# Stand Development Following Stand-replacing Wildfire

The stand developmental sequence described in Franklin et al. (2002) provides a useful template for understanding the concept of forest disturbance and succession. This simplified developmental sequence parallels the development of many Pacific Northwest forests following a stand-replacing event, such as a high-severity fire. A more detailed discussion of this developmental sequence as it applies to Douglas fir-western hemlock forests is provided in the companion volume *Identifying Mature and Old Forests in Western Washington* (Van Pelt 2007). While this forest type also occurs in eastern Washington, more species are often present than in the scenario presented for western Washington. Dry forest types, such as many dominated by ponderosa pine, do not follow the typical western Washington developmental sequence. In these forests, a high percentage of trees will survive mixed- and low-severity fire events. Historically, stand-replacing fire events were most common in the Cascade western hemlock, Pacific silver fir, mountain hemlock, Columbia Rocky Mountain western hemlock, and subalpine fir zones. More recently, stand-replacing fires have become common in the grand fir and Columbia Rocky Mountain western redcedar zones as a result of decades of fire suppression and the corresponding increase in stand density and ***fuel loading*** (the amount of combustible material available to feed a fire).

## Disturbance and legacy creation

The first stage in a developmental sequence is the disturbance itself. For the purposes of this discussion, disturbances are limited to stand-replacing events that allow a new ***cohort*** of trees to establish—a population of trees of a similar age class that develop together, such as those planted after clearcut logging. In our region, the three primary stand-replacing disturbance events are high-severity wildfires, epidemic insect outbreaks, and logging. While the canopy of the previous stand is removed under each of these scenarios, in most respects these disturbances are very different from each other.

Wildfire can completely kill a stand of trees, but usually consumes only a small proportion of the wood. Landscapes affected by stand-replacement wildfire are often a sea of snags (Figure 27). Epidemic insect outbreaks are occasionally stand-

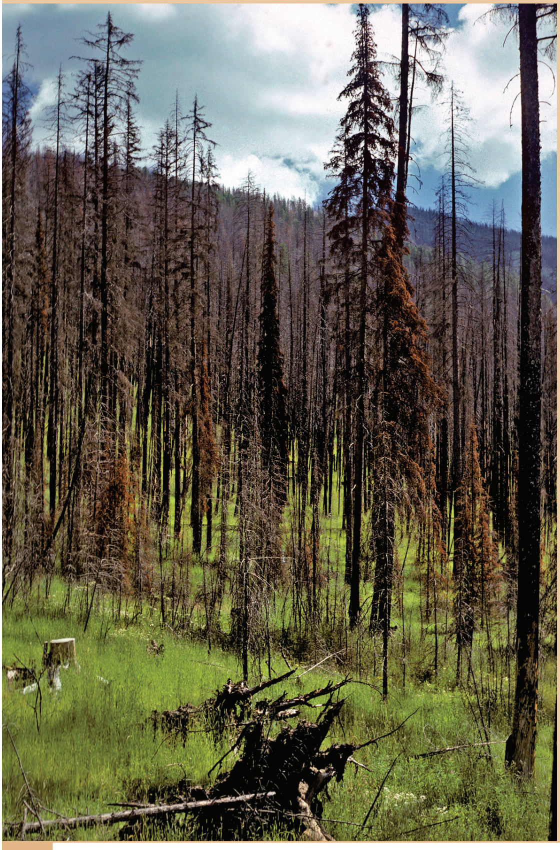


**Figure 27 above. A high-severity portion of the 2001 Thirtymile Fire in the Okanogan Highlands.** Six years later, nearly all of the wood remains. Green trees are filled with water and are often not consumed during the initial fire. These snags are likely to burn in a subsequent fire.

**Figure 28 left. Very large fires may eliminate seed sources of tree species that would otherwise recolonize the burned area.** In such cases, grasses or a shrubfield may persist for decades without human intervention.

**Figure 29. Aggressive aspen recolonization following fire.** While the fire killed the above-ground aspens, a portion of the underground root system survived. The result is the subsequent development of a dense aspen understory.

replacing events. It is more common, however, for an outbreak to affect only one or a small group of species. As with fire, insect outbreaks leave behind abundant dead wood. Once this remaining wood has dried, forests impacted by either of these situations are vulnerable to subsequent fire events.

Clearcut logging is also a stand-replacing event, but the post-logging situation is very different from those caused by either fire or insects, because dead wood may be nearly absent. Although it is now only one technique among several employed in modern silvicultural management, clearcutting was a major logging technique practiced in Washington for many decades. As such, it constitutes an important part of the disturbance history of many post-Euro-American settlement stands. As traditionally practiced, clearcutting leaves behind very little structure from the previous stand. During the late nineteenth and much of the twentieth century, cleared areas were allowed to reseed themselves naturally from surrounding forested areas. Since the 1950s, clearcuts generally have been replanted within a year or two after logging. Stands resulting from natural reseeding are patchier and it may take longer in some places for these stands to reach the ***canopy closure*** stage (described in a following section).

## Cohort establishment

Cohort establishment is the initiation of a new set of trees that forms the basis of a future forest. After a wildfire, conditions for cohort establishment vary tremendously between sites, depending on the extent and severity of the fire in question. Very large fires may leave limited seed sources with which to repopulate the burned area, often allowing shrubs or herbaceous vegetation to persist for a considerable time before trees get re-established (Figure 28). This is not often the case following smaller fires, but even stands subject to very large fires can regenerate quickly if there is a small but diffuse population of surviving trees. In eastern Washington, western larch, lodgepole pine, and aspen are among the quickest to re-establish themselves (Figure 29). Depending on site conditions, however, many other tree species may establish during this initial phase. Large burned areas often are replanted to hasten canopy closure and slow soil erosion (Figure 30).

**Figure 30. Cohort establishment.** Depending on the availability of seed sources, cohort establishment may take decades.

Repeated disturbances, such as subsequent fires, confound regeneration on several levels:

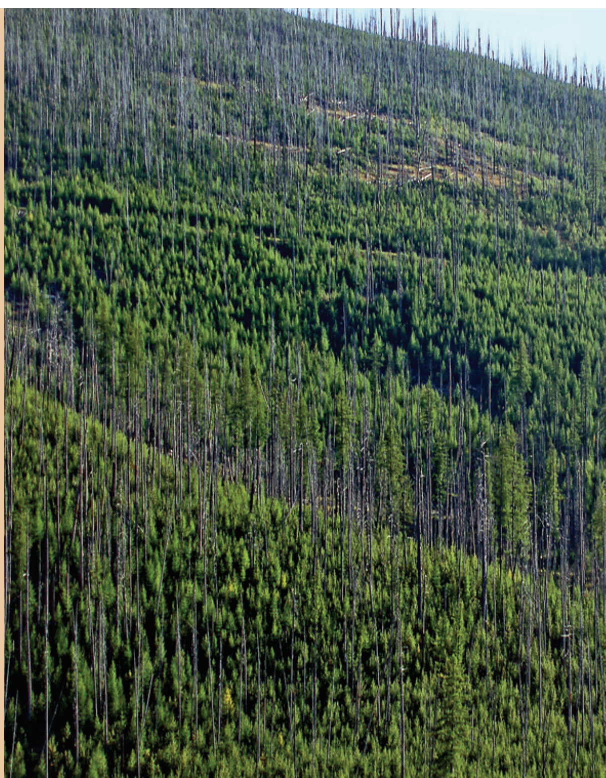
- The few surviving trees that were seed sources may be killed.
- The dense stand of newly regenerating trees most likely will be killed.
- More of the original biological legacies and residual organic matter will be consumed.

All of these processes are common in areas that burn repeatedly. For simplicities' sake, this section will focus on the processes following stand-replacing wildfire.

## Canopy closure

Canopy closure between two trees occurs when their crowns begin to touch. While this can take place within a single growing season, at the stand level it may take decades, as determined by the initial spacing of the young trees (Figure 31). Modern planting methods attempt to minimize the time for this process to occur,

**Figure 31. Canopy closure after the 1988 White Mountain Fire in the Okanogan Highlands.** The developing stand is a result of both natural reseeding and hand planting.



but natural processes are much more irregular. Natural colonization should be random, but often is aggregated according to the distribution of suitable germination sites. In these situations, canopy closure may occur in one spot decades before it occurs only a short distance away. Large piles of woody debris, competition from dense shrub layers, or exposed soils can all create situations that delay tree seedling establishment.

More dramatic environmental changes occur during this stage than in any other. During this relatively brief period, the area is transformed from open to closed canopy—from full sun to deep shade. Near the ground surface, temperature becomes highly moderated, and relative humidity increases. Many plant species, adapted to growing in the high-light environment of the early-colonizing stand, perish in the deep shade imposed by overlapping tree-crowns.

## Biomass accumulation/Competitive exclusion

Following canopy closure, the stand will spend several decades in the biomass accumulation/competitive exclusion stage. In eastern Washington, this may continue for 50-60 years on highly productive sites or up to 120 years on poorer sites. At

**Figure 32. High-density initial establishment can lead to high density stands.** As the average size of trees within a stand increases, the number of trees it can support declines. Density-dependent mortality results from competition for available resources, including light, water, and nutrients.

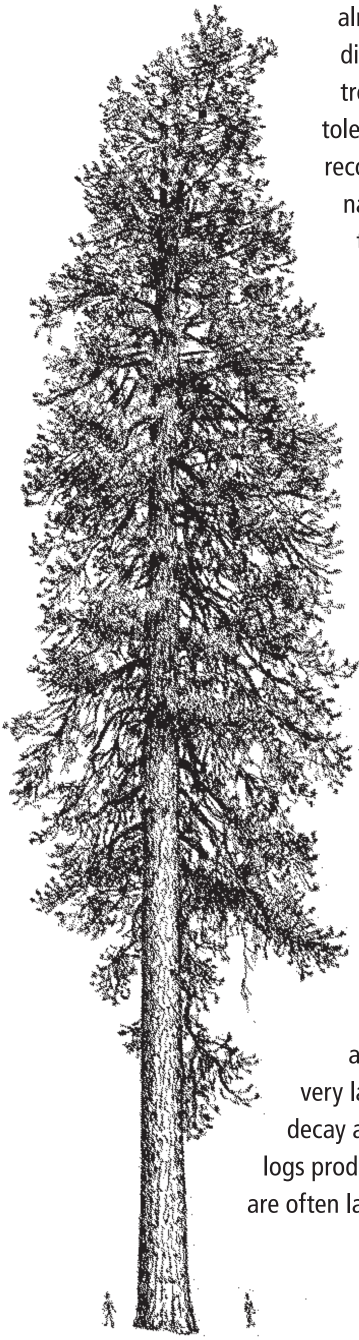
this stage, it is characteristic for a site to be completely dominated by trees. The trees can grow rapidly, converting a shrub field with tiny trees into a tall forest. Standing biomass increases by many orders of magnitude, yet recruitment of new individuals is limited by the deep shade at the forest floor.

Depending on initial stem densities, density-dependant mortality also will be prevalent during this stage (Figure 32). Dead, small-diameter trees are often abundant and appear to be strewn about the forest floor like jackstraws. As the trees grow taller, lower branches on many shade-intolerant tree species, such as lodgepole pine, die in the deep shade cast by branches above them. Crown depths may not change appreciably during these several decades. Crown bases will rise at the same rate as height increases, leaving bare trunks below the living crown as the dead branches fall off. The forest understory is at its most depauperate level during this stage, as the deep shade from a dense, upper canopy is at its most extreme.

## Maturation

At maturity, the trees that form the upper canopy have reached 60-90 percent of their ultimate height. Most of the original shade-intolerant cohort that has not

**Figure 33. Maturation. Mature forests often have two cohorts – a shade-tolerant understory developing beneath the overlying, maturing stand.** Left – subalpine fir beneath a lodgepole pine canopy. Right – western hemlock developing beneath a Douglas fir canopy.



already ascended into the upper canopy will have died. More light reaches the understory as taller tree crowns become isolated, allowing shade-tolerant plants, including various tree species, to recolonize. The rate of understory colonization naturally depends on many factors, including the proximity of seed sources. If the initial disturbance was very extensive, tree seedlings may not colonize for many decades, even if conditions are favorable. Ultimately, the understory is filled in by young, shade-tolerant trees, shrubs, and herbs common to that vegetation zone (Figure 33). The middle canopy will be completely free of foliage and consist only of the trunks of canopy trees. This area, known as the ***bole zone,*** is most dramatic at this stage.

## Vertical diversification

Vertical diversification is the first stage of old growth following a stand-replacing event. Shade-tolerant trees are now continuously establishing in the understory and have expanded to occupy the middle canopy (Figure 34). Height growth of the stand proceeds very slowly—most new growth goes into wood production and below-ground processes. Many trees in the shade-intolerant cohort comprising the main canopy become very large during this stage. Mortality continues as decay and other agents kill occasional trees. Snags and logs produced during this stage begin to accumulate and are often large enough to have significance for wildlife.

**Figure 34 left. Vertical diversification.** This early, old-growth forest has a Douglas fir main canopy, with grand fir and western hemlock present in a multitude of sub-canopy sizes. Large gaps and horizontal variability are lacking.

**Figure 35 below. Classic old-growth – horizontal diversification.** Structural patterns set up during the vertical diversification stage further develop. Large openings, patches of dense trees, and large, old trees transform the homogeneous canopy into a mosaic of very small patches.

**Figure 36. Pioneer cohort loss.** The Douglas fir cohort established following a previous stand-replacement disturbance will ultimately be replaced by western hemlock and Pacific silver fir, the assumed climax community at this high elevation site.

## Horizontal diversification

This stage is considered by many as classic old growth. Some trees within the original cohort of large trees die standing; others fall, often taking one or several smaller neighboring trees down with them. Gaps created by tree mortality increase light levels and nutrient availability in the understory. This pattern of gap formation, followed by infilling from trees in the understory, creates the horizontal diversification indicative of this stage in stand development (Figure 35). In addition, tree mortality is often higher near pre-existing gaps—gap expansion accentuates horizontal variability at the stand level. In eastern Washington, this stage often begins when the stand is between 250 and 350 years old, depending on site location and productivity. Since dominant species such as ponderosa pine, western larch, and Douglas fir easily can live for 500-800 years, this stage may last for several centuries.

## Pioneer cohort loss

The final stage of stand development begins when the last of the original cohort dies. At this point, none of the trees in any of the canopy levels are those that originated immediately after the initial disturbance (Figure 36). The structural presence of the original cohort, in the form of snags and logs, extends for a century or more after the last giant pine, larch, or fir dies. The word ***climax*** is often used to describe forests dominated by Engelmann spruce and subalpine fir, or western hemlock and western redcedar, and falsely implies an endpoint to forest succession. The phrase is discouraged by many ecologists, as it represents an idea, not reality. Succession does not really stop when it reaches this point. This final stage of the stand developmental sequence is rarely reached, especially in the disturbance-prone Eastside environments. It is likely that some event will occur to divert a forest from this idealized developmental trajectory. The most common event is an intermediate disturbance, which serves to increase structural heterogeneity and may reset the developmental sequence to an earlier stage.

## Other scenarios

The idealized stand-development sequence presented above is not the dominant scenario in eastern Washington. It is limited to wet forests experiencing stand-replacing events, with countless variations. The catastrophic wildfire scenario described above assumes complete mortality for all biological legacies. With such fire-resistant trees as western larch or ponderosa pine, chances are high that a stand-replacing fire will not kill every tree. Even in the hottest and most severe events, such as the Tripod Fire of 2006 or the White Mountain Fire of 1988,

## Key to stand development stages following stand-replacement events

The following key may be used for any stand-replacement scenario, including but not limited to development following stand-replacement wildfire, as described above. Throughout this key, the phrase ***original cohort*** refers to the first group of trees established following the stand-replacing event. Excluding legacy trees, this will be the only place that trees with low relative shade tolerance appear in the key. This includes western larch, but also ponderosa pine and Douglas fir when found in a moister vegetation zone, such as the grand fir or western hemlock zone. The phrase ***shade-tolerant cohort*** refers to trees establishing long after the original cohort. It will be useful to determine the vegetation zone (page 18) before using this key. While this key has been widely field tested in eastern Washington, stands may exist that do not key out properly. In these situations, relax the percentage values and retry.

1 Legacy trees present – trees obviously older/larger than the others, or a subset of the largest trees with charcoal on bark . . . . . . . . . . 2
No legacy trees . . . . . . . . . . 4

2 Legacy trees cover < than 20 % canopy cover . . . . . . . . Stand with legacies 4*
Legacy trees have ≥ 20 % canopy cover . . . . . . . . Two cohort stand 3

3 Each cohort must be keyed out separately
Older cohort . . . . . . . . . . 8
Younger cohort . . . . . . . . . . 4

4 Original cohort (live or dead) ≥ 25 % of main canopy stems . . . . . . . . 5
Original cohort < 25 % of main canopy stems . . . . . . . . 10

5 Young, planted or naturally reseeded original cohort trees < 10 years old . . . . . . . . . . **Cohort establishment**
Not as above . . . . . . . . . . 6

6 Young, planted or naturally reseeded original cohort trees 5-20 years old, abundant shrub cover . . . . . . . . . . **Canopy closure**
Not as above . . . . . . . . . . .7

7 Young original cohort trees, not yet overhead, overlapping crowns, shrubs present ≥ 15 % . . . . . . . . . . **Canopy closure**
Not as above . . . . . . . . . . 8

8 Original cohort canopy overhead, self pruning, scant understory . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **Biomass accumulation/stem exclusion**
Not as above . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 9

9 Original cohort canopy overhead, self pruning evident, shade-tolerant cohort seedlings present only in understory . . . . . . . . . . . . . . . . . . . . . . . . . **Maturation**
Not as above . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 10

10 Original cohort upper canopy, shade-tolerant cohort abundant and in several height classes, including main canopy . . . . **Vertical diversification / old-growth**
Not as above . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 11

11 Original cohort canopy patchy, large canopy gaps present, shade-tolerant cohort abundant in all canopy levels . . . . . . . **Horizontal diversification / old-growth**
All original cohort trees dead (snags or logs), shade-tolerant cohort abundant in all canopy levels . . . . . . . . . . . . **Pioneer cohort loss – old-growth****

* For legacy trees, refer to the individual sections for the relevant species.
** If the original cohort consisted of shade-tolerant species, the horizontal diversification stage will be equivalent to the pioneer cohort loss stage.

trees survived in ravines and around the edges of the burn. Fire boundaries are sometimes fairly abrupt, the result of a landscape feature capable of stopping a fire, such as a ridgetop or a stream crossing. In most situations, however, the boundaries will be either a gradual change from a burned to unburned area, or a mosaic of patches created by varying burn intensities (Figure 37). In situations where living biological legacies are not present, stand age must be determined by the stand-development sequence.

**Figure 37. Mixed-severity fire aftermath.** With increased stand densities, mixed-severity fires are now common in areas that previously supported only low-severity events.