Maturity Selection versus Improvement Selection: Lessons from a Mid-20th Century Controversy in the Silviculture of Ponderosa Pine

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ABSTRACT

Two rival silvicultural systems for promoting multiaged ponderosa pine stands emerged in the 1930s and 1940s. Maturity selection was developed to move the vast ponderosa pine (*Pinus ponderosa*) acreage in eastern Oregon and Washington into regulation to limit bark beetle losses. In the Southwest, improvement selection was designed to improve residual growing stock by making stands less susceptible to wind, lightening, and dwarf mistletoe. The primary difference between the systems was the treatment of undesirable smaller trees. Maturity selection tended to ignore them whereas improvement selection removed them. Improvement selection appeared to place a greater emphasis on the future whereas maturity selection focused more on current economic values. The controversy subsided by 1960 because of increased interest in even-aged systems. Although these systems have largely been forgotten, they provide interesting insights to the current trend of increased use of multiaged systems. Both systems involved greater volume removals at longer cutting cycles than current systems.

Keywords: *Pinus ponderosa*, uneven-aged, multiaged, silviculture, single tree selection

The history of ponderosa pine (*Pinus ponderosa* P. & C. Lawson) management in North America features cycles in the popularity of silvicultural methods to achieve a variety of goals. Some of these cycles have paralleled trends in other forest types; others were the result of the unique flexibility of ponderosa pine silviculture. During a surge of interest in multiaged silviculture in the 1930s and 1940s, two approaches for selecting individual trees for retention in multiaged stands emerged in different parts of the ponderosa pine range. An approach known as "maturity selection" was developed for forests in eastern Oregon and Washington, while an alternative approach known as "improvement selection" was developed for forests of northern Arizona and New Mexico. Proponents of each approach argued the merits of their respective systems in the pages of the *Journal of Forestry*; these arguments often were bitter and involved silviculture expertise from throughout the United States, but consensus was never reached. Before this controversy could be resolved, management of ponderosa pine shifted from an era that emphasized multiaged systems featuring individual tree selection into an era that emphasized even-aged systems. Both maturity selection and improvement selection systems were shelved and soon forgotten. In recent decades, there has been a renewed interest in multiaged silviculture of ponderosa pine that encourages complex stand structures and methods to accelerate the development and restoration of ponderosa pine forests. The objective of this article is to revisit the maturity selection versus improvement selection controversy to identify key differences between these two systems and, with the clarity of hindsight, assess their relative merits.

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Ponderosa Pine

Ponderosa pine is one of the most widely distributed pines in North America, occurring from Mexico to British Columbia and from California to Nebraska. In many places, ponderosa pine forms pure, multiaged stands where frequent, low-intensity fire historically maintained low overstory densities and open understories. These stands generally occur on sites with relatively low productivity in contrast to stands of ponderosa pine mixed with various other conifers that occur on sites with higher productivity. Eastern Oregon and northern Arizona contain some of the largest contiguous forests of pure multiaged ponderosa pine stands. These populations are often described as different varieties of ponderosa pine with var. *ponderosa* in the Pacific Northwest and var. *scopulorum* in the Southwest (Read 1980).

Early Management

Early 20th century harvesting in ponderosa pine stands was generally an opportunistic activity that removed merchantable material. This harvesting was accomplished through railroad logging and horse skidding (Munger et al. 1936) and this technology dictated to a large degree what could be economically removed. In the 1920s and 1930s, the availability of crawler tractor skidding, truck transportation, and other improvements in logging technology increased logging flexibility and reduced fixed unit area costs (Munger et al. 1936). Increased logging flexibility provided opportunities for new silvicultural methods in the ponderosa pine types. Heavy cuttings necessary to justify the higher costs of railroad and horse logging were no longer necessary and thus the cutting intensity could be reduced. This set the stage for the eventual development of new systems for selection silviculture in ponderosa pine.

Although these early harvest treatments were classified as "selective," the residual stocking was very low and only unmerchantable trees were left. By the early 1930s, private timber companies had cut over most of their lands in central Oregon and sought increased access to national forest timber (Joslin 2007). Early efforts by the Pacific Northwest Forest and Range Experiment Station [1] (hereafter, "PNW Station") were focused on developing methods to make ponderosa pine management both sustainable and profitable. On National Forest and Indian reservation land, a system of heavy removals was developed for leaving some fast-growing trees of high vigor (Clapp 1912). In the Pacific Northwest, this evolved into a more regulated system of removing 75–85% of the merchantable volume (Meyer 1934, Munger and Briegleb 1942). This system was based on the assumption of a future harvest entry in 40–75 years; Brandstrom (1937, p. 142) considered the entries so heavy that selection treatments could be described as "not far removed from clear cutting." In the Southwest, aggregated spatial patterns of age classes favored a group selection where older "yellow pine" groups were cut and younger groups were left uncut. To meet minimum volumes for economic harvest treatments, removals were heavy (4,000–6,000 bd ft) and entries were anticipated on 60- to 100-year cycles (Pearson 1950, p. 47).

Maturity Selection

Several events coincided in the Pacific Northwest to affect the changes in ponderosa pine management. On the west side of the Cascade Range in coast Douglas-fir (*Pseudotsuga menziesii* var. menziesii [Mirb.] Franco), Brandstrom (1933) showed the economic superiority of the crawler tractor to the donkey engine and railroad spurs. This efficiency, coupled with a network of permanent roads, would allow loggers to make a light initial cut to liquidate overmature trees with high stumpage conversion value and to increase growth of valuable residual stock. A subsequent study by Kirkland and Brandstrom (1936) provided a strong economic justification for "selective" cutting in coast Douglas-fir. Although the silvicultural aspects of this work were later discredited—and Munger, who was director of the PNW Station, would not approve publication through the station (Munger 1967)—this work was published through the Pack Foundation and became one of the more influential works in North American forest management (Munger 1950, 1967, Curtis 1998, O'Hara 2002).

A major tree-killing insect of ponderosa pine in the Pacific Northwest is the western pine beetle (*Dendroctonus brevicomis* LeConte), which typically kills large-diameter and weakened trees. Building on a tree classification by Dunning (1922), Keen (1936, 1943) developed a classification for individual trees that combined elements of tree age and crown vigor (Figure 1). This system included four age classes and four crown vigor classes, or a total of 16 categories of tree condition. These tree classes were strongly related to mortality (Salman and Bongberg 1942) and became a primary criterion for tree removals in selection systems.

Brandstrom's (1937) analysis for ponderosa pine in central Oregon focused primarily on economic factors affecting the feasibility of a lighter selection system than the heavy cutting used previously in the Pacific Northwest. He named this procedure "maturity selection" because it was based on the financial and biological maturity of individual trees (also see Munger et al. 1936). The financial maturity component was based on removing high-value and overmature trees and leaving high-value trees that were also vigorous. The biological component was based on Keen's crown vigor classes (Figure 1). Brandstrom (1937) and other subsequent descriptions of the maturity selection system (e.g., Munger and Briegleb 1942) emphasized the strong correlation between financial and biological overmaturity. For example, all trees in Keen's age classes 1 and 2 were retained while older trees in Keen's age classes 3 and 4 were cut or were retained depending on their diameter and log grade composition (Table 1). About 40% of the total volume was removed; this represented a substantial reduction from previous cutting practices and led to the description of this method as a "lighter selection."

The maturity selection method was recommended by the PNW Station as a tool to move a greater proportion of these stands into regulation or a more consistent balance between growth, harvest, and standing volume over time. Regulated stands were recognized as desirable to limit bark beetle losses and convert stands with zero net growth into more productive stands (Munger et al. 1936). By only removing half as much volume as in the previous heavy cutting, the expectation was that twice the area could be cut annually, and the entire administrative unit or working circle could be placed under control in half the time. In addition, bark beetle losses and slash disposal costs could be reduced and stand growth would be higher because residual stocking was greater. The 40% volume removal of the maturity selection system was expected to result in 30-year cutting cycles.

It is the economic justification of the maturity selection system that stands out in its development. Bruce (1939) characterized the new solution as arranging the trees in order of their net percentage earnings and then cutting the proportion of the volume needed beginning with the trees with the least net percentage earning. A requirement for implementing maturity selection was

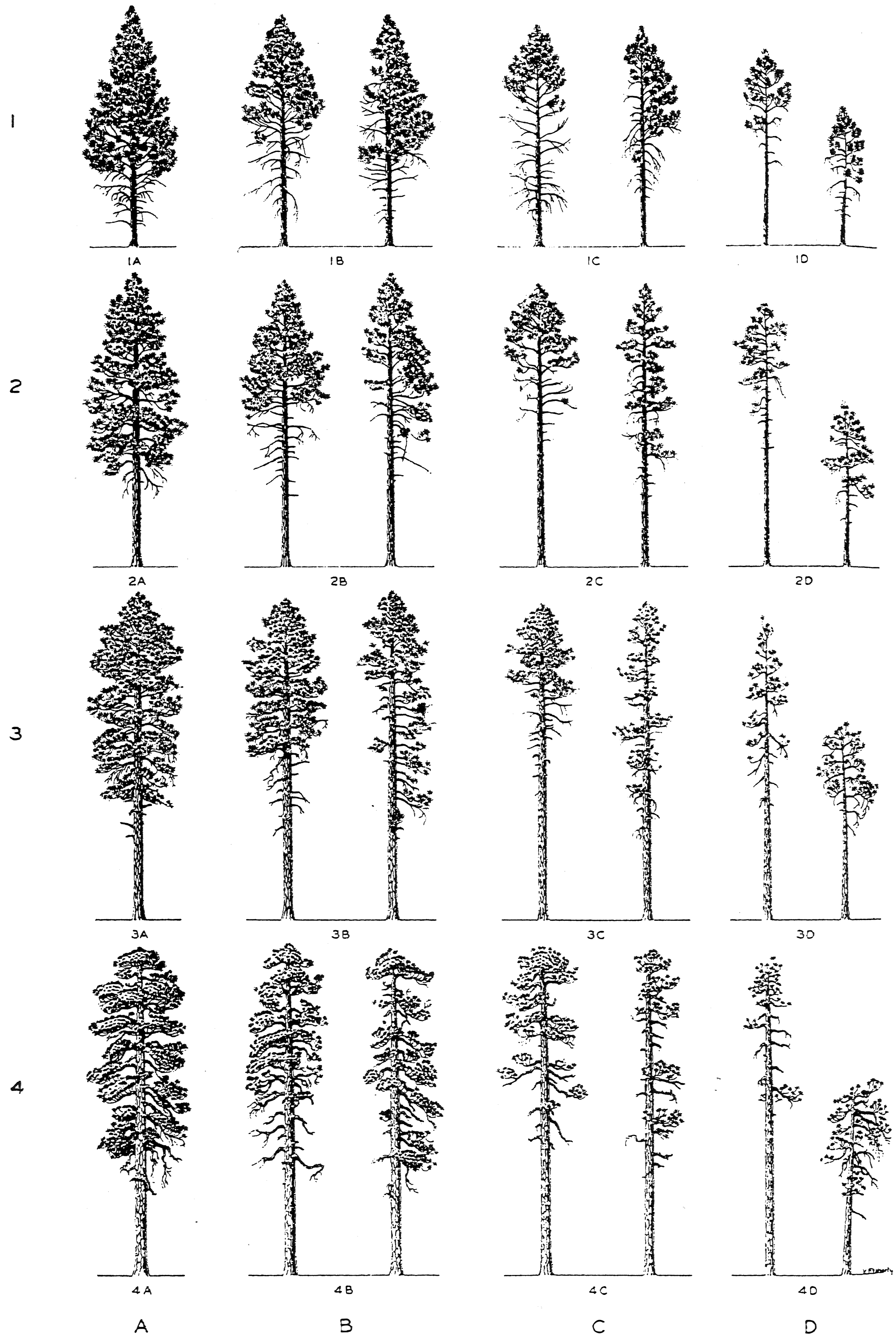

Figure 1. Keen's tree classes showing tree age classes 1–4 and vigor classes A–D. (Source: Keen 1936, 1943).

Table 1. Minimum diameters for a maturity selection cut in central Oregon based on Keen tree classes (Figure 1).

Keen tree class	Log grade comparison (first log grade–second log grade) 1–1	1–2	1–3
1 and 2	None	None	None
3A	27 in.	29 in.	38 in.
3B	24 in.	25 in.	31 in.
3C and D	20 in.	21 in.	23 in.
4A	All	All	All
4B	All	All	All
4C and D	All	All	All

Three log grade comparisons are shown. For a given log grade, smaller trees would be harvested in lower vigor classes in age class 3. All trees would be cut in age class 4, but no trees would be cut in age classes 1 and 2. This example assumes a 50% cut for different log grade compositions.
Source: Munger and Briegleb 1942.

knowledge of an approximate present value of every tree or of every Keen tree class. This form of "zero margin cutting" assessed the economics of individual tree removal in addition to considering the tree's potential for mortality. Trees were also assessed in terms of their percentage growth rates with a percentage reduction based on the probability of mortality. Trees with positive value and negative growth were a high priority for removal, trees with negative value and positive growth were left for continued growth, and trees with positive value and positive growth could be retained or cut depending on volume targets. The fourth category, trees with negative value and negative growth, "should be left severely alone with the hope that their high mortality rate will soon solve the problem without cost" (Bruce 1939, p. 45). The implication was that the expense of stand improvement associated with removing diseased, damaged, or otherwise undesirable trees was never worth any cost.

Nevertheless, the developers of maturity selection were apparently easily offended when critics noted the system deferred on biological considerations to the economic considerations. For example, an insert to the binding of the economic analysis published by Munger et al. (1934) noted that the bulletin was written in response to a publication by Anderson (1934) that extolled the virtues of zero margin cutting in ponderosa pine in western Montana. Later descriptions of maturity selection appeared to emphasize the biological side of tree selection procedures (Munger 1941, Munger and Briegleb 1942). To show the systems flexibility, Munger and Briegleb (1942) noted that the cut could range from 25 to 65% of the volume because of variations in stand structure.

Data summaries from a range of partial cutting trials were published by Mowat (1961a, 1961b) and included three studies that had bearing on the development and application of maturity selection. Unfortunately, no other records on the many trials of the maturity selection system are apparently still in existence. Mowat's reports focused primarily on bd ft volume production but data allow estimation of basal area. The oldest of these trials was initiated in 1913 on the Wallowa-Whitman National Forest in northeastern Oregon. It included a light treatment that indicates early consideration of alternative treatments long before the development of maturity selection in the 1930s. The "light selection" treatment in the Wallowa-Whitman trial, however, was relatively severe because about 62% of the volume was removed leaving a residual basal area of 47.2 ft^2/ac (Table 2). This early trial may have influenced the trend toward lighter harvests, but the light selection treatment had lower net increment than either the group treatment or the more traditional US Forest Service selection treatment. Mowat (1961b) attributed this in part to higher insect losses on this treatment.

A far more extensive trial was initiated in the Malheur National Forest in eastern Oregon. The 35,000 ac of treatment often was referred to as the "Hines study" and was used by Brandstrom (1937) for his economic analysis that provided much of the impetus for the maturity selection system (Cowlin 1988). Two variations of the maturity selection system were tested at the Hines study: a "value marking" that was intended to yield a margin of at least \$2.50/mbf (\$1,936) and a "thrift marking" where Keen's classes were used to guide removal of less vigorous and higher risk trees (Mowat 1961b).

It is not clear from Mowat's summaries how much data from the Hines study were included in his reports (Mowat 1961a, 1961b). The original marking of the Hines study was lighter than the 40% residual volume target in both the thrift and the value marking treatments (Table 2). The study planners also imposed a minimum diameter limit of 22 in. for cutting in both treatments. This left trees that were prone to insects and windthrow. Mowat noted lower mortality in

Table 2. Maturity selection study results for three Pacific Northwest trials.

Treatment	Residual trees/ac	Residual basal area ft^2/ac	Residual volume mbf/ac	Net inc. bd ft/ac/yr	Gross inc. bd ft/ac/yr
Wallowa-Whitman National Forest (36-yr data)					
Light (62% removal)	16.8	47.2	10.8	7	78
Group (70% removal)	11.6	30.3	7.7	35	64
US Forest Service (82% removal)[a]	10.4	22.5	5.9	39	74
Malheur National Forest–Hines Sale (10-yr data)[b]					
Value (29% removal)	20.9	53.2	11.7	39	99
Thrift (32% removal)	20.4	58.3	13.8	65	116
Pringle Falls Experimental Forest (11-yr data)[c]					
20% Thrift (24% removal)	23.0	67.5	17.5	112	124
20% Value (22% removal)	23.3	68.4	17.8	121	132
40% Thrift (40% removal)	22.8	53.8	12.9	94	121
40% Value (41% removal)	23.2	64.1	12.3	82	95
60% Thrift (57% removal)	22.5	50.1	11.8	102	125
60% Value (66% removal)	19.5	28.7	6.6	56	92
80% US Forest Service selection (72% removal)[d]	16.1	24.8	4.8	42	79

Basal area numbers were calculated from mean tree diameters in Mowat assuming they were quadratic means.
[a] The 82% selection was the standard US Forest Service selection in 1913.
[b] Malheur plots included small amounts of other species although Mowat attempted to exclude all but the ponderosa pine type. Other species included interior Douglas-fir, western larch, lodgepole pine, and white fir.
[c] Pringle Falls data includes lodgepole pine which ranged from 3.0 to 40.5% of residual stand volume in 1937.
[d] The 80% selection was the standard US Forest Service selection that was prevalent before maturity selection.
Source: Data from Mowat 1961b.

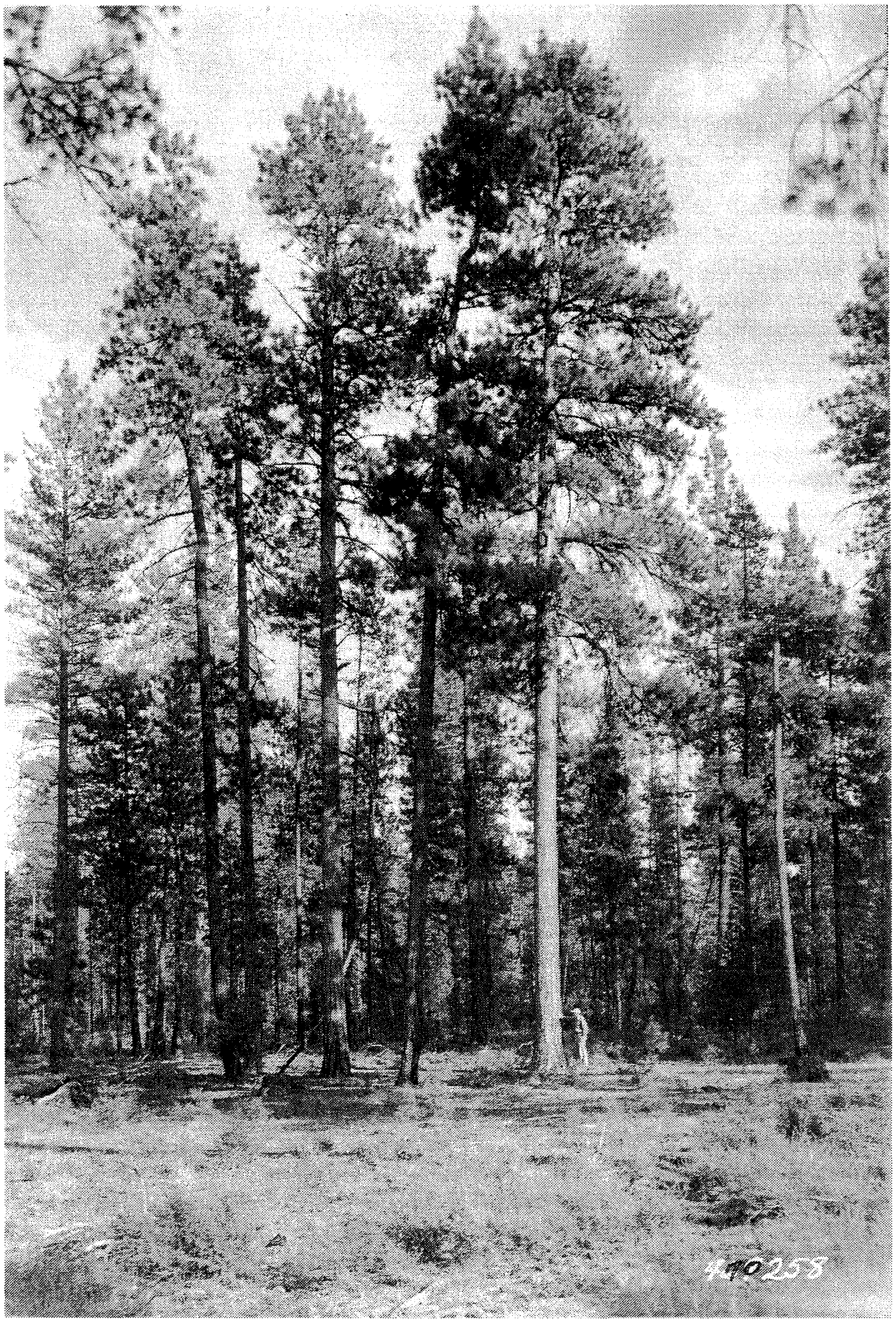

Figure 2. Maturity selection at Pringle Falls Experimental Forest. A group of residual trees in the 40% thrift maturity selection treatment. Photo was taken in 1951, or approximately 14 years after treatment. Edwin Mowat on right.

the thrift marking treatment; he described this mortality as "consistently low from year to year" as seen by the smaller difference between gross and net annual production in the thrift compared with the value marking treatment (Table 2). Total production was also greater in the thrift marking treatment although statistical comparisons are not possible.

The third maturity selection study was initiated in 1937 on the Pringle Falls Experimental Forest in central Oregon. In addition to Mowat's analysis, Dahms (1951) also analyzed these data. Six large plots were established to test different levels of removal using both the value and the thrift marking maturity selection systems. A seventh plot implemented the US Forest Service 80% removal treatment of that era. Treatments included 20, 40, and 60% removals (Table 2). An inventory of all trees greater than 7.0-in. dbh preceded any marking and was continued for 11 years. The value marking was based on Brandstrom's calculations of current annual earnings of each tree and then ranking these trees by value. Trees from the bottom of the list were then marked for removal until the specified volume was achieved (Dahms 1951). Mowat (1961b, p. 21) described the value marking as "practically the same as maturity selection." Dahms (1951) described Brandstrom's value marking method as identical to a sanitation cut if the cutting intensity was the same and noted that additional cutting would remove the highest-value trees first. The thrift marking method was also called the "silvicultural method" and consisted of PNW Station researcher, Ernest Kolbe, selecting trees for retention with greatest growth potential and lowest probability of mortality. Plots for a particular volume removal were marked using both value and thrift marking procedures but the cut was based on only one method (Figure 2). There is no indication of how treatments were assigned to plots although Dahms (1951) speculated some treatments may have been placed near the road to display lighter cutting. Mortality was lower in the thrift treatments for all removals and average bd ft losses across all treatments were only about 16% losses in the untreated area (Mowat 1948).

Results from Pringle Falls Experimental Forest included higher stumpage returns from the value marking compared with thrift marking in 1937 (Dahms 1951). In contrast, the thrift marking resulted in higher net increment in two of the three comparisons and on average across the six plots (Table 2). Dahms (1951) concluded that thrift marking was more profitable than value marking because of increasing stumpage prices between 1937 and 1950 and the higher-value trees retained in the thrift marking treatments. Increment was greatest on higher retention treatments and these differences were probably of more practical significance than the differences between value and thrift marking (Table 2). The traditional US Forest Service 80% removal treatment negatively impacted future growth and had little effect on reducing mortality (i.e., the proportional difference between net and gross increment).

Improvement Selection

An alternative to maturity selection emerged from the Southwest when Gus Pearson published his first article on improvement selection in 1942. As the name implies, this method was designed to improve stocking and the quality of residual trees. It reduced volume and favored retention of vigorous young trees as a means to improve the growing stock. It had evolved through Pearson's long career at the Fort Valley Experimental Forest near Flagstaff, Arizona, but the name was not published until 1941 (Pearson and Wadsworth 1941). Pearson saw the largest trees as lacking in timber quality and occupying space that could be used by fast-growing trees that were free of mistletoe and of good form. Trees greater than 30-in. dbh were considered uneconomical as residual growing stock. Pearson also promoted killing "minus-value" trees that had poor value, poor future prospects, and those that could not be economically removed. His expectation was that a removal of decadent and defective trees would improve stand productivity and reduce mortality losses. This could result in stands doubling or tripling their annual bd ft production (Pearson 1950). Stocking of pole-sized trees was reduced to prevent stagnation, but Pearson preferred to have sufficient numbers of Keen class C trees to promote high-quality bole development (Pearson 1950, p. 61–63). Pearson (1942) also referred to the role of individual trees in the community, but used this term primarily to represent the competition for growing space that could be redistributed to grow an improved group of trees. Pearson even extolled the virtues of improvement selection from a genetics perspective (Pearson 1944).

An important consideration in assessing ponderosa pine silviculture on the Colorado Plateau during this period was the abundance of the 1919 seedling cohort, considered "epoch making" in its effect on ponderosa pine population dynamics (Pearson 1923, p. 4). The cohort resulted from an abundant seed crop in 1918, followed by heavy summer rainfall in 1919. Several decades later this well-established and vigorous cohort reached the minimum height and diameter for inclusion in inventories of research plots at Fort Valley Experimental Forest. Pearson recognized the abundance of potential crop trees contained within this cohort and advocated use of improvement selection as a means to remove overstory trees and release the best of this massive cohort. He was also aware that these trees would respond to release based on experience at Fort Valley Experimental Forest (Wadsworth 1942).

As an example of improvement selection, Pearson (1942) summarized data from the S-9 plot at Fort Valley Experimental Forest (Figure 3). This plot was an 80-ac block converted to improvement selection in 1940–1941 and marked by Pearson (Frank Wadsworth, US Forest Service, retired, pers. comm., Aug. 19, 2008). The treatment removed about 53% of the bd ft volume but only 32% of the trees (Table 3). Residual basal area was 54.5 ft^2/ac. Pearson (1942) applied an adaptation of Keen's (1936) tree classification (Thomson 1940) for the Southwest that used similar age and vigor classes (Table 4). Pearson (1942) also classified trees in the residual stand by the more traditional Kraft crown classification (see Smith et al. 1997, p. 29–30) and reported 10.2% emergent ("isolated"), 47.8% dominant, 34.4% codominant, 7.1% intermediate, and less than 1% suppressed. It appears, however, that both the Keen crown vigor classes and the Kraft crown classes excluded trees less than 8-in. dbh, making it difficult to assess the improvement in the residual stand. The harvest treatment, however, reduced tree defect from 29.1% in the mature yellow pine class and 13.9% in the younger blackjack size class to only 10% for the entire residual stand. It is not possible to fully interpret the treatment effects on understory trees, but the small number of either "young blackjack" trees (Table 4) or suppressed trees suggests that despite the high density of trees in the 1919 cohort, understory trees were only left if "physiologically sound, of good bole, and in position where liberation was warranted" (Pearson 1942, p. 759).

The capstone to improvement selection was Pearson's Agricultural Monograph published in 1950 after his death. Although this work was an overview of ponderosa pine management, it represents the final document promoting improvement selection in the Southwest. It also includes data from the first growth period from 1941 to 1946 for plot S-9.

A further analysis of data for plot S-9 obtained from the archives of Fort Valley Experimental Forest is presented in Table 5. These data begin with study initiation in 1941 and go through 1966; in 1967 the S-9 area was converted to group selection. These data are averaged from four 2.5-ac subplots within S-9. Residual stocking levels after the initial treatment in 1941 and a salvage treatment in 1953 averaged about 48 ft^2/ac of basal area and 25 trees/ac. The residual basal area falls between the 40% thrift and the 60% thrift treatments at Pringle Falls (Table 2) although direct comparisons are not possible. The bd ft productivity is similar between the two studies although the Fort Valley Experimental Forest had greater time between thinning to adjust to residual spacing regimes than the treatments at Pringle Falls Experimental Forest.

The Controversy

The controversy between proponents of maturity selection and improvement selection systems began with Pearson's (1942, p. 753) article on improvement selection. In this article he referred to maturity selection as the "economic selection" method, a point

Figure 3. Improvement selection at Fort Valley Experimental Forest. Photo shows several age classes of ponderosa pine in plot S-9 in 1941 immediately after treatment. Trees in foreground ranged from 20- to 30-in. dbh.

that must have irritated PNW Station scientists based on their vigilant efforts to define the method as having both a biological and an economic component (Munger 1941, Bruce 1942, Munger and Briegleb 1942). The response was so immediate that letters appeared in the same issue and directly following Pearson's (1942) *Journal of Forestry* article.

The center of the disagreement was the treatment of small, unmerchantable trees. Donald Bruce, the consultant who completed some of the initial economic analyses on the Hines study in Oregon, questioned the cost of killing smaller, undesirable trees in his letter following Pearson (1942, p. 760). He stated that "It is doubtful if the best possible economic results can be assured as a byproduct of an exclusive concentration of attention on the future stands." Munger's letter in the same issue (p. 761) stated that the silvical and biological approaches of Pearson's improvement method were inadequate and "There must be a factual economic basis for the order of cutting." Two more letters followed before Pearson's reply (p. 765) in which he argued that foresters "should realize that they cannot increase production efficiency through economies which result in further deterioration of an already run-down forest plant." Pearson viewed the resource as the factory that needed to be maintained to preserve long-term productivity.

Table 3. Removals and residual stand after improvement selection treatment of plot S-9 at Fort Valley Experimental Forest.

Diameter size class groups (in.)	Cut trees		Residual	
	Trees/ac	Volume mbf/ac	Trees/ac	Volume mbf/ac
8–11	0	0	4.4	0.03
12–20	3.3	0.6	11.7	1.9
21–30	6.1	4.7	8.0	6.0
>30	2.2	4.0	0.3	0.5
Total	11.6	9.4	24.4	8.5

Source: Pearson 1942.

Although maturity selection was built on the economics of tree growth and the risks of retaining larger trees, improvement selection assumed the future value of these forests was best achieved through maintenance of future growing stock. Although neither group of researchers could foresee the increase in timber values after World War II, the best economic strategy would have left as much wood on the stump as possible (Dahms 1951). From a silvicultural perspective, Pearson's strategy of building growing stock in degraded stands was sound.

Table 4. Postcutting distribution of plot S-9 trees by Keen's tree classes showing total trees for each class for the entire 80-ac plot, trees/ac, and percent trees by age class.

	Vigor class				Total	
	A	B	C	D		
Age class	Full crown	Medium crown	Light crown	Weak crown	Trees/ac	Percent
1. Young blackjack	2.0	122.9	30.1	2.0	2.0	8.03
2. Blackjack	54.1	313.0	469.9	35.0	10.9	44.63
3. Intermediate mature	23.8	175.1	214.0	20.1	5.4	22.16
4. Mature-overmature	23.1	215.9	235.1	18.0	6.2	25.18
Totals (80-ac plot)	103.0	826.9	949.1	75.0	24.4	100.0

Age and vigor class names are slight revisions from Keen's classes based on Thomson (1940).
Source: Adapted from Pearson 1942.

Table 5. Improvement selection study results from four 2.47-ac plots on the S9 improvement selection trial at Fort Valley Experimental Forest.

Treatment	Residual trees/ac	Residual basal area ft^2/ac	Residual volume mbf/ac	PAI bd ft/ac/yr
1941	24.7	48.6	7.8	137
1946	26.0	52.0	8.5	110
1951	27.2	54.6	9.0	—[a]
1956	26.4	48/2	7.6	144
1961	30.0	52.7	8.4	76
1966	29.7	54.5	8.7	

This trial was treated in 1941 and received a salvage treatment in 1953. Board foot volumes (Scribner) were based on equation from Myers (1963) and a height-dbh equation derived from trees measured in 1941 from the these four plots (height = 104.318/[1 + 9.862*exp{−0.180 * dbh}]), height in feet, dbh in inches, n = 243, RSE = 12.26 ft).
[a] Plots were treated in 1953 so increments during this period were negative.
PAI, periodic annual increment.

It is likely that the majority of ponderosa pine stands in the Southwest were degraded from previous cutting and the future growing stock could more easily be improved, while uncut stands in the inland Northwest provided more options for retaining large trees.

Pearson (1942, 1943) also viewed forestry as more than a business; it was also a public service, particularly on public lands. Hence, his response to the letters that followed his 1942 article stated, "Cutting practice which strives to squeeze the last penny out of a God-given heritage, even to the point of reckoning interest on an 'investment' which has contributed nothing toward producing the crop, has no place in public forestry" (Pearson 1942, p. 766). Pearson was not ignoring economic issues, but believed that the relatively rapid increment of small trees would result in high monetary returns (Pearson 1943). He can be credited with attempting the release of young trees, and he compiled supporting data to show they could respond (Wadsworth 1942).

Pearson did not again refer to maturity selection as "economic selection" in any future articles or letters. But in 1946 he wrote a review of Briegleb's (1945) work on ponderosa pine growth that thoroughly criticized the need for such information (Pearson 1946). Briegleb's (1945) study provided tree growth estimates for trees in selection systems that advanced the previous work of Meyer (1934) and Keen (1943). Although this work had an obvious application to selection systems in ponderosa pine, its brief mention of maturity selection was almost in passing. Nevertheless, Pearson's (1946, p. 445) scathing review ended with the sentence, "Repairing maturity selection is like propping up a tottering wall when what it really needs is a foundation." Briegleb's work was an obscure document that did not even bear a PNW series number. The same issue of the *Journal of Forestry* included a second review by Francis Schumacher that praised Briegleb's contributions to ponderosa pine growth and yield studies (Schumacher 1946). This second review appears to be a conciliatory effort given the harshness of Pearson's criticisms.

Present Outlook

It would be easy, although unmerited, to dismiss maturity selection and improvement selection as similar approaches to multiaged ponderosa pine silviculture. Both methods consist of a marking strategy designed to remove older, decadent trees and retain greater residual volume than previous procedures. Differences between the methods did exist, however, and were of great importance to those involved.

The primary on-the-ground difference in the effects was the treatment of small, unmerchantable trees with poor prospects for future growth: under the maturity selection method they were ignored but under the improvement selection method they were strongly considered for removal by cutting or poisoning. Much of the argument centered on the issue of smaller trees. It is also probable that the name "improvement selection" was also a reaction to the older maturity selection system and emphasized the need to improve future growing stock. Pearson's improvement selection included the underlying theme of making an investment to enhance future values of stands even though he may not have expressed this as an economic decision. The maturity selection method was more of an analysis of current values using long-term economic assumptions. In this sense, Pearson can probably be credited with having a more forward-looking approach with the development of improvement selection.

Much of the controversy revolved around the importance of economics in tree-level cutting decisions. In its simplest form, the maturity selection approach of Brandstrom (1937) and Bruce (1939) was a ranking of trees by value, with the most valuable trees cut first. But rather than a complete ranking, all trees were assigned to a Keen crown vigor class with an associated log grade composition (Table 1). With a 3% alternative rate of return and relatively constant stumpage across different size classes, any tree greater than 21 in.—in this example of light selection in the Southwest—would lose value if left unharvested (Figure 4).

Pearson (1938, 1950, p. 74) also attributed the three primary causes of ponderosa pine mortality in the Southwest to wind, followed by lightning and dwarf mistletoe. In contrast, the primary cause of ponderosa pine mortality in the Pacific Northwest was bark beetles. These disturbances differ in temporal and spatial scale, with mortality from wind and lightning especially difficult to predict. This, along with the potential of dwarf mistletoe spreading from larger to smaller trees, probably led to the strategy for the Southwest whereby few of the largest trees were retained.

The importance of Keen and other entomologists to the development of the maturity selection system in the Pacific Northwest and California should not be overlooked. The tree classification systems (Dunning 1922; Keen 1936, 1943) were designed to reduce insect losses when cutting in selection systems. Keen believed the probability of mortality was inversely proportional to a tree's growth rate (Keen and Salman 1942). Bark beetles also were seen as a natural harvesting agent, "Year by year [the bark beetles] are making thinnings from below and a selection cutting of the older age classes" (Keen 1936, p. 924). It was a wonderful coincidence that the trees most prone to mortality caused by the three most common damaging agents—bark beetles, wind and lightning—were also the most valuable trees for harvest. Maturity selection had a biological component but it was primarily a sanitation/salvage treatment of the most valuable trees. This was Keen's concern after Brandstrom's (1937) presentation to the Society of American Foresters. Keen, who was in the audience, expressed his concern that Brandstrom's treatments left many lower crown classes that were of poor vigor and were highly susceptible to bark beetles. Pearson's improvement selection not only removed the vulnerable trees that were valuable, but also treated the lower crown classes that were not susceptible to wind or lightning but were susceptible to dwarf mistletoe. Pearson was looking to the future with his silvicultural treatments, but he was also using silvicultural concepts—such as growing space occupancy and genetic improvement—that are the foundation of contemporary silviculture.

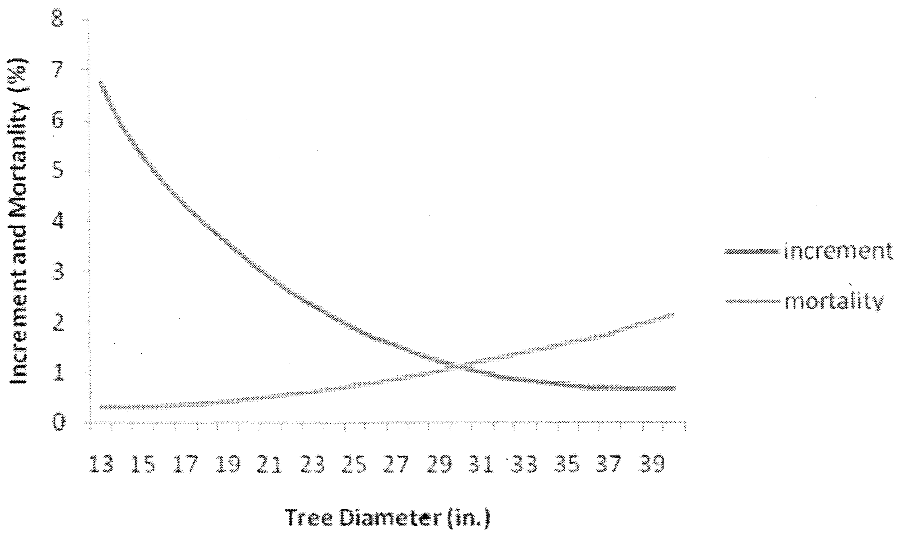

Figure 4. Percent bd ft volume increment and percent mortality for light selection treatment at Fort Valley Experimental Forest. (Adapted from Pearson 1940.)

An important consideration in assessing the sustainability of multiaged systems is their provisions for regeneration. Neither maturity selection nor improvement selection provided any discussions of the effects of their systems on subsequent regeneration. Mowat (1961a) described the regeneration after the partial cutting treatments in his analysis as partially successful but provided little detail. Pearson (1950), whose experience with regeneration in the Southwest was second to none, suggested regeneration could occur at any time in the improvement selection process, including in advance of the harvest treatments. In both systems, the relatively heavy cuts would have provided appropriate conditions for regeneration and there was probably little reason to be concerned. Reliance on bd ft volumes and merchantability limits prevented a detailed assessment of regeneration. Seventy years after his work at Fort Valley Experimental Forest, Frank Wadsworth remembers a shortage of understory trees after the cutting (Frank Wadsworth, US Forest Service, retired, pers. comm., Aug. 18, 2008). Neither the Pacific Northwest nor the Southwest group of developers considered regeneration a critical issue and their foci were on developing appropriate harvest regimes and residual stand structures.

Both maturity selection and improvement selection disappeared from discussions of silvicultural alternatives by about 1960, largely because of interest in even-aged silvicultural methods that allowed more precise control of spacing and density. A special variant of even-aged management for ponderosa pine stands was developed in the Pacific Northwest, consisting of either a complete or a partial overstory removal of old-growth ponderosa pine followed by management of the advance regeneration that developed after decades of fire exclusion or suppression (Youngblood 2005). This practice had at least three underpinnings: (1) the overstory was growing slowly and was susceptible to bark beetles; (2) the overstory had high value and revenue that was generated could be used for other management projects within the sale area; and (3) management of the advance regeneration avoided the high cost of treeplanting, it maintained a green forested setting thus avoiding the visual impacts associated with clearcutting, and it capitalized on the initial growth of the understory trees.

Pearson died in 1950 before completion of his monograph on ponderosa pine management. George Meagher completed the monograph and then became chief of forest management research of the PNW Station, which subsequently dropped maturity selection (James Barrett, US Forest Service, retired, per. comm., Aug. 7, 2008; Cowlin 1988). Mowat's (1961a, 1961b) work on partial cutting studies in ponderosa pine were an attempt to put closure on these Pacific Northwest studies with maturity selection (James Barrett, US Forest Service, retired, pers. comm., 2008). In the Southwest, a similar pattern was evident. Myers and

Martin (1963) summarized 50 years of converting virgin pine to managed stands that discussed the results from Pearson's Fort Valley Experimental Forest work. This study coincided with Clifford Myers'—who was a research forester at Fort Valley—decision to convert three of four of Pearson's Fort Valley improvement selection trials to other systems in 1961. The remaining improvement selection plot at Fort Valley, S10, was not retreated after 1963. Myers and Martin (1963, p. 586) closed their retrospective study with the suggestion that even-aged systems "appear most practical." With the swing toward even-aged systems, there was little interest in silvicultural research on selection systems, even in a species as well suited to uneven-aged silviculture as ponderosa pine.

A resurgence in interest in multiaged systems began again in the late 1980s as public values shifted from an emphasis on timber production to an emphasis on a wider array of resource values, especially wildlife habitat and forest health considerations (O'Hara 1998). During the intervening years, multiaged silviculture was still practiced in the ponderosa pine region. The BDq procedure (Alexander and Edminster 1977, O'Hara and Gersonde 2004) emerged as the system of choice for many practitioners. The BDq procedure is characterized by a reverse-J or negative exponential diameter distribution as the guide for stand structure described by the "q-factor." "B" and "D" define the residual basal area and the maximum leave tree diameter. This system differs from maturity selection and improvement selection systems because it adheres to a diameter distribution for controlling stand structure and included shorter cutting cycles. The trend toward shorter cutting cycles is apparent through the old US Forest Service selection system, to maturity and improvement selection and, finally, the BDq system. Pearson (1950) noted this trend even before the emergence of the BDq system.

More recently, multiaged ponderosa pine silviculture appears to be returning to the concepts that prompted development of the maturity and improvement selection systems. Stand density index (Long and Daniel 1990) and leaf area (O'Hara and Valappil 1999, O'Hara et al. 2003) are both means of dividing growing space that resemble Keen's crown vigor classes. Division of stands into fewer classes (either diameter or age) also would tend to increase cutting cycle lengths as more advanced classes are removed. These longer cutting cycles were noted to require fewer reentries, thereby reducing harvest costs, and also would provide more growing space for regeneration. Hence, cutting cycles of 25–50 years were recommended for ponderosa pine stands in the inland Northwest (O'Hara et al. 2003).

At least four key drivers may now be influencing the application of multiaged ponderosa pine silviculture. The first of these is restoration, where ponderosa pine stands are managed by practices designed to emulate natural disturbance regimes. Silviculturists likely will be asked to design treatments that are closer analogues or surrogates for a specific disturbance event and result in structures that resemble the multiaged, multistrata stands first entered in the early 20th century (Covington et al. 1997, Youngblood et al. 2006). Little is known of methods for developing future old-growth structure in young, uneven-aged or even-aged stands and forecasting the productivity of these stands. The second driver is the need for fuel reduction after nearly 100 years of fire exclusion and suppression. Fuel reduction treatments can result in changes in the horizontal and vertical distribution of trees; their composition; and the number, size, and distribution of gaps or canopy openings. A third driver is providing provisions for wildlife habitat such as the northern goshawk in the Southwest. Current goshawk guidelines suggest creation of multiaged stand structures containing groups of similar trees in areas typically less than 0.75 ac (Youtz et al. 2008). Finally, many future silvicultural prescriptions will need to recognize that the effects of climate change are largely unknown. There is little to guide the development of management scenarios to ensure that disturbance processes, other than fire, are fully incorporated. Ponderosa pine stands with low fuel accumulations and stand structures that emphasize low densities and large tree diameters likely are better able to resist the undesirable or extreme effects of multiple disturbances. Stands with this structure may respond favorably to change because they have been realigned to incorporate both current and expected natural disturbance processes.

Conclusions

Looking back at this controversy with the clarity of hindsight, the differences between maturity selection and improvement selection may have resulted in differences in stand structure over these 60 years. In the Pacific Northwest, maturity selection would have proven successful in reducing beetle losses and regulating harvest treatments. In the Southwest, consistent treatment under the improvement selection method would have proven successful in yielding greater quantities of high-quality timber and may have reduced overabundance of trees from the 1919 age class. If both maturity and improvement selection had been widely applied, it is also unlikely that land managers would face the same fuel accumulations that contribute to wildfires of uncharacteristic size. These are, however, only speculations. At the end of the section on improvement selection in his 1950 (p. 107) monograph, Pearson noted that "In about 50 years the new forest visualized in the first marking will have become a reality." The abandonment of many of these studies and the loss of data records prevented this reality from occurring and deprives us of a more detailed analysis. As ponderosa pine silviculture has moved back toward multiaged approaches, these studies likely would have yielded fabulous insights into long-term effects of sustained multiaged systems. One lesson that can be derived from the maturity selection versus improvement selection controversy is the lost opportunities to address issues that were not apparent at the initiation of research through the continuation of long-term studies.

It is also apparent that these systems may simply have been unsuitable outside the regions where they were developed. The proponents of these systems advocated their respective methods as though they should be universally applicable across the ponderosa pine range. A second lesson is that silvicultural systems should be adapted to local conditions and much of the difference between these systems may have been caused by the cutover status of ponderosa pine in the Southwest compared with being nearly uncut in the Northwest.

A third lesson is that, although this controversy provided an interesting analysis for the present, it accomplished little at the time. Instead, the controversy and the tone of the discourse appears to have alienated two groups of researchers and resulted in relatively uncompromising stances on both sides. However, Hawley (1942, p. 837) noted that this controversy was a sign of "progress" in the evolution of American silviculture. There were two groups of forest researchers actively debating the merits of similar silvicultural treatments. In many ways, this controversy shows that silviculture as a discipline had arrived in North America.

Endnote

[1] Name changed to Pacific Northwest Research Station in 1985.

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