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Aspen Regeneration in Riparian Management Zones in Northern Minnesota: Effects of Residual Overstory and Harvest Method

Brian Palik, Kory Cease, and **Leanne Egeland,** *USDA Forest Service, North Central Research Station, Grand Rapids, MN 55744, and* **Charles Blinn,** *Department of Forest Resources, University of Minnesota, St. Paul, MN 55108.*

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ABSTRACT: *We examined aspen regeneration under different riparian management zone (RMZ) treatments in aspen forests in northern Minnesota. We also compared aspen regeneration in partially harvested RMZs to adjacent upland clearcuts. The four RMZ treatments included: (1) full control (no cutting in RMZ or upland; (2) riparian control (RMZ uncut; upland clearcut); and partially harvested RMZs cut to 54 ft^2/ac, with upland clearcut using (3) cut-to-length (CTL), or (4) tree-length harvesting. Three years after harvest, aspen sucker densities in the tree-length and CTL treatments were significantly higher than the full control, but did not differ from each other or the riparian control. Mean individual sucker heights (63–73 in) and aboveground biomass (2.4–3.4 oz) varied among the riparian treatments, but not significantly. Sucker densities were 62% higher in the adjacent clearcuts than in the partially harvested RMZs. Mean suckers heights did not differ between the two locations (71 in.), but aboveground biomass of suckers did differ significantly, averaging 3.4 oz in the partially harvested RMZs and 4.5 oz in the clearcuts. Our results indicate that 60% removal of basal area within RMZs increases density and size of aspen regeneration significantly, compared to uncut forest, but stocking is still below what is considered adequate for 3-yr-old stands. Suckering responses were similar with cut-to-length and tree-length harvesting, suggesting that harvest system has little effect on sucker development. While aspen likely will be a component of partially harvested RMZs, density and biomass increment will be much lower than in single-cohort stands and lower than what is considered desirable for commercial production. North. J. Appl. For. 20(2):79–84.*

Key Words: Riparian forests, aspen, overstory retention, BMP.

In regions rich in surface water, riparian forests are important for the ecological services they provide (Gregory 1997), but also as a source of wood fiber (Burns et al. 1999, Palik et al. 1999). For example, in northern Minnesota, 37% of commercial forest lies within 187 ft of water (Hanowski et al. 2001). In these riparian areas, trembling and bigtooth aspen (*Populus tremuloides*, *P. grandidenta*) often are the dominant tree species (Hanowski et al. 2001). Aspen is the most important commercial timber type in Minnesota, as well as in Wisconsin and Michigan, comprising 47% of all roundwood harvested for pulp in the region (Piva 1999). As such, utilization of aspen timber from riparian areas, and management for aspen regeneration in these areas, historically has been important to forestry in the region.

Like many other agencies, the State of Minnesota has developed a set of management guidelines for riparian forests (Blinn and Kilgore 2001). The intent of these guidelines is to protect ecological services in riparian areas, while allowing utilization of and management for timber resources. A key guideline component is retention of residual trees in a designated riparian management zone or RMZ. The residual overstory may provide continuity of shade, organic matter flux, wildlife habitat, and bank stability. It also likely causes competitive inhibition of the new cohorts of trees, particularly for intolerant species.

Because of its shade intolerance, aspen does not grow well with retention of even modest amounts of overstory (Perala 1977). Consequently, the use of partially harvested RMZs in

NOTE: Brian Palik can be reached at (218) 326-7116; Fax: (218) 326-7123; E-mail: bpalik@fs.fed.us. The authors thank Jim Marshall and John Hanson of Blandin Paper Company for logistic assistance. Charles Goebel, three anonymous reviewers, and the associate editor provided helpful comments on an earlier version of the manuscript. Thanks to Jim Robl for study assistance. The Minnesota Forest Resources Council, the National Council of the Paper Industry for Air and Stream Improvement, Boise Cascade Corporation, the USDA Forest Service, North Central Research Station, University of Minnesota's Department of Forest Resources, the University of Minnesota Extension Service, and the Minnesota Agricultural Experiment Station under Project MN 42-042, supported this research. Copyright © 2003 by the Society of American Foresters.

areas traditionally managed for aspen is an issue of concern for the timber management community. However, we know little about the specifics of aspen regeneration in riparian areas. In particular, we do not know how well aspen regenerates in partially harvested RMZs, where side lighting from adjacent clearcuts and the stream channel may augment overall light levels.

We focus on this question by examining aspen regeneration and sucker growth over a 3 yr period following harvesting of riparian forests in northern Minnesota, USA. Specifically, we contrast aspen regeneration in unharvested RMZs that are adjacent to upland forest clearcuts, to regeneration occurring in partially harvested RMZs, again where the adjacent upland has been clearcut. Secondly, we compare regeneration in RMZs cut using different harvest systems: namely cut-to-length processing and tree-length harvesting. These two systems differ in type of site impact (Gingras 1994, Lanford and Stokes 1995) and, potentially, their influence on new cohort development. Finally, we contrast regeneration dynamics in partially harvested RMZs to regeneration in adjacent (upland) clearcuts.

Methods

Study Site Location and Experimental Design

The study area consists of four small watersheds drained by first- and second-order streams in north central Minnesota. Forest ecosystems of the study area are northern hardwood-aspen mixtures occurring on an end moraine. Soils are generally well-drained, fertile loams. The watersheds occur entirely on Blandin Paper Company property in Itasca County, Minnesota.

We established 12 treatment stands along the streams in 1996; each stand approximately 12 ac in size (6 ac on each side of the stream). Bank-full stream widths ranged from 5 to 15 ft among the 12 stands. Major valley floor landforms included narrow floodplains, ranging from 13 to 52 ft wide, one or two fluvial terraces, and hill slopes leading into the glacially deposited upland. Stream valleys in the four watersheds were oriented generally along a north-south axis. Consequently, the 12 stands included both easterly and westerly aspects. In each stand, the fixed-width RMZ consisted of a 200-ft-wide strip centered on the stream (Figure 1). The length of the RMZs along the stream ranged from 440 to 660 ft. Treatment areas that were located on the same stream were separated by at least 330 ft.

Our experiment was a randomized design, with four treatments (Figure 1) replicated three times. The upland portions in 9 of the 12 stands were clearcut, using either a cut-to-length or a tree-length system. The cut-to-length system used a Valmet 546 Woodstar Series II harvester or a Ponsse Cobra HS 10 harvester, both in conjunction with a Valmet 546 Woodstar Series II forwarder. The tree-length system used a Timbco 425B tracked feller-buncher with a Quadco 22 in. high-speed saw head, a John Deere 648E grapple skidder, and a roadside slasher. With the tree-length system, trees were limbed and topped in the woods by hand, within the upland portions of each stand, before being skidded to the landing for processing. We cut the RMZs in six of the nine

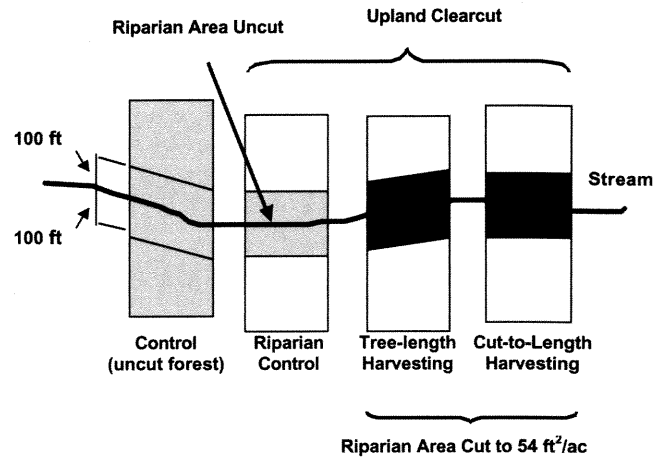

Figure 1. Diagrammatic representation of harvest treatments in riparian management zones.

stands, using the same system as in the upland, to a residual basal area of about 54 ft^2/ac. We left the RMZs of the remaining three upland harvested stands intact (riparian control). The remaining three stands were full controls, with no harvesting in the RMZs or adjacent uplands. Harvesting was conducted in late summer-early fall of 1997

Vegetation Sampling

In each stand, we established transects perpendicular to the stream. The number of transects ranged from five to eight per stand and alternated between sides of the stream so as to better capture the full range of environmental heterogeneity, including differing aspect, along a stream reach. We established permanent sample points along the transects, centered on major landforms (e.g., floodplain, terrace, hill slope, upland). The number of points per stand ranged from 16 to 42, depending on the number of transects and the number of landforms along each transect. At each point, we recorded data on overstory structure and regeneration. While we collected data on regeneration of all woody species, we report only on aspen response in this paper.

We sampled overstory trees (≥ 4 in at 4 ft) in 1997 (preharvest) and 1998 (1 yr postharvest) using the point-quarter method (following Brower and Zar 1984). At each point, we recorded the species, diameter (at 4 ft), and distance (from the point) to the closest tree in each of four quarters on the landform where the point occurred. We sampled aspen regeneration in two size-classes, including small regeneration (≤ 3.3 ft tall) and large regeneration (> 3.3 ft tall and < 1 in. dbh). We recorded small aspen suckers in 5.4 ft^2 quadrats and large suckers in 75 ft^2 circular plots, centered on each point. Data on sucker densities were collected yearly from 1997 to 2000. In addition, in 2000, we measured heights and basal diameters (at 6 in.) of large aspen suckers.

Statistical Analysis

We compared aspen regeneration variables, including stem densities, stem heights, and aboveground biomass, among the riparian treatments (full control, riparian control, cut-to-length, tree-length harvesting) using one-way ANOVA. We estimated aboveground biomass (stems plus leaves) of

large aspen regeneration using equations in Perala and Alban (1994). Before analysis, we assessed variance of the data and in some cases transformed the original data (square root or log) to better meet the assumption of homogeneous variance. If an overall ANOVA was significant, we compared individual treatments using Scheffe's test. We used paired *t*-tests to compare aspen regeneration in the harvested RMZs to the adjacent clearcuts. For these analyses, we pooled the six harvested RMZ's (three cut-to-length, three tree-length). In some cases, we transformed data (log or square root) to better meet the assumption of normality.

Results

Changes in Overstory Structure with Treatment

Preharvest overstory basal areas were similar for the four RMZ treatments, averaging (± 1 sd) about 131 (13) ft^2/ac. Sugar maple (*Acer saccharum* Marsh.), paper birch (*Betula papyrifera* Marsh.), basswood (*Tilia americana* L.), aspen, black ash (*Fraxinus nigra* Marsh.), and balsam fir (*Abies balsamea* [L.] Miller) dominated the preharvest overstory, comprising 85% of relative basal area. Postharvest basal areas in the two RMZ harvest treatments (cut-to-length, tree-length) averaged about 54 (13) ft^2/ac. Postharvest overstory composition was similar to preharvest composition (in a relative sense). In the harvested RMZs, mean basal area of aspen was reduced from about 13 (9) ft^2/ac to about 4 (4) ft^2/ac. Preharvest composition of the adjacent uplands before clearcutting was similar to the RMZs. However, mean (±1 sd) preharvest total basal area (174 ± 61 ft^2/ac) and mean aspen basal area (61 ± 61 ft^2/ac) were higher in the uplands than the RMZs.

Aspen Regeneration in RMZs

Aspen sucker densities within the RMZs varied considerably over the 4 yr study period. Small sucker densities (<1 m tall) increased initially after harvest in the three treatments (riparian control, CTL, tree-length), followed by a decline over time in all treatments, including the full control (Figure 2a). There was no significant difference in small sucker densities among treatments in 2000, the last year of postharvest sampling ($P = 0.120$). Densities of large suckers (> 3.3 ft tall, < 1 in. diameter at 4 ft) were low and constant in the full control, but increased after cutting in all three RMZ treatments (Figure 2b). Densities in 2000 were significantly different among treatments ($P = 0.0012$). Large sucker densities in the tree-length and CTL treatments were both higher than the full control ($P = 0.01$), but did not differ from each other or from the riparian control ($P > 0.10$). Large sucker densities in the riparian control were marginally higher than the full control ($P = 0.10$).

Aspen Sucker Development in RMZs

Mean aspen sucker height 3 yr after harvest ranged from 63 in to 73 in. among the RMZ treatments (Figure 3a)(the full control was excluded due to limited suckers in this treatment). Mean aboveground biomass of suckers ranged from 2.4 oz to 3.4 oz (Figure 3b). Both sucker height and aboveground biomass were marginally higher in the two RMZ harvest treatments than the riparian control, and in the tree-length treatment compared to cut-to-length processing,

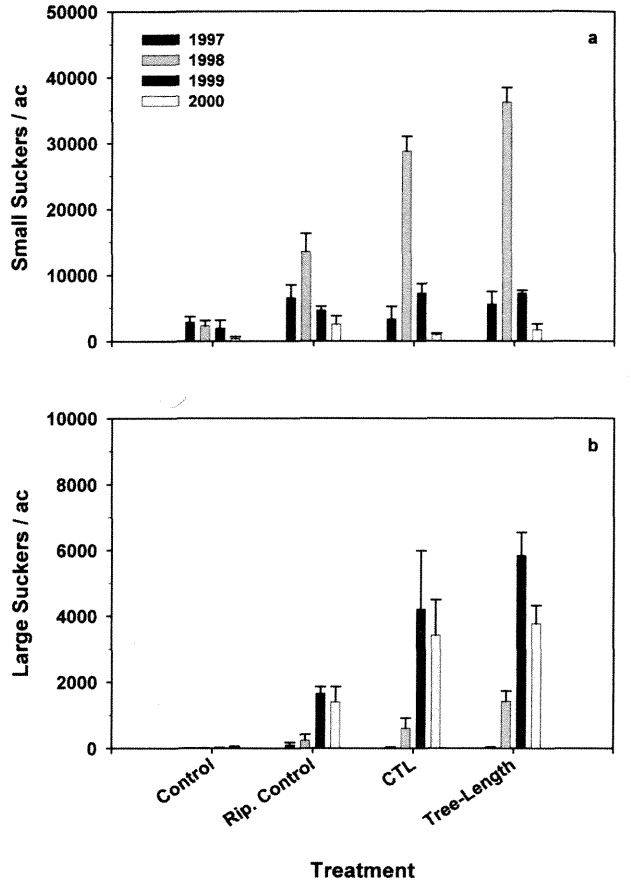

Figure 2. Changes in aspen sucker density over time in four riparian management treatments. Values are means of three replicates ± standard error. Small regeneration: < 3.3 ft tall; large regeneration: ≥3.3 ft tall and <1 in. diameter at 4 ft.

but the differences were not significant (height, $P = 0.228$; biomass, $P = 0.360$).

RMZs versus Adjacent Clearcuts

As in the partially harvested RMZs, densities of large aspen suckers increased in the clearcut uplands in the first 2 yr after harvest and then declined slightly in the third year (Figure 4). However, the initial increase was greater and the third-year decline was lower in the uplands than in the RMZs. The mean difference in densities between the two locations was significant by the third postharvest year ($P = 0.045$).

Three years after harvest, mean aspen suckers heights did not differ between the partially harvested RMZs and the adjacent clearcuts ($P = 0.415$), averaging about 71 in. for both locations (Figure 5a). Aboveground biomass of individual suckers averaged about 3.4 oz in the partially harvested RMZs and about 4.5 oz in the adjacent clearcuts (Figure 5b). The difference was significant ($P = 0.0001$).

Discussion

Aspen Regeneration in RMZs

Our results, 3 yr after harvest, indicate that removal of 60% of the basal area within riparian management zones that are adjacent to clearcuts increases the density and size of aspen regeneration significantly, compared to uncut forest.

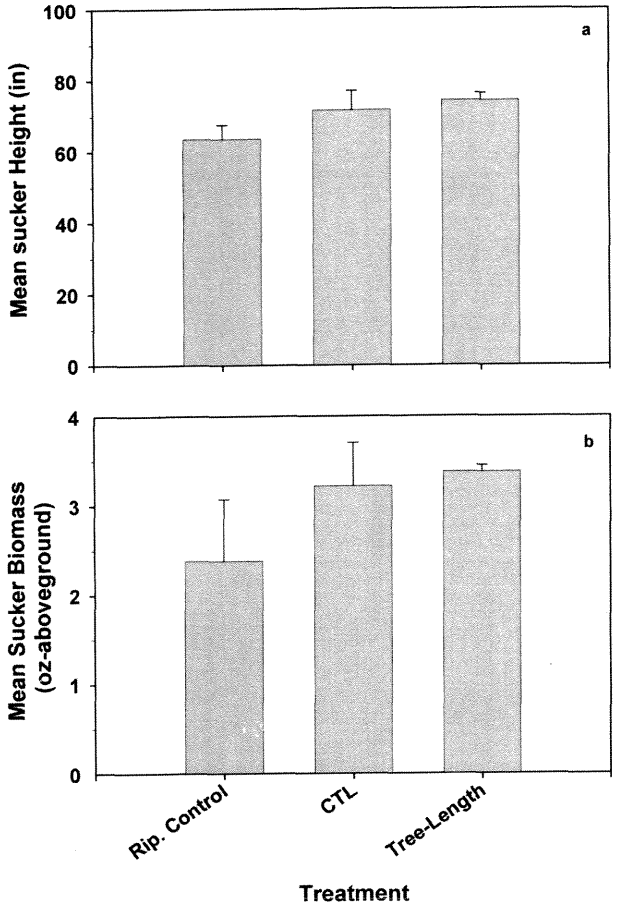

Figure 3. Mean sucker height and aboveground biomass of aspen suckers 3 yr after harvest in three riparian management treatments. Values are means of three replicates ± standard error.

Over time, regeneration response was concentrated increasingly in the large sucker size class (≥ 3.3 ft tall). This is because most surviving suckers had grown out of the small size class (< 3.3 ft tall) by the third year after harvest.

Differences in sucker densities and growth were less distinct between the unharvested RMZs that were adjacent to clearcuts (riparian control) and the partially harvested RMZs. This suggests that responses in the partially harvested RMZs were due in part to environmental changes associated with the creation of edge along the RMZ border. In fact, our results indicate that approximately 40% of new suckering in the partially harvested RMZ treatments resulted from edge effects. Similarly, about 87% and 72% of the height and biomass responses, respectively, resulted from edge effects (assuming zero height and biomass growth in the full control).

Numerous studies document increases in stem densities in forest edge, extending anywhere from 50 to130 ft into the stand (Palik and Murphy 1990, Murcia 1995). Increased solar radiation and higher soil and air temperatures occur in forest edges, relative to the interior. These changes can extend 70 to 200 ft into the forest, depending on edge orientation (Chen et al. 1995). Since aspen suckering depends on increased soil temperature (Perala 1977), it is likely that microclimatic changes from edge effects triggered the aspen regeneration response we found in the uncut RMZs bordering the clearcuts.

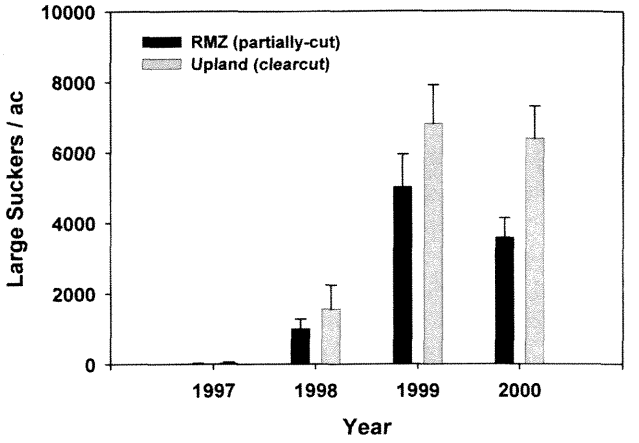

Figure 4. Changes in aspen sucker density over time in partially harvested riparian management zones (54 ft^2/ac residual basal area) and in adjacent (upland) clearcuts. Values are means of six replicates ± standard error.

Aspen suckering responses were similar with cut-to-length and tree-length harvesting. This suggests that the choice of harvesting system may have little effect on short-term sucker development. Others report that cut-to-length harvesting results in less site disturbance (e.g., less ground disturbance and mineral soil exposure, less area that is heavily trafficked, less compaction) than harvesting systems using skidders (Gingras 1994, 1995, Richardson and Makkonen 1994, Lanford and Stokes 1995). In fact, in our study, the tree-length system did expose more organic and mineral soil, displace more soil, and traffic more area than the cut-to-length system (Perry et al. 2001). Since aspen suckering generally increases in concert with increased mineral soil exposure, due to higher soil temperatures (Perala 1977), one might expect increased sucker densities with the tree-length system, but we detected no such response.

Partially Harvested RMZ versus Upland Clearcut

In comparing partially harvested RMZs to the adjacent uplands, the effects of overstory treatment (partial harvest vs. clearcut) are confounded with location (RMZ vs. adjacent upland). We cannot distinguish between the influences of the two factors because of the nature of the experimental design. Nevertheless, the comparisons are useful because many foresters now manage RMZs and adjacent stands just this way, with partial cutting in the riparian area and heavier cutting outside of the RMZ.

In these comparisons, large sucker densities in the partially harvested RMZs were only 59% of densities in the clearcuts, 3 yr after harvest. These results suggest strong competitive inhibition of the new aspen cohort by the residual overstory in the RMZ. In fact, aspen sucker densities in the RMZ treatments are well below stocking levels in similar aged single-cohort stands in the region (Perala 1979, Stone et al 1999), whereas densities in the adjacent clearcuts fall within the range of adequate stocking (Perala 1977).

Three years after harvest, mean height of aspen suckers did not differ significantly between the clearcuts and the partially harvested RMZs, but mean aboveground biomass of individual suckers was, on average, 27% lower in the RMZs. This, combined with lower sucker density, suggests a greatly

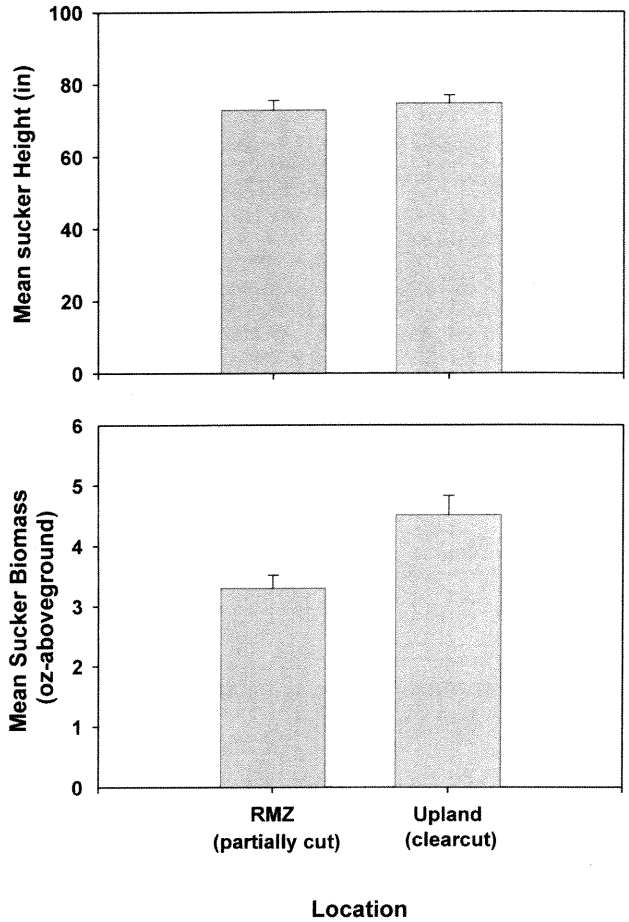

Figure 5. Mean sucker height and aboveground biomass of aspen suckers 3 yr after treatment in partially harvested riparian management zones (54 ft^2/ac residual basal area) and in adjacent (upland) clearcuts. Values are means of six replicates ± standard error.

reduced potential for aspen fiber production in partially harvested RMZs compared to adjacent clearcuts.

The reduction in aspen sucker density is not surprising, as others report similar results with overstory retention (Huffman et al. 1999, Stone et al. 2001). However, expectations regarding sucker growth with overstory retention are not straightforward. Perela (1977) suggests that as little as 9 to 13 ft^2/ac residual overstory reduces sucker volume growth by 35 to 40% over a 40 yr rotation. Over a short time period, Stone et al. (2001) found no inhibition of first-year height and diameter growth of suckers (thus biomass, presumably) with 11 ft^2/ac of residual basal area. The 27% reduction in biomass increment in the RMZs that we found is considerably less than the 35 to 40% predicted by Perela (1977), even with four times more residual basal area (54 ft^2/ac), but over time the growth reduction may increase.

Management Implications and Future Research

Aspen regenerates well in the type of riparian area we studied, that is, mixed hardwood forests, extending close to the stream (due to narrow floodplains) on well-drained soil. Historically, foresters in the region clearcut this type of riparian area, concurrently with the upland, to regenerate aspen. Application of riparian management guidelines, particularly leaving residual basal area within an RMZ, may constrain this management option. Our results suggest that aspen will likely be a component of partially harvested RMZs, but its density and biomass increment will be much lower than in single-cohort stands and lower than what is considered desirable from the standpoint of commercial production.

This suggests two alternative approaches for forest management in similar types of riparian areas. The prescription might leave much lower residual basal area in the RMZ than we did in our study. Alternatively, a forester might give greater emphasis to regenerating shade-tolerant species, by leaving substantial residual basal area in the RMZ. The first approach risks loss of some riparian functions dependent on overstory cover, but may be acceptable if used only on a limited basis in a watershed. The second approach is more conducive to maintaining riparian functions dependent on large trees (i.e., shade, particulate organic matter and large wood flux, bank stability), not only because large trees are left uncut, but because regenerating shade-tolerant species tend to be long-lived, larger in size, and slower to decompose after death, compared to aspen.

Our study examined only the first three postharvest years of aspen sucker development. Additional sampling, over the next 5 to 10 yr is needed to determine if differences in sucker densities, heights, and biomass among treatments persist, decline, or increase over time. Also, there is a need to understand aspen sucker response across a range of residual basal area, including levels below and above that used in our study. Moreover, sucker development could be examined under a fixed level of residual basal areas, but different spatial patterns of retention (i.e., dispersed to aggregate). Such research might foster ways to better manage trade-offs between structural complexity and growth and yield of timber species, if aspen grows better under one spatial pattern of retention than under others (Palik and Zasada, in press). Finally, in our study, long-term followup sampling is needed to understand regeneration dynamics and population development of more tolerant, later successional species under the different RMZ treatments.

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