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Silviculture for Acadian Spruce-Fir Forests

Natural Regeneration

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Silviculture for Acadian Spruce-Fir Forests No. 5

Ecology of Seedling Establishment

Natural regeneration methods in silviculture are defined by the mechanism by which new trees become established. New trees can begin life only if some of the overstory trees die or are removed, freeing growing space (light, moisture, nutrients) for a new cohort. We distinguish between seedlings that establish after a disturbance via "seed rain" versus those that are "stored" on the site and respond to the post-disturbance environment. The clearcutting and seed-tree methods emulate stand-replacing disturbances such as wildfires where trees must reestablish from survivors either off-site or as scattered individuals within the fire. Although common worldwide, such disturbances and tree species adapted to them are virtually absent from the Acadian Forest. Northern conifer forests reproduce naturally after partial disturbances (gap dynamics) such as wind storms and pest attacks, releasing some form of stored regeneration (Fraver et al 2009).

The most important form of stored regeneration is the pool of seedlings in the understory, termed advance regeneration – new trees that establish in partially shaded understories prior to the death or removal of the parent trees. Most Acadian tree species are tolerant of shade and depend strongly on well-established advance growth; they will not establish reliably from seed rain in fully exposed environments created by clearcutting.

Natural regeneration silviculture must create suitable microsites for seeds to germinate and establish. Germination requires abundant water for the seed to break dormancy and

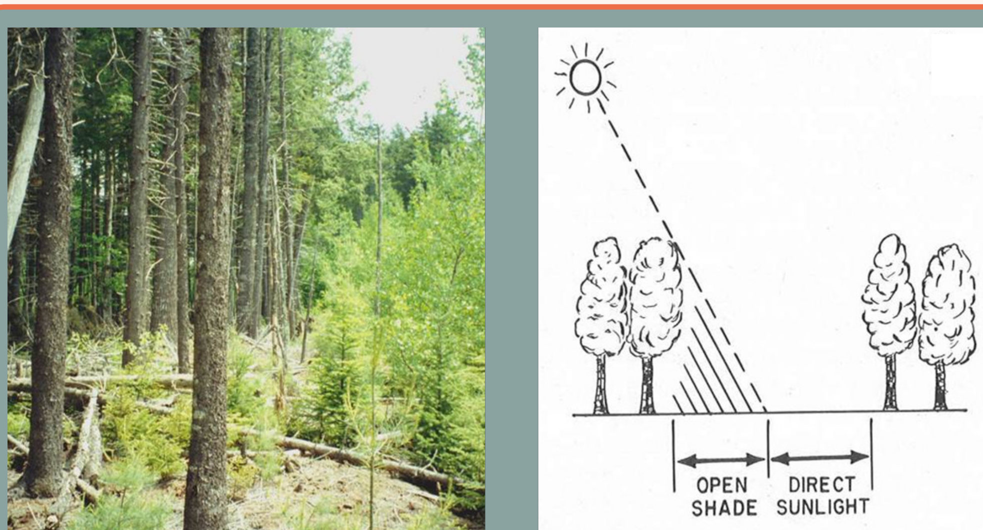

Figure 5.1. Illustration of shading gradients caused by the sun angle at 45 degrees N latitude. White birch dominates the sunlit harvested strip, while spruce-fir advance seedlings thrive in the partially shaded zone.

establish root contact with the soil, along with warm soil temperatures. Light to moderate shade is always better than full sun here. We think of the shade-intolerant paper birch as thriving after clearcuts and fires, but experiments have shown that even paper birch germinates and establishes better under light shade. Just a few hours of direct sun on a bright, hot day in May can kill new germinants via desiccation and heat injury. Two kinds of shade are always beneficial: high shade, resulting from partial overstory cover that admits mostly diffuse light rich in photosynthetically active radiation (PAR), and dead shade, resulting from logging debris, standing snags, large boulders, and other non-living features that do not compete with the seedlings for resources. Open shade, on the shaded south side of an east-west harvested strip in northerly latitudes where the sun is never overhead, can also provide a narrow hospitable zone (Fig. 5.1). In contrast, low shade, characterized by dense, suffocating foliage of unwanted competing vegetation, completely intercepts all PAR and even very tolerant species such as balsam fir will succumb under dense Rubus cover (Osawa 1994).

Figure 5.2. Red spruce seedling growing on a nurse log.

In addition to partial shade, the ideal microsite will allow roots of the new germinant to contact a stable supply of available water. Undecomposed leaf litter on the forest floor (the duff, or O horizon) binds any water so tightly that it is unavailable, so the worst possible seedbed is a thick duff layer baking in the bright sun. In contrast, partially shaded, uncompacted mineral soil and rotten wood (so-called "nurse logs", Fig. 5.2) are excellent seedbeds. Weaver et al. (2009) found that red spruce and hemlock were more abundant on decayed wood substrates than on the undisturbed forest floor; conversely, fir and red maple were less abundant on decayed wood. Fir has larger seeds and allocates more early growth to roots than spruce and thus had an advantage in early establishment (Place 1955, Greenwood et al 2008).

Another form of stored regeneration — viable seeds in the forest floor, or the "seed bank" — is an important regeneration mechanism for pioneer species pin cherry, raspberry (Rubus spp.), and mountain-ash (Sorbus spp.). No Acadian conifers persist in the seed bank (Frank and Safford 1970); most require a winter chilling period but must germinate the following spring or perish.

Silvicultural Treatments

The Shelterwood Method

Securing abundant spruce-fir regeneration is conceptually simple: advance regeneration must be well established before most of the overstory is removed. This critical principle was demonstrated nearly a century ago by Westveld (1931) who observed extensive areas of old-growth forest that had recently been heavily harvested for all merchantable softwoods. Where tall advance saplings were well established, spruce-fir forests were maintained; where it was absent or destroyed in logging, stands reverted to hardwoods.

The importance of advance regeneration leads naturally to some form of the shelterwood method. Optimally, advance growth should be at least 4-5 feet tall (saplings) when released from the overstory (Fig. 5.3; Table 5.1). If such regeneration develops naturally then the establishment cutting is not needed and the overstory can simply be removed in a manner that leaves saplings undamaged. This is an example of the one-cut shelterwood method.

If the stand is in the stem exclusion stage with no advance growth, or any advance seedlings are small and not established, then the options are (1) do nothing and allow the stand to develop naturally until reaching the understory reinitiation stage, or (2) carry out a shelterwood establishment cutting. Establishment cuttings should target the lower crown classes for removal, favoring the largest-crowned upper crown classes for shade and seed production (Fig. 5.4). Windfirmness of the residual overwood is a critical consideration, especially on shallow, poorly drained soils. Removals should be as light as the economics of harvesting allow. Overwood density should be at least 80 square feet of basal area, and removals should not exceed 40 percent of the preharvest stand (Seymour 1995). High

Table 5.1. Height Class Descriptions

Height Class	*Height Range (cm)*	*Description*
1	less than 10	**Pre-Established:** survival uncertain, with or without overstory removal.\
2	10 to 29	**Established:** capable of continued survival in understory, able to survive overstory removal
3	30 to 149	**Established:** ideal stage for overstory removal
4	greater than 149	**Too Tall:** special care may be required during overstory removal to prevent damage

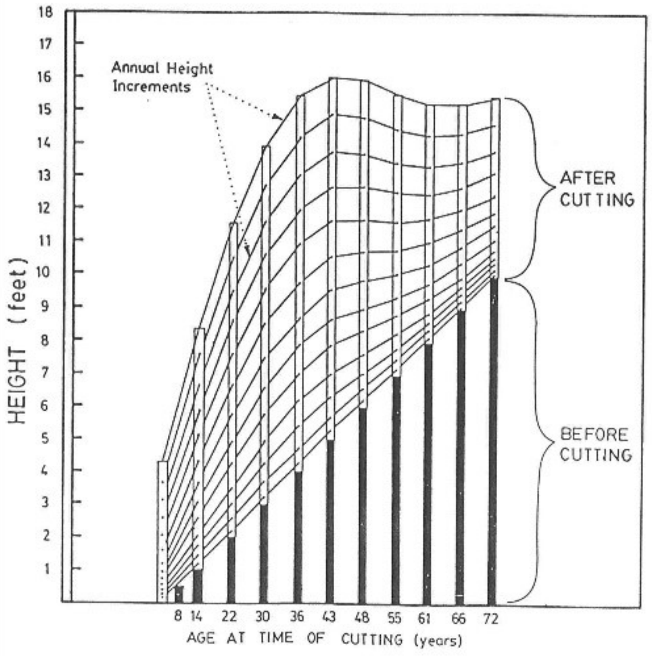

Figure 5.3. Height growth response of red spruce advance regeneration after overstory removal, by sapling height and age at time of release (from Westveld 1931).

overwood densities minimize problems with intolerant competing vegetation. The largest, most dominant trees account for most seed production, so it is critical not to remove them until their species is well represented as advance growth.

Subsequent overstory removal (OSR) cuttings must wait until the advance seedlings reach sapling size (over 4.5 feet tall) to exclude the development of competing shade-intolerant competition (Fig. 5.3). This is termed an extended shelterwood regeneration system to distinguish it from variants where the overstory is removed soon after the establishment cutting to favor less shade-tolerant species. Smaller seedlings may be established and survive OSR, but will require herbicide release treatments to eliminate competing weed species. Delaying OSR cuttings even longer imparts more irregularity in height to the sapling regeneration but requires special attention by harvester operators to prevent damage. Such irregularity promotes also promotes a natural expression of dominance, reducing or eliminating the need for precommercial thinning.

Late-successional and older mixedwood stands often have a population of suppressed, flat-topped red spruces in the understory. Although not ideal, such "umbrella" trees (Westveld 1931) should be considered desirable forms of advance regeneration, because they will respond after a few years and resume normal height growth. Indeed, this was the common growth pattern in the original presettlement spruce-

Figure 5.4. Well-stocked red spruce stand after light shelterwood establishment cutting in western Maine.

Figure 5.5. Umbrella spruce recently released from overhead competition (right), compared to mature red spruce that originated as such an umbrella tree (left).

fir forests (Cary 1894), and such an umbrella origin can often be identified in older trees by a distinct transition from a clear branch-free lower bole to a zone of densely packed dead branches, which represents the live crown base of the umbrella tree when released (Fig. 5.5; Davis 1991).

Using shelterwood cutting to favor red spruce is challenging because fir and tolerant hardwoods (red maple and beech) also thrive under the same shaded conditions. Ideally, these species would be removed in earlier entries, but this is difficult unless the spruce stocking is exceptionally high and uniform. Harvesting all the fir in the establishment cutting, coupled with moderate forest-floor disturbance that destroys fir advance growth and creates receptive seedbeds for spruce germination, can be effective if a good spruce seed year follows soon thereafter. However, under an extended regeneration period when the shade-tolerant conifer saplings develop in a shaded understory, there is no specific light level that favors red spruce over fir or hemlock (Figure 5.6, Moores et al. 2007). In very dense shade, hemlock has the advantage in height growth; at higher levels, red spruce responds but never surpasses fir.

Successful regeneration from seed obviously requires fecund parent trees as seed bearers. Balsam fir is well known to produce abundant seed crops when young (age 30), but its longer-lived associates do not bear seed until at least age 50. This difference is magnified when stands have a history of precommercial and commercial thinning, causing fir to reach maturity at age 40 well before any spruce or hemlocks bear cones. Early commercial thinning (ages 20-30) will promote the development of advance fir and hardwood regeneration but not spruce (Olson et al. 2014). If the goal is to enhance stocking of species other than fir, then immature trees of these species must be left when the fir is removed in a partial removal cutting, employing the concept of "two-rotation" species (Seymour 2023) — species that mature in two rotations of their shorter-lived associates, in this case, fir. The regenerated stand will have a two-aged

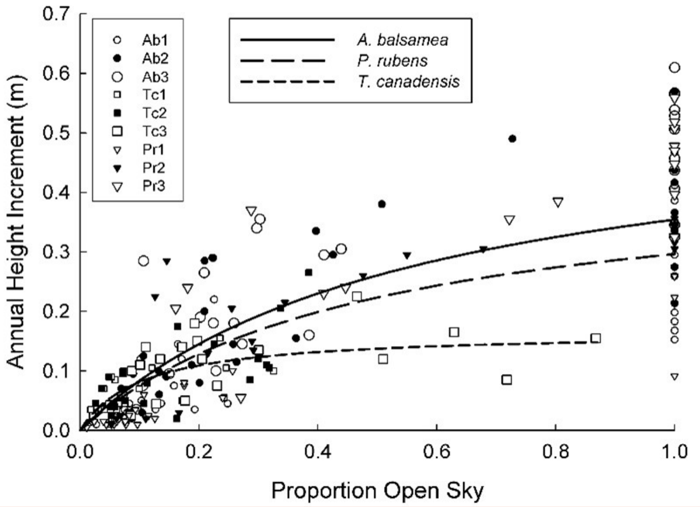

Figure 5.6. Height growth response of red spruce, balsam fir, and eastern hemlock to a gradient of increasing light (from Moores et al. 2007).

structure dominated by the regenerating fir, but when this second fir cohort matures at age 80-100, the spruces will be dominant and sexually mature and thus valuable as a shelterwood overwood.

Multi-aged Regeneration Methods

The principles and practices above can be implemented via a simple regular uniform shelterwood system that maintains a single-cohort structure if beginning with mature spruces, or a two-cohort structure if fir matures early and the two-rotation concept is needed. However, if silvicultural objectives require creating or maintaining a more diverse multi-aged structure, these same principles will result in successful regeneration as long as partially shaded conditions exist (Brissette 1996; Baitaineh et al 2013; Raymond and Bedard 2017). The main difference is that under multi-aged systems such as irregular shelterwood or selection, regeneration is generally not present or required over the entire stand, but rather, occurs in groups or patches within. A good example is the irregular group shelterwood with reserves system in the AFERP experiment (Seymour 2023), in which advance regeneration is recruited along the periphery of harvest gaps and released on a 10-year cutting cycle.

Clearcutting and Seed-tree Methods

True silvicultural clearcutting, where new seedlings germinate in exposed microsites after a complete harvest, is very risky and undependable. If there is no seed crop in the year of cutting, or soon thereafter, clearcut sites invariably are taken over by intolerant hardwoods, Rubus, or other competing vegetation. In rare cases where conifers do establish, release treatments using aerially applied herbicides are essential.

Seed tree cutting is also not recommended, for essentially the same reasons. However, leaving immature spruce, hemlock, and cedar seed sources as legacies in an overstory removal treatment (shelterwood with reserves) is strongly recommended because it will provide seed sources and other options during the next rotation that otherwise would not be there.

Lessons from History

The misapplication of true clearcutting was the main cause of the loss of 1.5 million acres of spruce-fir forest — 25% of the total area — in northern Maine from 1982 to 1995, the era of spruce budworm pre-salvage harvesting (see Section 1, the Acadian Spruce-Fir Resource). Where dense fir stands in stem exclusion were harvested without advance regeneration, true early-successional vegetation regenerated and has persisted for decades (Fig. 5.7). Where the overstory was removed in a "clearcut" harvest, releasing small advance seedlings (i.e., a one-cut shelterwood or overstory removal), the fir-spruce composition was usually maintained if the landowner subsequently released the seedlings from competition via aerial herbicide spraying. Where release treatments were not applied, stand composition is now dominated by off-site intolerant hardwoods (paper birch, pin cherry, aspen) that are the object of rehabilitation treatments to restore the conifer stocking.

Figure 5.7. Early successional vegetation dominates a clearcut of a former spruce-fir stand after 25 years.

During the 1980s, some foresters were perplexed about why some stands were not regenerating well after clearcuts, based on the misperception that these same stands had been clearcut before and had regenerated densely. This superficial view overlooked the fact that the commercial pulpwood "clearcuts" of 1910 were applied to the last remnants of the old-growth spruce forest, which had been partially cut many times during the 1800s for sawlogs, was well stocked with tall advance regeneration (Fig. 5.8a), using logging with low-impact methods, entirely during the winter in deep snow — effectively shelterwood removal cuttings (Seymour 1992). In 1980, everything was different: stands were very dense, often in

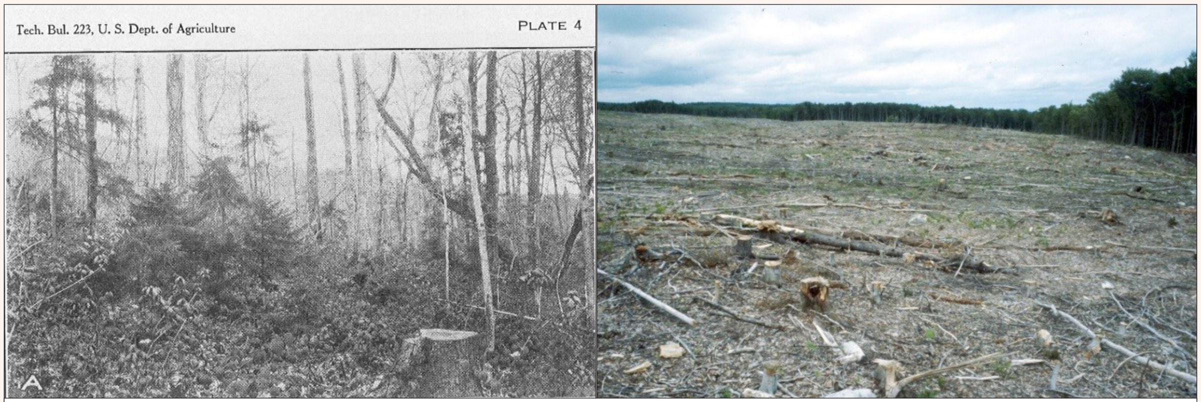

Figure 8. (a, left) Typical post-harvest regeneration pattern after pulpwood "clearcuts" ca. 1920 (from Westveld 1931). (b, right) Typical post-harvest regeneration pattern after a mechanized clearcut, ca. 1980.

stem-exclusion with poorly established advance regeneration, and logging was fully mechanized and conducted year-round with no requirement to minimize site disturbance (Fig 5.8(b)). In effect, a generation of foresters had forgotten the important findings of Westveld, or chose to disregard them in the zeal to presalvage dying fir defoliated by the spruce budworm. Wildlife biologists also seemed unaware of this distinction; two-thirds of the permitted patch-clearcut harvests in regulated deer wintering areas failed to regenerate to conifer species, permanently losing future cover (Simons-Legaard 2018).

The resurgence of the Canada lynx population ca. 2000 has falsely been attributed to the "clearcutting" associated with the budworm salvage era of the 1980s. In fact, lynx thrive only in areas where spruce-fir regeneration is successful, fostering high populations of snowshoe hares (Fig. 5.9). Researchers studying lynx found nearly as high populations in stands managed with shelterwood cutting, which was rare at the time and hence poorly studied, but few in young hardwood-dominated forests that arose from clearcutting. Lynx habitat was only created where one-cut shelterwoods followed by herbicide release allowed the development of dense conifer thickets. Note that such habitat is not early successional as is sometimes claimed, but rather, young forest of late-successional species that results from shelterwood methods. True early successional habitat that did follow some true clearcuts (Fig. 5.7) is not lynx habitat.

Figure 5.9. Stands of dense spruce-fir saplings arising from one-cut shelterwood silviculture provide ideal hare and lynx habitat.

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