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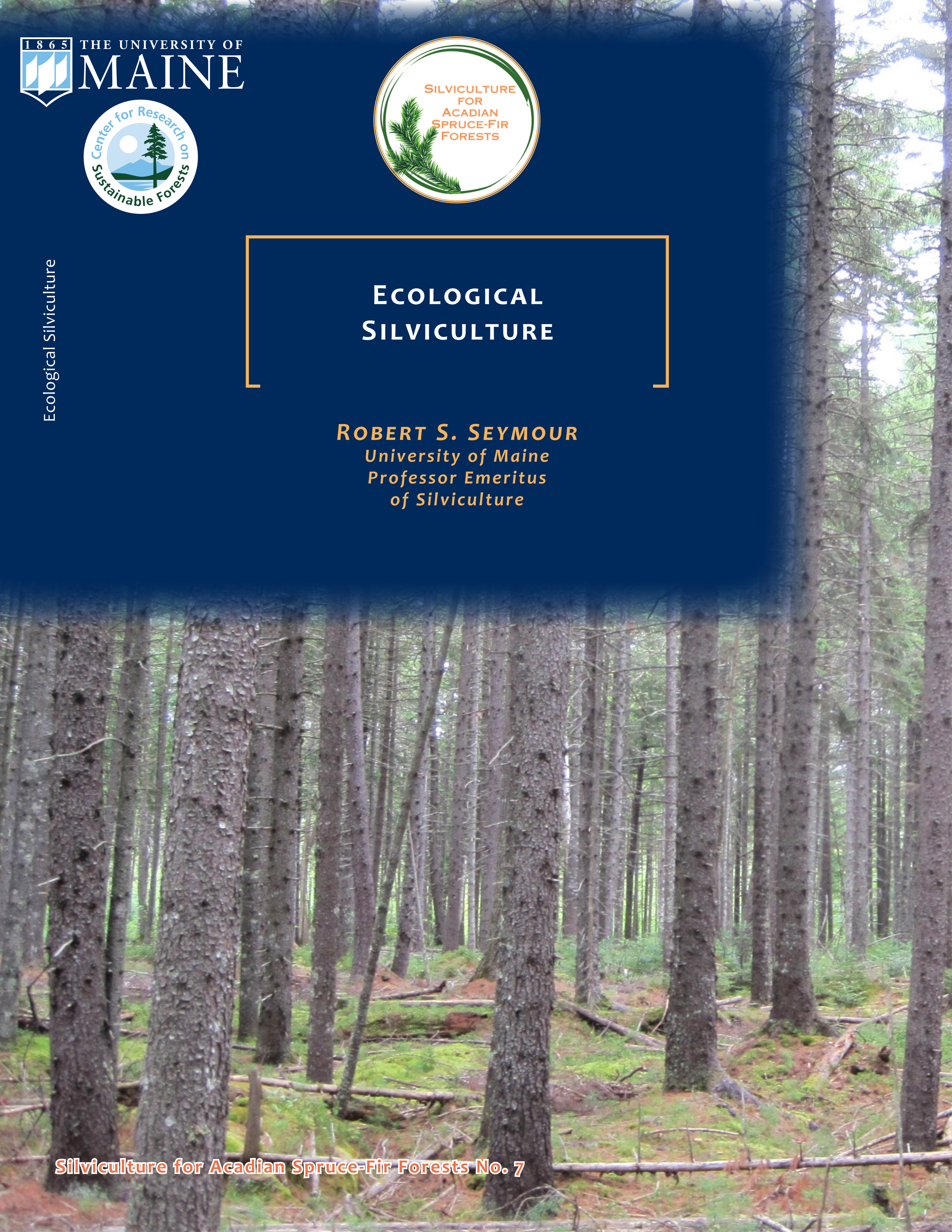
Silviculture for Acadian Spruce-Fir Forests

Ecological Silviculture



ECOLOGICAL SILVICULTURE

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Silviculture for Acadian Spruce-Fir Forests No. 7

ECOLOGICAL SILVICULTURE

During the 1990s, the emerging discipline of disturbance ecology began to characterize forest development according to natural disturbance regimes that prevailed prior to human exploitation, in recognition that virtually all forests are affected by disturbances of some kind (Oliver and Larson 1996). The key parameters of any forest disturbance regime – specific causal agents (wind, fire), severity, return interval (frequency), and post-disturbance legacies (both living and dead) – all have direct analogs to key aspects of silvicultural systems. Ecological silviculture uses this knowledge to inform choices in these parameters, essentially working within nature's template to prioritize biodiversity over traditional production and economic objectives (Palik et al 2021).

Northern Conifer Disturbance Regimes

For Acadian northern conifers, causal agents are largely windstorms and forest pests that result in partial canopy disturbances (Lorimer 1977, Fraver et al. 2009), sometimes referred to as "gap dynamics" because impacts often occur in specific patches. Using dendrochronological analysis of tree cores from the 2000-ha old-growth Big Reed Reserve in the heart of the Acadian Forest, Fraver et al. (2009) found no evidence of any disturbance exceeding 55% of the canopy killed during any decade on 37 0.15-hectare plots spanning 12-18 decades. The mean decadal disturbance rate, averaged over five forest types, was 9.6%, approximately 1% per year, confirming estimates in the reviews of Seymour et al. (2002) and Lorimer and White (2003). No stand-replacing events were found; the calculated return interval for a 50% canopy removal at the 0.15-ha scale was 1150 years. Silviculturally, these are true all-aged stands, with somewhat irregular age structures owing to varying severity of disturbances over time. These forests follow the Archetype 3 pattern of Palik et al (2021), except that some gaps result from senescence of single large 300+-year-old trees as well as species-specific pests such as spruce budworm and beech bark disease, in addition to wind.

The forests of today (*see* Section 1, The Acadian Spruce-Fir Resource) bear little resemblance to those dominant during presettlement. The exploitative logging of 1860-1930 created extensive areas of young forest over an unprecedented scale on the landscape. By 1970, millions of acres of these artificially even-aged stands reached the mature forest stage, dominating the Acadian landscape. These stands were densely stocked, intensely self-thinning, and in the stem-exclusion stage of stand development; no gaps were present,

and any advance regeneration was small and not well established (Seymour 1992, 2024). A resource-wide, severe outbreak of spruce budworm in the late 1970s led to extensive regeneration harvesting and tree mortality, resulting in third-generation forests of today that remain simplified in age structure relative to natural benchmarks. The focus of ecological silviculture must therefore be on a restoration strategy that recreates a forest dominated by diverse multi-aged stands, with some having a late-successional component that is most deficient in the commercial forest.

Restoring Diverse Age Structures

Given the natural dominance of partial disturbances, ecological silviculture of northern conifers must follow some multi-aged silviculture system that maintains three or more cohorts at a fine scale within the stand. Treatments must avoid stand-wide regeneration unless there is no better option. Foresters must regenerate only a portion of the stand at each entry while keeping the canopy of the surrounding matrix relatively intact and in stem exclusion. Areas regenerated should not average over 1% per year over a 100-year period and occur in small (under 0.5-acre) gaps (Seymour et al. 2002).

Ecologically, the ideal system would involve light single-tree and small-group selection cuttings every decade, but such operations are not practical with modern logging systems. Raymond et al (2009) outline a more feasible model, involving variants of the irregular shelterwood system, which recently became the dominant silvicultural paradigm on one million hectares of crown land in Nova Scotia (McGrath et al. 2021). Variants of the irregular shelterwood system are described in Multi-aged Silvicultural Systems (*see* section 6 of this series), and all can be employed in an ecological silviculture framework.

The ***extended*** irregular shelterwood (or shelterwood with reserves) is the simplest option, maintaining a stand structure containing only two cohorts. Natural forests are far more complex, but this may be the only feasible option if stand composition is dominated by fir or other non-LIT, short-lived species and stand-wide regeneration is thus unavoidable. Here, it is important to leave as many reserve trees of LIT species as possible, which will serve as seed sources during the next rotation as well as provide some vertical structure in an otherwise uniform-height stand.

The ***continuous-cover*** variant is best suited to stands that exhibit some degree of irregularity in height and age, and the various age cohorts are not spatially aggregated. This system is probably the most flexible and adaptable to a broad variety of stands that have a long history of heavy partial harvests but retain some irregularity and structural complexity. However, because regeneration is not quantified or mapped, it is difficult to ensure that the 1% goal is not exceeded over time. A useful surrogate is the basal area of mature trees removed from the main canopy. Unlike thinnings in immature cohorts, the residual canopy after removal of upper crown class mature trees does not close in, but rather admits light and frees other resources to promote the establishment and growth of advance regeneration. As with other variants, permanent legacies must be retained to create and maintain a component of ecologically mature trees that eventually become senescent and die. Given the diversity of such stands and the need to closely control harvest rates, continuous-cover prescriptions are best implemented by skilled foresters laying out extraction trails and marking trees to harvest.

The ***gap-based*** variant of irregular shelterwood is best suited to several conditions, which are quite different initially. If the stand structure appears to be a single mature cohort (or several mature cohorts) dominated by LIT species with little advance regeneration (i.e., still in stem exclusion), the forester has wide latitude to create new spatially defined cohorts using gap harvests during the restoration process. Other stands may have entered the understory reinitiation stage in distinct patches within the stand, that unlike candidates for continuous-cover treatment, are well defined spatially and mappable. A third reason to employ gap-based treatments is their improved resistance to post-harvest wind damage, as long as gaps are not too large and contain reserve trees to dissipate winds.

Nearly 30 years of experience from the AFERP study has shown that gap-based multi-aged systems have many advantages, both ecological and operational, in comparison to other multi-aged alternatives (Seymour 2024):

1. Regeneration is managed explicitly, not by assumptions of future ingrowth.
2. Ecological sustainability is guaranteed if the cutting cycle and area regenerated are within natural limits.
3. There is no need to assume a problematic linkage between size and age, as with dbh-based structures.
4. Pre-harvest layout, logging, artificial regeneration (if needed), and early tending are all concentrated on 10-20% of the stand at a time, with obvious efficiencies.
5. Stand-wide tree marking is not needed. Reserve trees must be designated within gaps as they are harvested, but remain obvious over time and are easy to identify and retain in subsequent harvests.
6. Harvests can be planned and executed with modern spatial-information technologies (GIS, GPS); there is no need for a pre-harvest stand table or keeping a marking tally.

7. Light harvests (removing under 25% of the stocking) are feasible with mechanized equipment because the wood is concentrated. Such light cuttings are impractical operationally if distributed evenly throughout the stand, with too many trees removed for trails and machine access.
8. Perhaps most importantly, advance regeneration in gaps can be largely avoided and thus protected in harvest entries by expanding the gaps outward and locating extraction trails in the matrix.

The target structure is defined as an area (not dbh) distribution, namely (1) the percentage of the stand regenerated at each entry and (2) a distribution of patch (gap) sizes and their locations. To emulate the natural 1% canopy disturbance frequency, foresters should plan to regenerate the entire stand in a series of at least three entries over a period no shorter than 100 years. To create a balanced within-stand age structure, the proportion of the stand area regenerated in each harvest entry is simply the length of the cutting cycle, and the number of entries (and resulting age cohorts) is the inverse of this proportion. For example, to create a balanced 5-cohort stand, entries should be made every 20 (= 100/5) years, and cover 20% of the stand area (1% x 20). Such balance is not required, and for some northern conifer forests, may not be natural. Fraver and White (2005) describe three old-growth red spruce forests in the Big Reed Reserve in which the age structures exhibit distinct episodes of recruitment during severe spruce budworm outbreaks, while still averaging about 1% over a 150-year chronology. One example of an unbalanced structure is the large-gap "Acadian femelschlag" treatment in the AFERP study (Seymour 2024), patterned after the German system that employs gaps over 20% of the stand, which are expanded this amount every 10 years. When regeneration is complete after 50 years, only stand-tending treatments are employed (no regeneration).

Structural Retention and Permanent Reserve Trees

A central tenet of ecological silviculture is to respect and maintain nature's biological legacies – mostly large, often senescent trees that survive partial disturbances and provide ecological continuity across pre- and post-disturbance cohorts (Palik et al 2021). This is accomplished in practice simply by permanently retaining some proportion of the growing stock unharvested. These trees eventually grow old and die, providing many ecological values and functions that are not maintained in stands managed under financially driven goals. Palik et al (2021) devote an entire chapter to this issue; in essence, any retention strategy should aim to create and maintain some structure of large, old, decadent trees that typically are not part of a forest managed for timber yields.

There are no fixed standards on how much retention is adequate. Because unharvested natural forests retain 100% of their trees forever, any silvicultural strategy with legacy retention represents a balance between the perfect ecological emulation and some practical treatment. Approaches used in practice tend to vary between 10 and 30% of the stocking (usually basal area), meaning that 70-90% of the stand's biological productivity can be harvested over time. Higher retention levels may be appropriate for some special conditions, but at some point, the volume harvestable trees would be so small that it would be impractical to manage. Such a forest is probably better off being completely reserved with commodity extraction directed elsewhere on the landscape.

It gap-based systems where regeneration is concentrated, it is critical to designate permanent reserves as the gaps are harvested and expanded (Fig. 7.1). This is true regardless of gap size, because if no retention is left in gaps, there will be none over the entire stand in the long run. Two decades of monitoring 787 such reserve trees in gaps averaging about one-half acre found that nearly 92% were still alive after 20 years, even though they initially comprised only 10% of the pre-harvest basal area (Carter et al. 2017). Even species not considered to be windfirm, notably red spruce, experienced nearly 89% survival. If 20-30% of the pre-harvest basal area is retained as a light, well distributed overwood (some permanently, some temporarily), gaps can be much larger than one-half tree height in width and still avoid having any direct sunlight reach the forest floor, a major advantage in regenerating most Acadian species.

Dead Wood

Another stand attribute that is not commonly considered under commodity-driven silviculture is the abundance of dead wood, in the form of standing snags and downed logs on the forest floor. These structures are habitat for birds, amphibians, and a myriad of invertebrates, and store significant amounts of carbon. They also provide an important seedbed for some species. Such material steadily decays and must be replaced over time. In theory, mortality of permanent reserve trees should accomplish this, but there have been no attempts to work out such a long-term dead-wood budget. Much research (e.g., Hoover et al 2012) has established that second-growth forests are deficient in dead wood relative to natural old-growth benchmarks, so any practices that add to this important carbon pool are beneficial to biodiversity.

Figure 7.1. Mature red spruce tree left in a 0.1-acre gap that is regenerating well to white pine and red spruce saplings.

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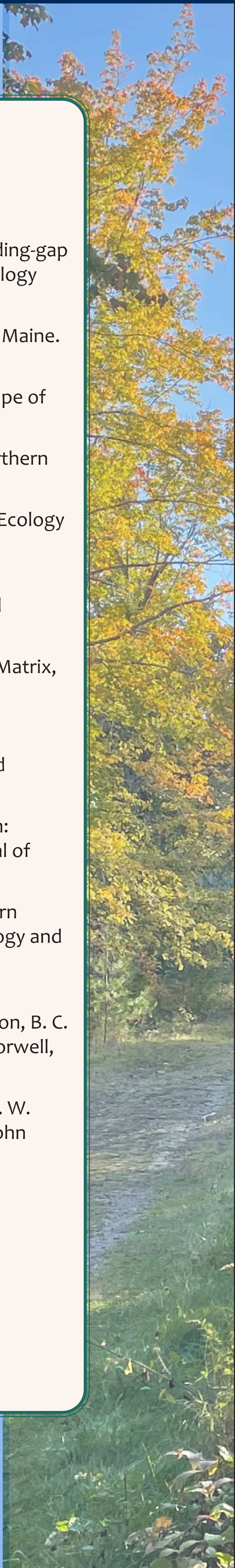

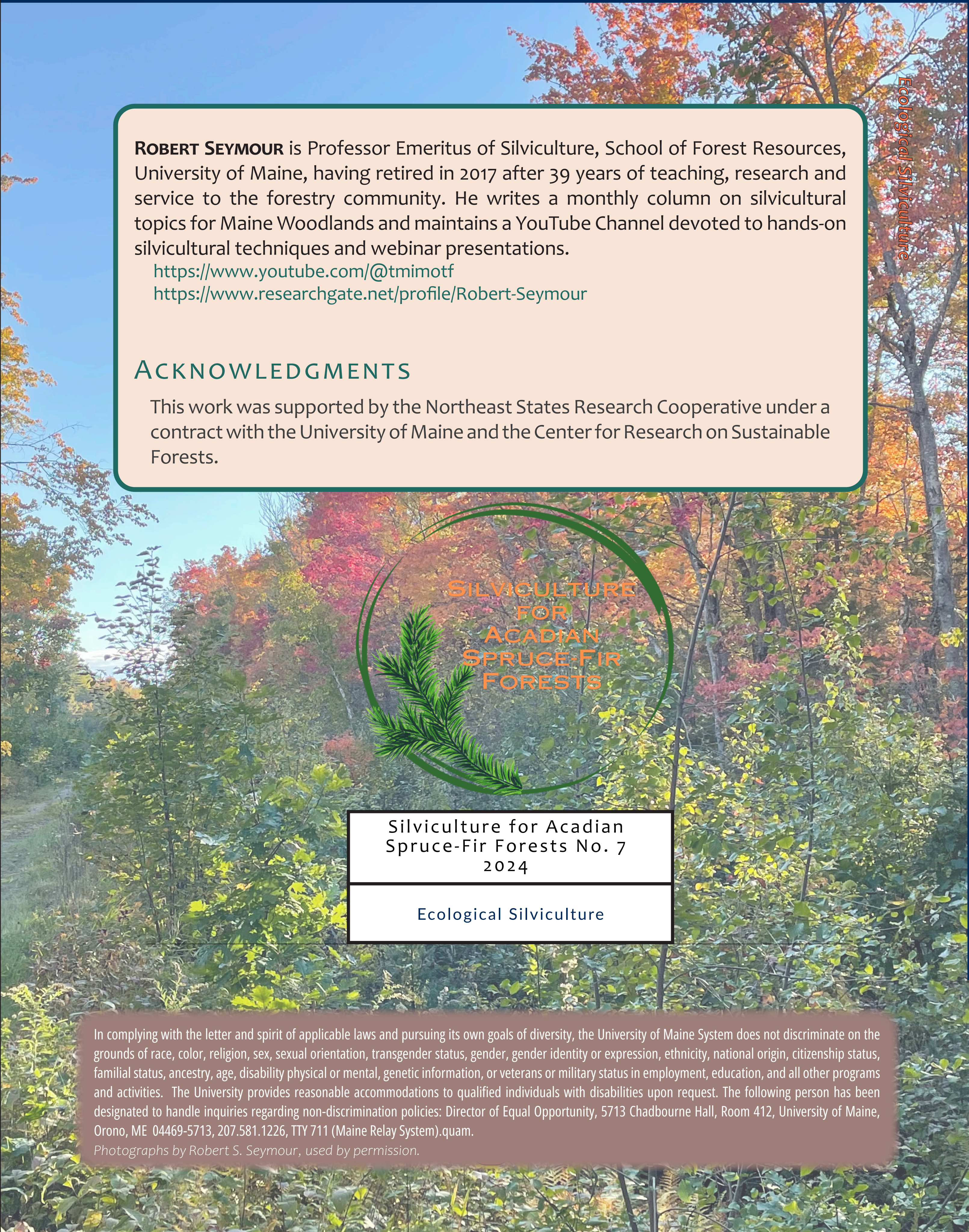

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https://www.youtube.com/@tmimotf
https://www.researchgate.net/profile/Robert-Seymour

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