'	11'	10'	8'
Maximum Stocking	100	▼ Average diameter at breast height (DBH) ▼	58"	45"	38"	33"	29"	27"	25"	23"	21"	20"	19"	17"	15"	11"
Zone of No Return	75		53	41	34	30	27	24	22	21	19	18	17	15	14	10
	70		49	38	32	28	25	22	21	19	18	17	16	14	13	10
Danger Zone	65		45	35	29	25	23	20	19	17	16	15	15	13	12	9
	60		42	33	28	24	21	19	18	17	16	15	14	12	11	8
	55		40	31	26	23	20	18	17	16	15	14	13	12	10	8
Upper Goldilocks Zone	50		38	29	25	21	19	17	16	15	14	13	12	11	10	7
	45		36	28	23	20	18	16	15	14	13	12	12	10	9	7
Lower Goldilocks Zone	40		33	26	21	19	17	15	14	13	12	11	11	10	9	6
	35		30	24	20	17	15	14	13	12	11	11	10	9	8	6
Enthusiastic Growth Zone	30		28	21	18	16	14	13	12	11	10	10	9	8	7	5
	25		25	19	16	14	12	11	10	10	9	9	8	7	6	5
	20		21	17	14	12	11	10	9	8	8	7	7	6	6	4
Crown Closure	15		18	14	12	10	9	8	8	7	7	6	6	5	5	4

Table: Withrow-Robinson and Maguire, © Oregon State University

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Appendix F. Western redcedar stand density table

Approximate tree size in inches DBH at different absolute densities (trees per acre, or by approximate spacing [in feet]) and competition level (RD). Based on stand quadratic mean diameter and a maximum stand density index of 722.

Zones and thresholds ▼	Relative density ▼	Trees per acre ▶	50	75	100	125	150	175	200	225	250	275	300	360	435	680
		Spacing ▶	30'	24'	21'	19'	17'	16'	15'	14'	13'	12.5'	12'	11'	10'	8'
Maximum Stocking	100	▼ Average diameter at breast height (DBH) ▼	53"	41"	34"	30"	27"	24"	22"	21"	19"	18"	17"	15"	14"	10"
Zone of No Return	75		48	37	31	27	24	22	20	19	17	17	16	14	12	9
	70		44	34	29	25	22	20	19	17	16	15	14	13	11	9
Danger Zone	65		40	31	26	23	20	18	17	16	15	14	13	12	10	8
	60		38	30	25	22	19	18	16	15	14	13	13	11	10	8
	55		36	28	24	21	18	17	15	14	13	13	12	11	9	7
Upper Goldilocks Zone	50		34	27	22	19	17	16	14	13	13	12	11	10	9	7
	45		32	25	21	18	16	15	14	13	12	11	10	9	8	6
Lower Goldilocks Zone	40		30	23	19	17	15	14	13	12	11	10	10	9	8	6
	35		27	21	18	16	14	13	12	11	10	10	9	8	7	5
Enthusiastic Growth Zone	30		25	19	16	14	13	11	11	10	9	9	8	7	6	5
	25		22	17	14	13	11	10	9	9	8	8	7	7	6	4
	20		19	15	13	11	10	9	8	8	7	7	6	6	5	4
Crown Closure	15		16	13	11	9	8	7	7	6	6	6	5	5	4	3

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