Understanding the Connection Between Historic Range of Variation, Current Social Values and Developing Desired Conditions

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Abstract—Relationships between the development of desired conditions based on today's social values, and an understanding of the historic range of variability (HRV) are key to the implementation of ecosystem management. Relevant to the discussion are wildlife habitat values, forage production, economics related to wood resources, aesthetics and visual quality, changes in predicted and actual fire intensity especially within the urban interface. Potential risks to air quality, and risks associated with changes in insect and pathogen activities, and significant degradation of soil and aquatic resources are also discussed. The HRV for western larch and ponderosa pine cover types are described in terms of vegetation composition, structure, pattern and areal extent at broad- and mid-scale. They are also described in terms of broadscale fire regimes and mid-scale processes mediated by insects and pathogens.

Introduction

Understanding the significance of the historic range of variability (HRV) or "reference conditions" can give land managers a tool to judge the feasibility, or the probability of providing for current day social values on public lands. Western larch and ponderosa pine forest communities are particularly useful for exploring the connection between social values and the ecological values represented by HRV because these forest types make up much of the interface areas between forest and human communities.

Although there is evidence that humans used forests of the Northern Rockies for thousands of years, more intense use and sometimes, conflicting uses have increased significantly in the past 100 years. Because of this, the implications for managing outside of historic disturbance regimes become more significant. Vegetative disturbance prior to European settlement produced vegetative mosaics in ponderosa pine and western larch cover types that allowed for frequent, low intensity fires and infrequent insect and disease outbreaks. As human settlement increased after the turn of the century, the need to protect settlement from wildfire increased. Therefore, fire suppression became a significant factor causing the distribution of vegetation cover types to shift to trees that had once been held in check by frequent fires. These included Douglas-fir, grand fir, subalpine fir, western redcedar, and western hemlock in place of ponderosa pine, western white pine, lodgepole pine, and western larch. These forested settings became much more susceptible to large outbreaks of insects, diseases and large wildland fires. The change in vegetation and subsequent change in disturbance regimes affected a variety of social conditions, including location and need for protection of human settlements, reduction of vegetative size classes, availability of forage, and recreation settings.

Shrubland/grassland cover types also provide important social values in terms of wildlife habitat and forage for livestock. Big game winter ranges are most commonly associated with the open conifer, shrubland/grassland interface. With the exclusion of fire and invasion of housing tracts, this important habitat and resource has declined. This decline has resulted in reductions of important forage for both livestock and wildlife, often pitting the two herbivore classes against one another for priority use. Losses of these cover types have also occurred on private land due to urban interface and development, making the social value of these cover types even greater on public lands.

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A variety of demographic research has indicated that migration from urban to rural settings has increased significantly in the past 20 years, particularly in the West. Due to both expansion of urban boundaries and the desire to "live in the woods," more people are building homes in the urban/wildland interface. That same urban/wildland interface is also showing a significant change in the fire interval and intensity. Data from the Upper Columbia River Basin (Quigley 1997) indicates that both fire intervals and the percent of crown fires have increased five-fold since the 1950s. Although the public is beginning to recognize the need for prescribed fire to decrease tree density and the risk of wild fire, they also are concerned about the potential effects on their "backyard," along with health risks associated with increased smoke.

Historic Forest Land Use

When European settlers arrived in the upper Columbia River basin, they found vast, untouched forests. Of greatest interest to these early settlers were stands of western white pine, ponderosa pine and western larch that occupied the lower elevations of the mountain ranges. All of these species were highly valued for their wood. Mills sprung up across the region to exploit the abundant wood supplies. A 1945 Forest Service report indicates that Montana and Idaho forests had about 14 percent or 31 billion board feet of the nation's total standing sawtimber inventory of ponderosa pine at that time. By contrast, the nationwide western larch sawtimber inventory was estimated to be about 24 billion board feet in total with Montana and Idaho forests supporting over 15 billion board feet.

Economics were a major factor in determining which of the forest types and the types of areas were harvested. Beyond meeting local demand for development, the most valuable and marketable wood was white pine, followed by ponderosa pine. Value was highly dependent upon accessibility, because log transportation was by railroad, chutes, and river drives.

In many cases, the highest quality, easiest to reach timber was found on state and privately owned lands. These lands were located frequently at the lower elevations of major drainages. Federally held lands, which were managed by the USDA Forest Service, were not as desirable for harvest by the major mills because they were often situated in rougher terrain, at higher elevations and supported stands which contained substantial amounts of inferior species such as lodgepole pine, Douglas-fir, grand fir and subalpine fir.

In a 1926 Timber Management Plan for the Lolo National Forest, it is stated, "Until the private timber becomes more scarce, the large mills will not seek Government timber. Because it will require heavy outlays for railroads or flumes, the timber in most of the larger drainages will eventually go to owners of large sawmills. These chances are the most inaccessible now and will probably be among the last in demand." This same plan reports that between 1907 and 1925, harvest from the Lolo NF had amounted to 176.7 million boardfeet or about 9.3 million per year. This forecast proved to be true. It was not until after World War II that there was significant demand for the national forest timber in Region One. Technology, developed during the war, allowed a rapid tapping of the huge reserves. The bulldozer, cheap petroleum, and the diesel-powered truck changed the character of logging and allowed cheap access to the timber on the National Forests. Soon an extensive road system was extended across the forests. Sale economics were seriously considered, thus the harvest focused on the species of highest value, western white pine, ponderosa pine, and western larch.

Historic Range of Variability for Western Larch and Ponderosa Pine Cover Types

Although the attributes of interest to characterize vegetation are likely to be similar at all scales; the level of detail in these attributes will vary considerably according to the scale of analysis. For example, cover type is of interest at all scales but at the broadest scale, broad physiognomic classes such as "shade intolerant forest" may provide sufficient information; whereas at the mid scale, this cover type may be characterized as "ponderosa pine"; and at the fine scale it is identified as a "ponderosa pine/Douglas-fir/grand fir forest type." The data available at each scale largely dictate the level of detail we can use to characterize historic range of variability. For the purpose of this paper, broad scale is defined as the Interior Columbia River Basin, the mid scale as an ecological section or group of sections identified by the National Forests contained within the sections, and the fine scale as a project area or stand. Following are examples of both broad- and mid-scale HRV descriptions. At the scale of the stand, many local studies have been completed documenting fire histories and successional pathways the stands have taken over time (Arno and others 1985; Shearer 1986). The context of both the broadscale and mid-scale HRV provides a means to interpret the finer resolution data on such things as site fire history as it relates to the broader fire regimes. Similarly, insect and disease activities in stands are considered within the context of broader scale historic range of variability of the insect and disease regimes.

Broad Scale Vegetation—The findings at the broad scale, Interior Columbia River Basin, give us a partial view of the historical dynamics and how composition of the western larch and ponderosa pine forests have changed over time. In describing ecological changes in space and time, the Columbia River Basin Assessment defined HRV as 75 percent of the full range of historical conditions prior to Euro-American settlement (Quigley and others 1997). This range is described for the basin through model simulations and by potential vegetation groups and physiognomic types in table 1.

Simulations completed for the Columbia River Basin Assessment indicated that western larch and ponderosa pine historically occupied from one-third to over one-half of the basin (Quigley and others 1997). Current extents of the ponderosa pine and western larch cover types are considerably less compared to their calculated HRV (table 2). For the Basin as a whole, a 2 percent reduction in ponderosa pine and 36 percent reduction in western larch cover types have occurred. Much of this area has changed to the more shade tolerant grand fir and Douglas-fir forests.

Table 1—Changes in coverages of broad classes of vegetation.

Potential vegetation group	Physiognomic types	Historic range of variability	Federal lands current percent	All lands current percent
Dry forest	Early-seral shade intolerant forest	7–15	17	15
	Mid-seral shade intolerant forest	16–21	25	35
	Late-seral shade intolerant multi-forest	7–10	10	8
	Late-seral shade intolerant single-forest	21–47	4	5
Moist forest	Early-seral shade intolerant forest	14–23	14	13
	Mid-seral shade intolerant forest	28–35	33	36
	Late-seral shade intolerant multi-forest	14–17	4	3
	Late-seral shade intolerant single-forest	7–10	1	1

Also based on the Columbia River Basin Assessment, forest densities have increased significantly. A large portion of the current forests consists of overstocked conditions atypical of the historical period. Quigley and others (1997) reported a shift toward a more homogeneous landscape with a significant increase in mid-seral forest communities at the expense of the early and late-seral forest communities (table 1).

For the historical period, prior to Euro-American settlement, the influence of mixed severity and high severity fire regimes probably led to the persistence of residual large-tree structures of approximately 20 percent canopy cover commonly throughout the range of the western larch and ponderosa pine cover types (Quigley and others 1997). This large-tree structure, that occurred as single trees or in large groups, is currently much less abundant.

Broadscale Fire Regimes—Reference conditions in terms of composition, structure, and pattern of forests in the Northern Rocky Mountains developed under characteristic fire regimes. The findings for the Interior Columbia River Basin show major changes in fire severity potential in the current period. Table 2 indicates the significant overall shift in fire regimes for the Northern Rocky Mountains.

Midscale Vegetation—At the mid-scale, various studies have provided more detailed resolution of the attributes of HRV. Both Hessburg (1999) and Hagle and others (1995) relied on aerial photographs taken as part of a broad forest survey in the 1930s (USDA 1948). Hessburg (1999) used the photos to analyze vegetation changes in a sample of 6th HUC code watersheds from two National Forests, the Flathead National Forest in Montana and the Wenatchee National Forest in Washington. From this, they developed landscape composition, structure and pattern statistics to help guide management. In describing vegetation change in space and through time, Hessburg (1999) defined HRV as 80 percent of the full range of historical conditions prior to Euro-American settlement. This range was described for composition structure and pattern within selected sample 6th HUC code watersheds and used a comparison of photo-interpreted attributes from the 1930s photos to present day interpretations to identify trends in specific landscape attributes. They reported a significant decrease in areal extent of western larch cover type from historic to present on the Flathead National Forest, and only a minor decrease overall in the extent of ponderosa pine cover type on the Wenatchee National Forest (table 3a).

In addition to the land coverage and patch size changes for western larch (table 3b), Hessburg (1999) found significant changes in structure classes on the Flathead National Forest. Reductions in the early-seral structure classes were

Table 2—Fire regime changes in the Northern Rocky Mountains.

Severity/frequency class	Historical	Current	Absolute change	Proportional change
	percent			
Lethal frequent	0.4	6.8	6.4	1600
Lethal infrequent	10.8	35.6	24.8	229.6
Lethal very infrequent	15.4	30.2	14.8	96.1
Total lethal	**26.6**	**72.6**	**46**	**172.9**
Mixed frequent	26.3	0.1	–26.2	–100
Mixed infrequent	19.4	22.0	2.6	13.4
Mixed very frequent	4.0	0	–4.0	–100
Mixed very infrequent	9.1	0	–9.1	–100
Total mixed	**58.8**	**22.1**	**–35.3**	**–60.0**
Non-lethal frequent	1.2	0	–1.2	–100
Non-lethal infrequent	4.4	4.8	0.5	9.1
Non-lethal very infrequent	8.7	0.1	–8.6	–98.9
Total non-lethal	**14.3**	**4.9**	**–9.3**	**–65**

Table 3a—Cover type changes reported by Hessburg (1999) for two National Forests of the Columbia River Basin.

Cover type	Historical mean	Current mean	Mean difference	Proportion
		percent		
Western larch[a]	7.8	6.4	–1.4	–0.18
Ponderosa pine[b]	55	53	2	–0.04

[a]Flathead National Forest
[b]Wenatchee National Forest

Table 3b—Changes in patch size reported by Hessburg (1999) for two National Forests of the Columbia River Basin.

Cover type	Historical mean	Current mean	Mean difference	Proportion
		acres		
Western larch[a]	209	111	–98	–0.47
Ponderosa pine[b]	286	31	–255	–0.89

[a]Flathead National Forest
[b]Wenatchee National Forest

observed, as well as increase in the dense, mid-seral structure classes.

Change land in coverage of ponderosa pine on the Wenatchee National Forest was minor, but changes in patch size were highly significant with an 89 percent reduction in mean patch size (table 3b). Hessburg (1999) also reported significant changes in structure classes in this sample. Reductions of early-seral structure classes were accompanied by an increase in the dense, mid-seral structure classes, and a very significant reduction of the old forest structure classes.

Hagle and Johnson (1999) analyzed changes in a 76,000-hectare sample (6th code HUC scale) drawn from the 8 ecological sections of north Idaho and western Montana (Bailey and others 1994). Cover types and structure classes were interpreted using the 1930s photography as well as the maps and survey data resulting from the 1930s federal forest survey (Lewis and Stipe 1999). Forest composition and structure were compared to survey data and true color photography of the same locations taken in 1975. Changes over this roughly 40-year period, in the absence of both fire and timber harvest, were studied to better understand the successional roles of insects and pathogens.

This study provides further evidence of substantial changes in the vegetation in a relatively short time (table 4). Although vegetation in the landscapes occurring in 1935 may not represent the true historic range of variability across the ecological sections, it is likely to be a much better measure than were the conditions in 1975 or in the present.

In the dry potential vegetation types (PVTs), much of the ponderosa pine cover type had converted to Douglas-fir with only about half remaining in pine cover type. The real change may have been even more dramatic as indicated by the 1975 forest type in which nearly two thirds of the former pine type had a majority of Douglas-fir (by basal area) by 1975.

In the moist PVT types, western larch cover type was even more likely to be replaced by a variety of more shade and competition-tolerant species. Douglas-fir, grand fir and, somewhat surprisingly, lodgepole pine made the greatest gains in former western larch cover type (table 5). At higher elevations, subalpine fir increased considerably in the larch type.

Like the ponderosa pine type, little of the landscape that has converted to other species will revert to western larch

Table 4—Ponderosa pine forest type[a] and western larch forest type in 1935 and 1975. Change over 40 years in dry and moist potential vegetation types (PVT), respectively. (Hagle and Johnson 1999)

Physiognomic group	Tree species	1935 (hectares)	1975 (hectares)	Net change	Proportion change
		percent			
Dry PVTs	Ponderosa pine	26.8	16.3	–10.5	–0.39
Moist PVTs	Western larch	20.2	10.8	–8.2	–0.41

[a]Forest type was based on the most populous three tree species in a polygon.

Table 5—Fate of the 1935 western larch cover type: 1975 cover type and forest type of polygons, which were western larch in 1935. (Hagle and Johnson 1999).

1975 Cover type	Percent (hectares)
Western larch	25
Douglas-fir	19
Grand fir	19
Lodgepole pine	14
Subalpine fir	8
Cedar or hemlock	8

without the disturbance of fire or active management to provide opportunities for regeneration.

Changes in Fire, Pathogen and Insect Regimes Lead to Further Changes in Vegetation Patterns—The ability of ponderosa pine to maintain site dominance in the absence of fire or active management depends on their size and density. Stands of large pines which fully occupy the site have a much higher probability of retaining pine cover type than those which are young or have open canopy (table 6). Least likely to retain site dominance are seedling and sapling stands of pine. Without natural fire or active management few sites occupied by young or open stands of pine will still have pine cover types just four decades later.

Insects and Pathogens in the Landscape

As both native components of the forest, and, as in the case of white pine blister rust, established exotics, insects and pathogens alter landscape conditions through their activities. In turn, landscape conditions greatly affect the way in which insects and pathogens function. Hagle and others (1999) found that, in the absence of fires or active management, insects and pathogens controlled about 80 percent of successional changes. Despite their high level of activity over most of the pine and larch types, clearly, insects and pathogens alone do not maintain HRV. Tree species composition and the distribution of structure classes have changed in the absence of fire. As the landscape has changed, so have the ways in which insects and pathogens function in the landscape.

Table 6—Polygons with ponderosa pine cover type in 1935. Influence of developmental stage on retention of pine covers type. (Hagle and Johnson 1999).

1935 Structure class	Still pine cover type in 1975 (percent hectares)
Seedling/sapling	34
Pole-size, dense	41
Large trees, close canopy	76
Pole to large trees, open canopy	44

Pine Forests: Bark Beetle-Dominated Dynamics

In the seedling and sapling stage of pine forests relatively few insects or pathogens have significant effect on stands. Western gall rust, and root weevils girdle and kill individual trees but seldom greatly affect tree density. Needlecasts such as Dothistroma and Elytroderma are chronically severe in some areas and can slowly kill a majority of young ponderosa pines producing low-density forests, which mimic the effects of frequent low-intensity fires. Microclimate and genetics of local populations of both pines and pathogens greatly affect the course of development of gall rust, root weevils and needlecasts. For the most part young pine forests are genetically suited to offer resistance to local pathogens and insects. An advantage has resulted from long-term site dominance by ponderosa pine on these sites maintained by frequent partial-replacement fires.

Pole stage and overmatue stands favor bark beetles in pine forests. These forests have left behind their childhood diseases once they reach an average diameter of about 6 inches. At this stage, their greatest threat is probably overcrowding. If the competition doesn't kill them, bark beetles may. Until the stands average about 12 inches in diameter, pine engraver beetles, known as *Ips* beetles to many, prey heavily on stands weakened by competition and drought. They attack groups of trees, creating gaps, and probably mostly improving the overall condition of most of these overly dense, young forests. A recent study of successional patterns moderated by insects and pathogens found 45 percent of pole stage ponderosa pine stands sampled became low-density stands with large tree components over a 40 year period (table 7), with pine bark beetles pushing the changes (Kegley 1999). Almost another 40 percent were still classified as pole stage after 40 years, an expected outcome from consistent pressure from bark beetles. Harvested units were excluded from the statistics in this study and no fires occurred in the 48,800-hectare sample, which was scattered across northern Idaho and western Montana.

As the phloem thickens, *Ips* beetles move their attack to the occasional top of weakened or damaged trees. They are supplanted by the mountain pine beetle as the dominant stand influence. Infrequent large outbreaks and incessant small groups of mountain pine beetle kills were undoubtedly once a dominant force in pine type landscapes. The fuels generated by beetle groups and outbreaks probably fed ground fires into crown fires and provided mixed severity burns as well as the occasional stand-replacing event. Kegley (1999) found that more than ⅓ of large-tree stands were impacted sufficiently by bark beetles to be converted to seedling, sapling, or pole stage stands (fig. 1) in just 40 years. Another 40 percent of stands became low-density stands, which still had a significant component of large trees. Less than 20 percent of stands, which had been typified by large trees and closed canopies, remain in this condition throughout the 40-year period.

Where fires were not forthcoming or incomplete, individual survivors grew in relatively open conditions and were able to achieve great size and age. At this stage, stem decays became important sources of cavity nesting habitat. As heartwood decay advances in these individuals, breakage by

Table 7—Changes in overall size and density of Douglas-fir stands between 1935 and 1975, mostly as a result of root diseases and Douglas-fir beetle activities.

1935 structure class	Percent of Douglas-fir cover type in 1935	1975 structure class	Percent of 1935 structure class
Seedling/sapling	11	Seedling/sapling	4
		Small trees	48
		Large trees with close canopy	40
		Large trees with open canopy	7
Small trees	57	Seedling/sapling	3
		Small trees	56
		Large trees with close canopy	3
		Large trees with open canopy	37
Large trees with close canopy	1	Small trees	34
		Large trees with open canopy	58
Large trees with open canopy	32	Seedling/sapling	12
		Small trees	21
		Large trees with close canopy	5
		Large trees with open canopy	59

physical forces such as wind, snow or ice slowly removes a tree or two at a time. Western pine beetle is also important in killing these large, old trees. Generally, the attack involves only one or a few trees but does not reach outbreak proportions as sometimes seen in mountain pine beetle attacks. Annosum root disease has probably always played a minor role in pine forests but that role is poorly understood. Old individuals are seen to develop advanced root infections, which lead to slow decline, often with the final blow dealt by western pine beetle. The root pathogen is also seen infrequently in young pines associated with chronic patches of mortality in stands.

Douglas-Fir in the "Pine Type" Mixture: Root Pathogens and Bark Beetles Share the Spotlight

West of the Continental Divide, root diseases are the dominant influence in Douglas-fir forests, with Douglas-fir beetle outbreaks also important at times. East of the Divide, Douglas-fir beetle takes over the dominant role. In the pine type, patches of fungal root disease are more often small, less than 1 acre in size, but, they can be the largest biomass organisms known to man, and they have the potential to be very old, in excess of 1,500 years (Smith and others 1992). Ponderosa pine is not generally a preferred host for root pathogens (the most notable exception is annosum root disease).

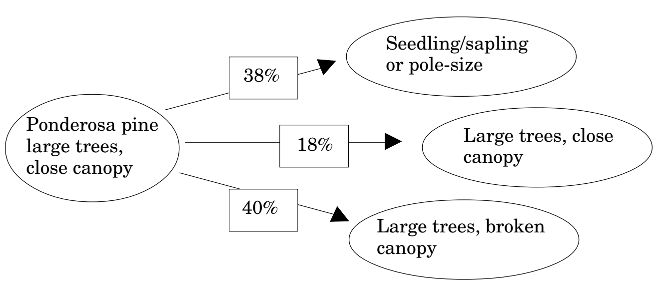

Figure 1—Structure changes of mature ponderosa pine stands in 40 years without the influence of tree harvest or fires. Pathways are largely driven by bark beetles.

Although the mycelium of root pathogens is mostly underground and insulated from heat and surface changes caused by fires, fire intervals greatly influence the ability of the fungal colonies to grow. Frequent low-intensity fires favor ponderosa pine and open spacing. Both of these conditions will tend to minimize the extent of root pathogens.

When sections of the landscape periodically escape fire for long enough intervals to convert to a majority of Douglas-fir and sufficient stocking for root closure to occur, the root pathogen colonies will slowly increase in biomass and subsequent root disease mortality will increase in extent and intensity.

Root pathogens have probably always played an important role in maintaining ponderosa pine on mixed pine/fir sites by reducing competition from Douglas-fir and grand fir. In the absence of fire or tree harvest, this function was seen to occur in nearly a third of the type over a 40-year period.

So what difference does it make which pathogens or insects are functioning in pine forests? The outcomes of pine beetle activities are very different from those that result from root diseases and Douglas-fir and true fir bark beetles as well (table 7). Among the more significant effects are the tendency for root disease afflicted stands to remain perpetually young as few trees reach old age, and a sustained shift in species composition. Once converted to Douglas-fir and grand fir most stands are expected to remain so even with root diseases and bark beetles killing many of the Douglas-fir and grand fir. From 1935 to 1975, 73 percent of ha of Douglas-fir stands remained Douglas-fir. Only 7 percent of ha converted to ponderosa pine cover type. Relatively few ha can be expected to progress to large-tree, close canopy conditions as well. With each generation of Douglas-fir and grand fir on site, the biomass of root pathogens is likely to increase, resulting in even shorter life expectancies for Douglas-fir and grand fir.

The longer that sites remain in the pine type with mostly Douglas-fir and grand fir cover, the more extensive and severe the root disease will become. Stand conditions maintained by severe root disease significantly alter the appearance and, probably, many of the functions of forests. Among the differences is the limited production of large-tree elements. Root pathogens kill trees of any age, thus through a lifetime of root disease, stands generally produce relatively few large trees where root disease is severe. Production of few large trees means there are few large snags to provide nesting and roosting sites and, when they fall, they are smaller "large woody debris" that deteriorate more rapidly than larger logs.

There is usually abundant regeneration except in the largest of disease patches where seed-availability can be limiting. The tall canopy is sparse, providing little site protection, and production of merchantable wood volume is low.

Stands tend to develop into mosaics of multistoried tree structures, with few large trees, dense saplings and, depending on the site type, abundant shrubs such as ninebark or mountain maple. As the shrubs age, their quality as wildlife forage declines.

Douglas-fir stands that have less severe root disease become susceptible to outbreaks of Douglas-fir beetle as they reach maturity. These outbreaks are not greatly different from those of mountain pine beetles in pine forests. The larvae are a food source, the large snags are available for cavity nests, the deadfall is fuel for potential fires, and the unburned debris provides soil amendments. Kegley (1999) estimated that about 20 percent of ha of National Forest in Northern Idaho and most of western Montana have become moderately to highly susceptible to significant effects from Douglas-fir beetle outbreaks, up from an estimated 3 percent showing significant effects from 1935 to 1975. Reactions of forest users to Douglas-fir beetle outbreaks are likely to be similar to their reactions to mountain pine beetle outbreaks in pine forests. For example, the Douglas-fir beetle outbreak, which was set off by ice and hail damage in Northern Idaho in 1997, has generated considerable public interest.

Western Larch Forests, Root Pathogens and Bark Beetles Work With Fire to Maintain Balance

Moist sites where western larch cover type was historically important initially had a high proportion of Douglas-fir or grand fir. These mixed stands have some of the greatest root disease effects seen in the Northern Rockies. The habitat types on which larch grows appear to be among the most conducive for root pathogenic fungi (Byler and others 1992). The omnipresent root pathogens tend to remove much of the Douglas-fir and grand fir from the mixed stands, thereby thinning the stands and further favoring the larch. In the past, the combination of root disease, low- intensity ground fires, and mixed severity fires probably worked in concert to maintain larch cover types. Even in the absence of fires, root disease was estimated to cause retention of larch cover type on as much as 25 percent of ha of forest in northern Idaho and western Montana (Hagle 1999). This is a significant role for root pathogens but still no replacement for fire.

Although the pathogens are nearly always in evidence at the stand (or polygon) level, at any one time most trees will appear outwardly healthy. Large to small groups of dead and dying trees are normally seen within the stand. These represent "hot spots" or clumps of particularly active inoculum, and if the trees are very large, Douglas-fir beetle and fir engraver beetle attacks are common. With time, symptomatic and attacked trees develop in places, that may have gone decades without evidence of infection (van der Kamp 1995; Theis and Nelson 1997).

Fire returns, which are sufficiently frequent to allow western larch to become well-developed as the dominant species in the forest, may serve to reduce fungus biomass somewhat by keeping the size of grand fir and Douglas-fir root systems small, making it difficult for pathogens to maintain biomass. A single generation of Douglas-fir appears to be sufficient to rebuild the fungus biomass. As maturing Douglas-fir are killed by root pathogens and Douglas-fir beetle, canopy openings develop. Seedling Douglas-fir and grand fir will begin growing in the openings. Generations become abbreviated in these openings with young trees succumbing to root disease before or shortly after reaching cone-bearing age. The forest becomes a mosaic of increasingly uneven-aged patches. Since it may take a generation or two before species composition is again shifted mostly away from Douglas-fir and back to western larch (with stand replacement fire), large root disease patches may develop as colonies merge.

When burning occurs, and there is sufficient seed source for larch to regenerate in the stand initiation phase, the large biomass of root pathogens will again play an important role in removing Douglas-fir, and to some extent, grand fir from the stands. The stage is then set for conversion back to western larch for perhaps two or more generations.

In the absence of fire, the species composition in the patches is likely to shift quickly toward Douglas-fir and grand fir. The amount of the site occupied by grand fir is eventually more than that by Douglas-fir because of significantly longer survival of grand fir in the presence of a large root pathogen biomass. Root disease and bark beetles are, as in pine type, unable to perform the functions of fire in these systems. Without fire, there is limited opportunity for larch to regenerate.

The cycle is broken without larch. Root pathogen biomass builds to a point of indefinitely dominating successional dynamics. Large trees become increasingly rare elements and the tallest canopy becomes sparse while the low canopy, that produced by saplings, may be very dense in patches. Fire behavior, forage, and habitat characteristics can be very different from those that were typical of larch forests.

Social Implications of Managing Within the Historic Range of Variability

Wood Utilization—Ponderosa pine was and continues to be preferred species for its clear, straight-grained wood. It is used primarily for boards. The highest-grade lumber produced from old growth trees was and continues to be utilized for applications such as window frames, sash, trim, molding, siding, furniture, and flooring. A substantial amount of lower-quality ponderosa pine has been utilized for paneling.

As the largest, highest-grade trees have been depleted, utilization standards have changed to accommodate the poorer wood quality of smaller diameter trees with a greater frequency of knots. To achieve clear lengths for many applications, knots are sawn from boards and the resulting clear lengths are joined and glued to produce an artificial clear effect. While this process achieves an appearance of clear wood, the product isn't completely satisfactory. The various strips that are joined in the process will finish differently and lack the durability and aesthetic value of the true clear ponderosa pine board. There continues to be a strong market for the premium grade boards. This material is used by furniture makers and hobby woodworkers alike. One might expect that this market will persist over time. The highly valued, clear ponderosa pine board can only be produced from old growth trees.

Western larch by contrast is not valued for boards, but is very desirable for many other applications. Larch is an excellent material for dimension lumber, plywood, utility poles, sawn beams, laminated beams and even roofing shakes. Early on, after settlement, larch was used extensively for mining timbers. The tight, straight-grained wood produced in older larch is very strong and desirable in support applications. In the current market place, historic lumber of large dimension is commanding very high prices. Recently in the Missoula market area, 12 by 12 sawn larch beams were advertised at $1/board foot. Applications are being made to produce a variety of chemical products from larch stumps.

Forest product availability and size is affected by the forest composition and structure. As stand density and stems per acre increases, tree size decreases thus reducing the availability of large sawlogs and increasing the availability of small logs and poles. This has resulted in a significant change in sawmill production capability, sometimes requiring a "retooling" of sawmill infrastructure, and in some cases the elimination of forest-related industry in small communities. This has consequences within the economic and social structure of those communities.

Habitat and Forage—The reduction in the use of fire to control tree density and expansion of undesirable species, along with the desire to "control" wildfire, has led to a reduction of meadows and open stands of trees that historically have been available for domestic and wildlife forage (Arno and Gruell 1986). A general increase in stand density and canopy coverage has led to significant declines in all shrubland/grassland cover types that were dispersed throughout almost all coniferous cover types as non-forested openings. This has been observed qualitatively by comparing historical photos of forested landscapes with more recent photos across much of the western United States. The ponderosa pine cover type is a good example to use to understand the connections between HRV, social values, and desired conditions in rangeland settings.

The ponderosa pine cover type and the associated shrubland/grassland cover types (bitterbrush/bunchgrass, sagebrush/grassland, fescue/bunchgrass, and wheatgrass/bunchgrass) occurring as understory and interfacing with the ponderosa pine cover type have experienced sharp declines due to invasion of Douglas-fir and juniper. The Juniper/sagebrush cover type was documented to have increased by 160 percent and is at ecologically significant high coverages compared to historic levels.

As stand density and canopy coverage have increased from invasion of Douglas-fir and juniper, important shrub/grass cover types, and understory communities have declined in coverage. These declines have lead to ecologically significant minimum coverages of the shrub/grass cover types; falling outside of the historic range of variation. Ponderosa pine and the associated shrubland/grassland cover types evolved under frequent, low intensity fire regimes, which have been interrupted in the last 100 years, pushing these cover types outside the historic range of variation.

In some forests, increasing frequencies and severities of defoliation and cone predation by western spruce budworm has slowed the advance of Douglas-fir into adjacent grasslands. Although useful, the effects of western spruce budworm have been too limited in scope to replace the important functions of fires.

Although not yet demonstrated, the loss of large trees and subsequent loss of large snags and logs are likely to be emerging issues as a result of the shift to shorter-lived tree species. Douglas-fir and grand fir have relatively limited abilities to produce the large, hard snags valued as cavity nesting sites.

By understanding the fire disturbance regimes, which resulted in the composition, structure, and pattern of the ponderosa pine cover type and associated shrubland/grassland cover types, land managers can tailor management to mimic these natural disturbance processes and return to coverages within the historic range of variation. This will once again produce the social values associated with these types. If these habitats and ecological processes were maintained within their historic range of variability, the wildlife species that once survived in those situations will once again be able to flourish.

Recreation and Aesthetic Values—Increased stand density along with increased insect and disease activity and the resultant susceptibility to large wildfires has minor effects on recreation opportunities. These effects tend to be very localized and may affect specific areas that people return to each year. Access through the forests becomes more difficult as stand density increases. Because of the large amount of open space in the intermountain West, this has not been a significant factor influencing recreation activities.

Perhaps of greater concern is aesthetic impact of losses of ponderosa pine and western larch. Both species are significant components of the scenery in western Montana and northern Idaho. The western larch cover type in the Intermountain West is 35 percent less than it was 100 years ago. Ponderosa pine cover type is 25 percent less. Stands of large, old ponderosa pine remain in only a few places and although the larch cover type is still present in sufficient numbers to present a spectacular display of fall color, the downward trends in both species is a cause for concern.

Conclusion

This paper has pointed out several significant scientific reasons for managing vegetation within a historic range of variation. Any decision about manipulation of vegetation, whether within or outside the HRV, ultimately becomes a social decision. As long as humans interact with and utilize forested settings, there will be a need to approach these settings as designed landscapes. Nature could run its course; however, it may not be the course that people desire for it to run. Rene Dubos, author of *So Human an Animal* once wrote, "Nature is like a great river of materials and forces that can be directed in this or that channel by human intervention." As the Forest Service and other land management agencies make decisions about vegetative changes, new landscape patterns will be created affecting many social systems, from recreation settings to sustainable communities. The hope is that these decisions will lead to what Dean Apostol and Nancy Diaz identified in their book *Forest Landscape Analysis and Design* as "a more enlightened, purposeful, and objective development of forested landscapes."

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