LIGHT TRANSMITTANCE FOLLOWING MIDSTORY REMOVAL IN A RIPARIAN HARDWOOD FOREST

Bradford J. Ostrom and Edward F. Loewenstein[1]

Abstract—Midstory cover may negatively affect the growth of desirable oak reproduction. Where such cover exists, midstory control may be warranted prior to a regeneration harvest so that species that rely on large advance reproduction for regeneration can become established and grow into a more competitive position before overstory removal. Unfortunately, how midstory removals alter the light environment under a riparian hardwood canopy has not been quantified. To understand how midstory removal affects the light regime below the canopy, we measured light intensity following four levels of midstory control. The treatments consisted of the removal of none, 33 percent, 50 percent, or 100 percent of the midstory stems on 50 0.05-ha plots located within a riparian forest. The resulting light characteristics were then compared to published data on light requirements for particular species to determine whether midstory control alone is adequate to allow for the establishment and growth of a new cohort.

INTRODUCTION

For many years, researchers have examined the problem of sustaining oak reproduction on mesic sites throughout the Southeastern United States. While this issue may be the result of a shift in the disturbance regime, problems with herbivory, or the extreme vegetative competition on these productive sites, one direct abiotic cause relates to the low light levels present in unmanaged, mesic forests (Lorimer 1993). The low light conditions found in these stands are problematic specifically because of the conservative growth strategy of oak reproduction. Oak seedlings are said to have a conservative growth strategy because they will oftentimes have slow initial height growth as true seedlings, instead allocating resources to develop a large root system. This strategy is ideal for the droughty sites that oaks will normally inhabit; their large root systems allow them to survive under moisture stress that might kill seedlings of other species. Additionally, having a large proportion of resources sequestered in the root system ensures that these seedlings are able to sprout back if the top dies due to moisture stress, predation, or is otherwise destroyed mechanically.

Whereas this early growth strategy is well-adapted to dry sites or sites with frequent disturbance, it is detrimental in undisturbed mesic forests; the light levels tend to be lower than might be expected on the drier sites where oak is usually found. Oak seedlings will begin to germinate regardless of the light conditions because of the resources stored in the cotyledon of the acorn. Once those resources are used, however, these seedlings will usually die because the light levels are not high enough for oak seedlings to produce sufficient amounts of photosynthate to compensate for respiration. On drier sites, light levels tend to be somewhat higher because of the lower degree of competition, which allows newly germinated oak seedlings to persist for a longer time without release. While the inclination would be to simply release those seedlings still surviving on mesic sites to allow them additional light to develop, the inability of these seedlings to produce sufficient height growth to remain competitive on these sites is a real problem. They cannot compete with fast-growing, shade intolerant species such as yellow-poplar that are common on these sites, and they cannot survive for an extended period of time without increases in the light levels on these productive sites (Hodges and Gardiner 1993, Lorimer 1993).

With these problems in mind, silviculturists have struggled to develop management regimes that will enable them to maintain oak in these stands because of the value oak provides as a timber product and as a food source to wildlife. As indicated previously, in most cases clearcutting is not a viable method for regenerating oak on these sites. Similarly, single-tree selection as currently practiced does not appear to be a method that can be relied on to produce the light environment necessary for the maintenance or growth of oak reproduction on these sites (Della-Bianca and Beck 1985, Schlesinger 1976). Selection silviculture may yet prove to be a useful tool to address this problem; however, it has yet to be shown that it is economically feasible to maintain the amount of control needed to sustain oak reproduction in these stands using this method as currently practiced. Rather, the only silvicultural method that has yielded any real promise to date in terms of maintaining oak reproduction on mesic sites has been the shelterwood method, even though the results vary and sometimes a crop of desired reproduction fails to emerge (Loftis 1990, Schuler and Miller 1995). When successful, the shelterwood method is able to maintain oak reproduction because the canopy has been altered to the point where light conditions are not sufficient to allow the establishment of shade intolerant species but are high enough to allow oak seedlings already present to remain in a competitive position compared to other seedlings. In those instances where a shelterwood fails to maintain oak reproduction, the cause could be from a general lack of reproduction present prior to the implementation of the preparatory cut to cutting intensities not suited to providing the light environment needed to sustain oak reproduction in a competitive position (Schuler and Miller 1995).

While it would be inappropriate to propose cutting guidelines for use across all locations, some studies suggest that removing the midstory canopy tier while leaving the main canopy intact is necessary to promote growth of oak seedlings on high quality bottomland sites (Janzen and Hodges 1987, Lockhart

[1] Graduate Research Assistant and Assistant Professor, respectively, Auburn University, School of Forestry and Wildlife Sciences, 602 Duncan Drive, Auburn, AL 36849-5418.

Citation for proceedings: Connor, Kristina F., ed. 2006. Proceedings of the 13th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–92. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 640 p.

and others 1992). This level of canopy manipulation would not likely allow enough light to foster shade-intolerant reproduction, and if the targeted midstory stems are prevented from sprouting, it is reasonable to expect that oak reproduction could remain viable. Yet, the benefit of using midstory competition control as an initial cut of a shelterwood is most clearly seen in a study conducted in the southern Appalachian Mountains. In this study, Loftis (1990) demonstrates that northern red oak (*Quercus rubra* L.) advance reproduction will continue to grow under a continuous main canopy as long as the midstory has been treated. By removing the subcanopy, it appears that the light environment below the main canopy is increased to the point that oak seedlings are able to maintain slow but positive growth. This study also demonstrates the realization that as site productivity increases, greater alterations to the canopy structure will be needed to ensure that light levels are high enough to produce the desired response in the oak reproduction present. Once these seedlings attain a size when they will not be out-competed once released by fast-growing yellow-poplar, the overstory can then be removed.

Given the positive response seen in the southern Appalachians following an effective control of the midstory competition, we wanted to evaluate how a similar treatment might perform in a riparian hardwood forest in the Southeastern United States. To accomplish this goal, we first wanted to quantify how various intensities of midstory competition control actually altered the light environment below the main canopy. Although midstory control has been shown to improve the growth of desired oak reproduction, the actual increase in light availability produced with these treatments has not been quantified. Given the conditions created by removing the midstory canopy tier, the next question we wanted to explore was how much removal is necessary to promote positive seedling growth of desirable species. These treatments can be labor-intensive so it makes sense, especially for a small landowner, to reduce the amount of treatment as much as possible. This question is one that we did not try to answer in the field study itself. Rather, we wanted to see how the light levels created compare with growth trends found in the literature to see what observations could be made from these comparisons. By demonstrating the actual effectiveness of these treatments in these riparian forests, we hope to continue the discussion on the feasibility of maintaining oak as a significant component in these stands.

METHODS

The study site was located within the Blanton Creek Wildlife Management Area (WMA), GA, a 1,822-ha preserve located in the Piedmont physiographic region, and bordered on the west by the Chattahoochee River. The topography is undulating, with the uplands converted primarily to pine plantations, while the riparian zones and lowland areas are dominated by mixed hardwood forests. The riparian forests are reproductively mature and composed primarily of sweetgum (*Liquidambar styraciflua* L.), yellow poplar (*Liriodendron tulipifera* L.), and dogwood (*Cornus florida* L.). Red maple (*Acer rubrum* L.), Florida maple (*Acer barbatum* Michx.), boxelder (*Acer negundo* L.), two winged silverbell (*Halesia diptera* Ellis), ironwood (*Carpinus caroliniana* Walt.), winged elm (*Ulmus alata* Michx.), and various oaks (*Quercus* spp.) are also present. As a group, oaks comprise only a small portion of the stand, with water oak (*Q. nigra* L.) being the most common. Several invasive exotic species are also present including Chinese privet (*Ligustrum sinense* Lour.), Japanese honeysuckle (*Lonicera japonica* Thunb.), kudzu [*Pueraria montana* (Lour.) Merr.], and microstegium [*Microstegium vimineum* (Trin.) A. Camus].

Along the east bank of Blanton Creek, located in the central portion of the management area, a transect line of 50 0.05-ha circular plots (12.62 m radius) was established in the early summer of 2003. The transect was laid out in a systematic fashion with 38 m separating each plot center (allowing for a 12.6 m buffer between plots). Each plot was randomly assigned one of four different cutting regimes. The 4 treatments consisted of a control (10 plots), a light removal [every third midstory stem (10 plots)], a moderate removal [half of the midstory (15 plots)], and a complete midstory removal (15 plots). Vegetation < 1.37 m was not removed unless it posed a hazard to the cutting operation. Trees were felled with a chainsaw and all stems were left on site.

Light measurements were collected throughout the summer of 2004 beginning after full leaf expansion and concluding prior to leaf fall. Light quantity, the amount of photosynthetically active radiation (PAR), was measured with an AccuPar linear PAR/LAI ceptometer (Decagon Devices, Inc., Pullman, WA). A total of 12 readings were taken at 3 locations in each plot, each within 2 m of plot center and approximately 1.3 m above the ground. Each reading was an average of 80 sensors equally spaced along the 86.5-cm-long ceptometer. The ceptometer was pointed in the direction of the brightest light source so that the operator's shadow was not cast on the measurement sensors. Percent full sunlight was calculated based on PAR readings collected continuously at a weather station in an adjacent clearcut.

All PAR measurements were made under overcast conditions, usually during the late morning hours. Measuring PAR under clear skies often does not give an accurate description of average daily PAR levels due to the wide variation caused by direct radiation reaching the forest floor in the form of sunflecks (Messier and Puttonen 1995). However, studies have shown that instantaneous measurement of PAR made under completely overcast skies does provide a good representation of average daily growing season PAR levels (Messier and Puttonen 1995, Parent and Messier 1996). Data was collected from each plot at least three times during the growing season; average daily growing season PAR levels were calculated by averaging all readings. Data were analyzed with ANOVA as a completely randomized design. Tukey-Kramer analysis was used to test for differences between the treatments ($\alpha = 0.05$).

RESULTS

The analysis of the light intensity data shows a significant difference among midstory reduction treatments (p-value < 0.0001). As expected, there is an increase in PAR availability with increasing treatment intensity (fig. 1). The Tukey-Kramer analysis indicates that the one-third and one-half midstory removals did not significantly affect the light environment compared with that found in the uncut control plots. The control plots had average growing season PAR levels of 4.18 percent full sun, while the one-third and one-half removals had values of 5.02 percent and 6.52 percent respectively. The complete midstory removal significantly increased the light availability compared to the other treatments; PAR levels in the complete removal averaged 10.67 percent of full sun. The Tukey-Kramer

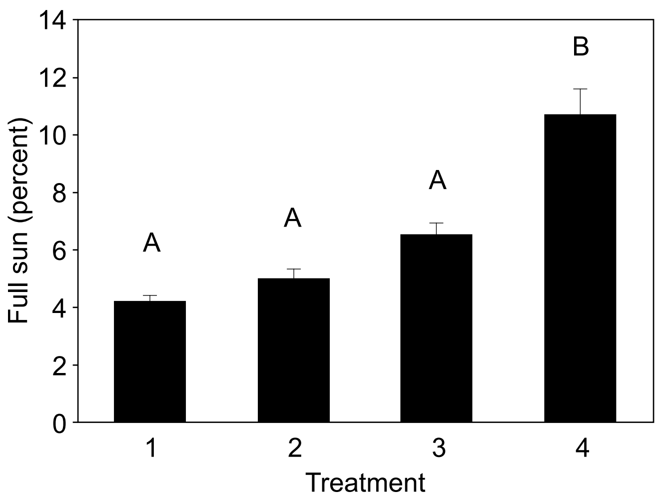

Figure 1—PAR levels below the main canopy increase with increasing midstory control intensity. Only the complete midstory removal (treatment 4) significantly improved light levels above those found in the uncut plots (treatment 1). The complete midstory removal results in an average daily growing season PAR level of 10.67 percent full sun.

test is fairly conservative. Had the analysis been done using LSD to examine differences among treatments, in addition to the complete midstory removal, the one-half midstory stem removal would also have been declared significantly different from the other treatments. This, however, is a case where statistical significance may not translate into biological significance. Given the low light conditions measured, it is unlikely that an increase of only 1.5 percent full sun would translate into a meaningful improvement in light conditions to seedlings growing in this environment.

The second portion of this study was to examine the literature in an attempt to predict how desirable reproduction might react to the light environments created by increasing levels of midstory removal. From past studies that report growth trends resulting from varying light levels, it is clear that the light environments created by midstory control in this stand are still well below what would be considered optimal conditions. Several studies indicate that the growth pattern for oak seedlings is best described by a parabolic curve; in many cases the growth realized in the lowest light levels tested was comparable to that seen under full sun conditions (Gardiner and Hodges 1998, Ziegenhagen and Kausch 1995). For cherrybark oak (*Q. pagoda* Raf.) for example, it appears that the range of light conditions needed for maximum height growth is likely between 25 percent and 70 percent full sun (Gardiner and Hodges 1998). Gottschalk (1985) examined a larger gradient of light conditions and was able to determine that the optimal growth for northern red (*Q. rubra* L.) and black oak (*Q. velutina* Lam) was closer to 20 percent full sun. Similar results have been found by Ziegenhagen and Kausch (1995) and Crow (1992).

Based on these comparisons, it is evident that oak seedlings growing in the conditions created after a midstory removal would not likely increase significantly in size. When compared to the growth seen with higher PAR levels, the growth in these low light conditions is relatively poor. Indeed, the light levels created in this study are barely included in the growth trend analysis; in most cases the conditions created in the complete midstory removal would be the lowest light level examined. Although the light levels created by midstory removal do not create conditions necessary for maximum seedling growth, the growth seen in these studies should not be equated to the actual growth that may occur following this treatment in riparian forests. Rather, since few of these studies were actually established in a forested setting, it is likely that varying moisture and nutrient availability, as well as competition, would impact the actual growth rates seen following the implementation of a midstory removal treatment. Thus, it is difficult to tell from the literature whether or not the light conditions created by removing the midstory will be enough to sustain oak seedlings in a similar forest type as the one studied. Despite the poor growth rates seen in low light conditions, Ziegenhagen and Kausch (1995) demonstrated that oak seedlings growing in 10 percent full sun conditions one year but 25 percent full sun conditions the second year were able to regain productive growth rates. Although working with pedunculate oak, this study shows that oak seedlings may become more competitive by gradually improving their light environment; this is the goal of midstory competition control. While the improved conditions resulting from the midstory control may still appear to be too poor to sustain oak reproduction, there is the example of Loftis' (1990) shelterwood which seems to indicate that some oak species can respond to the midstory control and the subsequent overstory removal.

DISCUSSION

Hodges and Gardiner (1993) present an excellent illustration of the problem summarized in this study. They indicate that the range of light conditions favorable to oak seedling growth is related to the moisture availability of the site where the seedlings are growing, with the range being narrower on mesic sites compared to xeric sites (Hodges and Gardiner 1993). When this understanding of the relationship between the necessary light conditions for oak reproduction and site quality is placed within the shelterwood prescription detailed by Loftis (1990), it appears that the midstory removal used in the shelterwood prescription creates an understory environment that falls within the narrow range of suitable light conditions illustrated by Hodges and Gardiner (1993). In short, the conditions created by Loftis' (1990) shelterwood prescription are not suitable to the establishment and growth of fast-growing competitors such as yellow poplar but are sufficient to allow slow but steady growth by the desired oak reproduction already present on site. Because of these conditions, oak reproduction was able to maintain a competitive position below the main canopy. The hypothesis explored in this study was determining whether midstory treatments can create conditions that are favorable to oak reproduction on riparian sites.

It is apparent from the analysis presented above that the minor midstory removals did little to enrich the light environment below the main canopy; only the complete midstory removal appears to significantly improve the light environment in this riparian forest. Since the partial midstory removals failed to create conditions significantly different from the surrounding uncut stand, it is likely that these treatments are not sufficiently intense to promote oak seedling growth in this ecosystem. However, the question remains whether a complete midstory removal creates conditions that promote development of the desired oak reproduction while controlling faster growing shade intolerant species. Although not quantified in this study, the conditions created (approximately 10 percent full sun) do not seem to be sufficient for the establishment of these species. Even so, we cannot yet determine whether these conditions are sufficient to promote oak development.

A review of the literature indicates that the light conditions created in this study are too low to maximize oak seedling growth. Further, greater mortality is expected under these conditions over time than would occur under an ideal light environment (Crow 1992). However, it is important to distinguish between creating conditions to maximize oak seedling growth and creating conditions that optimize oak seedling growth relative to the competition. As shown in Loftis (1990), relatively slow seedling growth is acceptable provided that the desired species remains in a competitive position prior to the overstory removal. If the desired species can be maintained and remain competitive to this point, then there is an increased likelihood that they will remain in the future stand. Since the main competitors in the low light conditions typified following a midstory removal are shade tolerant species, it is against these species that growth studies should be conducted. Chambers and Henkel (1989) did attempt to compare the height growth of several species including desirable oaks and common, less-desirable species over a range of light conditions created by partial cutting. Over the 2-year measurement period, however, this study fails to indicate whether the differences in heights between the oaks and the shade tolerant competitors are significant or not. By further exploration of these growth comparisons, researchers will be able to better determine whether the light conditions created by a midstory removal are sufficient to promote the development of desirable oak reproduction in riparian forests.

ACKNOWLEDGMENTS

We are grateful for financial support from the Center for Forest Sustainability at Auburn University, Georgia Power, and to the Georgia Department of Natural Resources for their assistance and the use of Blanton Creek Wildlife Management Area; and finally to John Lhotka, Patrick Rawls, Troy Taylor, and Ben Blass for their assistance in the field.

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