ECOLOGY AND MANAGEMENT OF NORTHERN WHITE-CEDAR

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INTRODUCTION

"The object of forestry is to discover and apply the principles according to which forests are best managed."

"The forest is the most highly organized portion of the vegetable world. It takes its importance less from the individual trees which help to form it than from the qualities which belong to it as a whole. Although it is composed of trees, the forest is far more than a collection of trees standing in one place. It has a population of animals and plants peculiar to itself, a soil largely of its own making, and a climate different in many ways from that of the open country."

"Perhaps no other natural agent has done so much for the human race and has been so recklessly used and so little understood."

[Gifford Pinchot, 1900]

Since that time, forestry professionals have been trying to discern the principles of forest management and apply them in a wide array of forest types under an increasingly complex set of user demands.

One small North American forest type that has received little notice is dominated by Northern white-cedar. These forests occur in inhospitable parts of North America and were traditionally exploited for their timber values (posts, cabin logs, shingles, etc.) as cedar wood is light weight and resists decay. Recently though, attention has been turning toward cedar stands as their condition deteriorates and as awareness of their wildlife and watershed values has increased. In the mid 1900's Thomas C. Nelson [1951] wrote,

"Fewer ecological and silvicultural studies have been made on [cedar] than on any other commercial tree species in the [Lake States]. None have been made that would serve to indicate possible management practices."

Nelson began a series of field and laboratory studies of northern white-cedar for the then Michigan Department of Conservation in 1939, and pursued the secrets of the swamp species for over ten years. Others followed including William F. Johnson, who eventually wrote "The manager's handbook for northern white-cedar in the north Central States" and Louis J. Verme, who conducted many investigations on the Cusino Wildlife Research Station near Shingleton, MI.

The half-dozen, or so researchers that have addressed the management principles of northern white-cedar have advanced our understanding of the forest type a great deal. Other people working in related areas have also contributed. But, when one considers the legions of researchers working on other forest types (consider loblolly pine alone) we can understand why there is so far yet to go.

Cedar stands in the Lake States are now under limited cutting moratoriums by both State and Federal agencies because of regeneration problems experienced over the last 30 years. Although this and other papers may seem to speak authoritatively about the ecology and management of northern white-cedar, the proof is out in the swamps where real problems exist.

We have not reached the goal set by Gifford Pinchot; we have not yet discovered the principles by which this forest type can be best managed. This paper attempts to summarize the understanding we now have about northern white-cedar but it should be remembered throughout that further investigation is still required to reconcile conflicting observations and to explain failed attempts at management.

Three sections follow: 1) **Silvics** provides a brief summary of the range, site conditions, associated species, and growth of cedar; 2) **Wildlife** use summarizes the role of this forest type as wildlife habitat; and 3) **Management** provides a summary of current recommendations, problems, and options.

SILVICS OF NORTHERN WHITE-CEDAR

Range*:* Northern white-cedar (Thuja occidentalis) occurs naturally in a broad band extending from the Lake States and New England States of the United States in the south to the southern part of James' Bay in the north; and from southeastern Manitoba, Canada in the west to the Atlantic Ocean in the east (Figure 1). There are isolated natural pockets of the species as far south Tennessee and North Carolina, and cultivars have been planted even more widely as ornamentals.

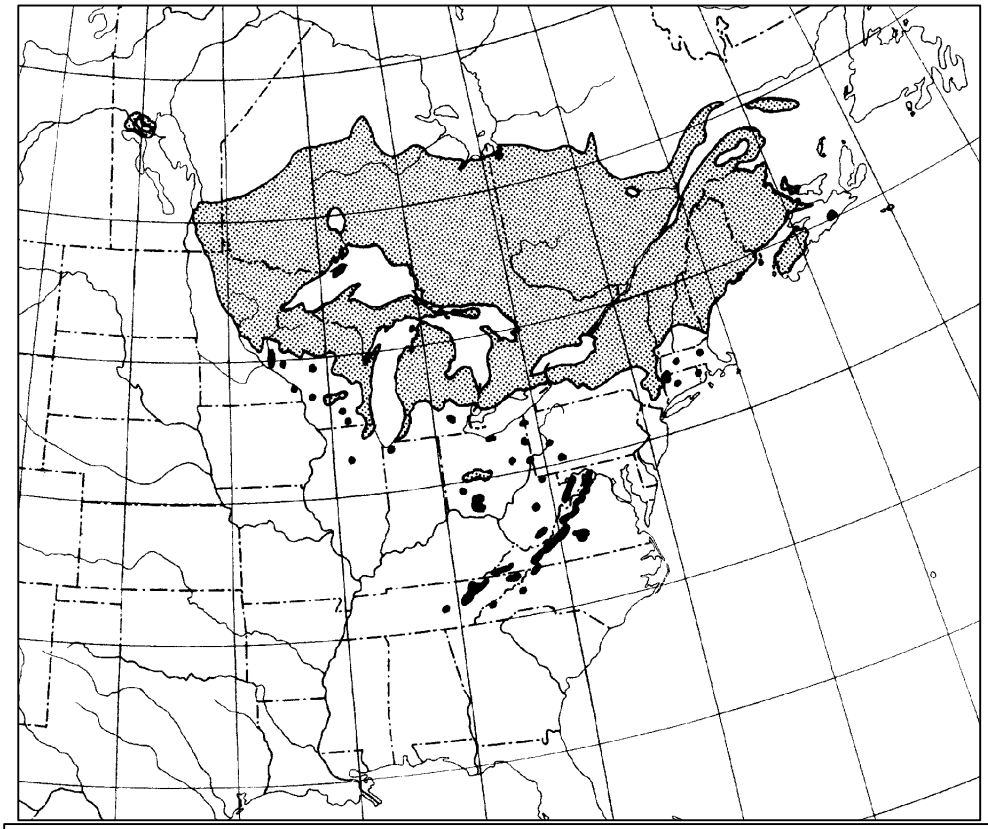

Figure 1. The native range of northern white-cedar. From Burns and Honkala, 1990.

Climate and Soils*:* The climate in cedar's natural range can be characterized as being cool (average annual temperatures of 5° to 18°C) and moist (76 to 127 cm precipitation per year -- about half as snow). Growing seasons are short, from 30 to 200 frost-free days [Fowells, 1965].

Within this glaciated region, cedar grows primarily on soils of limestone origin. These sites are extremely variable, however, and range from draughty limestone gravels with high pH, through well-drained upland loams of nearly neutral pH, to poorly-drained, acidic organic swamps and bogs.

Cedar is a slow growing, long-lived, and shade tolerant tree. Although it grows best on upland sites (three times as much in some cases [Curtis, 1946]), it is best able to compete on sites at the extremes of drainage and pH and most commonly found in the ubiquitous swamps of this region. On these organic soils cedar's growth depends on at least these characteristics [Pregitzer, 1990]:

- Soils with *shallow organic layers* overlying loamy or sandy sub-soils are best.
- Sites with enough relief to have *flowing groundwater* support better growth.
- Cedar does best on sites with *well decomposed organic layers*.
- Sites with *neutral or slightly basic* pH are favorable.

Associated Species: Northern white-cedar rarely grows in pure stands, but in mixtures with other woody species. At the northern extremes of its range (in boreal regions) it is commonly found with white spruce (*Picea glauca*), black spruce (*P. mariana*), balsam fir (*Abies balsamea*), and trembling aspen (*Populus tremuloides*). In the south it is found with these species and other conifers: White pine (*Pinus strobus*), eastern hemlock (*Tsuga canadensis*), red spruce (*Picea rubens*), tamarack (*Larix laricina*); hardwoods: yellow birch (*Betula alleghaniensis*), paper birch (*B. papyrifera*), black ash (*Fraxinus nigra*), American elm (*Ulmus americana*), and red maple (*Acer rubrum*); and various shrubs such as: tag alder (*Alnus rugosa*), willows (*Salix spp*.), and red-osier dogwood (*Cornus stolonifera*).

Growth: Northern white-cedar begins to produce seed at age 6-years but not reliably until age 20 to 30-years. It flowers in the spring, with separate male and female flowers occurring on different parts of the same tree. Seeds mature and are shed by late fall or early winter of the same year. An average tree in good condition may produce about 1/4 bushel of cones (or about 160,000 seeds) each year. Cedar usually produces some seed each year and has large seed crops every 3 to 5 years. Seed is dispersed by wind up to 60 m away from the parent tree or occasionally by squirrels over larger distances.

Seed does not usually require stratification prior to germination but dormancy has sometimes been observed when seed has been either stored for prolonged periods or dried too rapidly at high temperature. Seed germinates in about 21 days when subjected to temperatures that alternate between 30^{o} C during the daylight and 20^{o} C at night. It is thought that partial shade improves germination and early growth [Schopmeyer, 1974].

Cedar also reproduces by layering if foliage is brought in direct contact with the moist ground. This happens when trees are windthrown or when branches are cut by animals. This method of reproduction occurs frequently on deep organic soils in areas that receive heavy snowfall. Almost half of the cedar regeneration found in the eastern part of the Upper Peninsula of Michigan is of layer origin [Nelson, 1951].

Northern white-cedar grows slowly but lives for up to 400 years and is shade tolerant. In its natural association with other conifers and hardwoods cedar is not initially dominant but rather exists patiently in a lower crown class and outlives the more rapidly growing species. 52% of Michigan's cedar stands are on poor sites [1] and only 17% are on good to excellent sites [Smith, 1982; Spencer, 1982].

Pests and Problems: Cedar seed can become established easily under a wide range of conditions but it has been suggested that regeneration problems occur after seed establishment, thus preventing seedlings from maturing or being "recruited" [Pregitzer, 1990]. Young seedlings are most frequently killed by desiccation; when the loose organic material in which they are growing becomes too dry in the summer [Nelson, 1951]. Saplings are often over browsed by snowshoe hare *(Lepus*

[1] Data show that 52% of cedar stands in Upper Michigan have a site index of 30 or below and only 17% have a site index greater than 40. (Site Index = Height in feet at age 50 years).

americanus) and white-tailed deer (*Odocoileus virginianus*). This is thought to be the principle deterrent to stand development in some areas. Groundwater drainage patterns are often changed by man (or occasionally by beaver) causing sites to become too wet. The shallow root system of cedar does not always provide sufficient support, so toppling due to wind, snow, or ice loads is common. Fire can severely damage cedar due to its flammable, shaggy, oil-rich bark and shallow root system.

Northern white-cedar has relatively few disease and insect pests. Among the rare diseases are leaf *blight (Fabrella thujina*) and juniper blight (*Phomopsis juniperovora*). Both cause premature leaf browning and shedding and should not be confused with the natural browning and shedding of leaves that occurs each fall. Insects that occasionally attack cedar include aphids, leaf miners, root weevils, mites, and cedar tree borer (*Semanotis ligneus*) [Pirone, 1978]. The only problems mentioned in management guides for cedar occurs mainly in old trees where butt-rot fungi (white stringy rot or brown cubical rot) attack trees encouraging carpenter and red ant colonization [Johnston, 1977]. This constitutes a loss in commercial value more than a threat to the life of the tree.

Stand Origin: The cedar dominated swamp stands we find today are thought to have originated in one of three ways [Pregitzer, 1990]. It is proposed that in some areas hot fires burned through the swamps during years of severe draught, leaving islands of trees unburned as seed sources. The fires prepared a seedbed that favored cedar: high pH, black surface heated by the sun, undecomposed organic material burned away, and elimination of hardwood sprout competition.

Examples can be found where stands of cedar have arisen from layering. Trees in these stands frequently have curving main stems or occur in straight rows aligned with wind-thrown parents. Fires in these stands would have prevented layering by killing foliage on downed trees.

Other examples can be found of trees that obviously germinated on stumps and logs probably as advanced regeneration in an existing stand. When the decaying wood was finally gone, these trees were left standing on what appear to be stilts; the exposed roots that supported their initial development. This would be how a climax forest of cedar might sustain itself, but examples of this are not common.

WILDLIFE USE OF NORTHERN WHITE-CEDAR

Species Diversity: Northern white-cedar stands in the central Upper Peninsula of Michigan have been found to support 83 species of animals in addition to their most celebrated resident: the white-tailed deer (Table 1). Of the 84 species, 47 are birds, 34 are mammals, and 3 are herpitiles. 51 species are permanent residents of cedar stands, 30 reside there only in summer, 2 are migrants, and one (the white-tailed deer) is exclusively a winter resident [Doepker, et. al., 1990].

Mature cedar stands were found to support more wildlife diversity than regenerating or young stands. Perhaps this is due to the development of strata within the canopy and the presence of dead and down material in these stands. Boundaries between stands (edges) also provide rich habitats for animals as long as the combination of cover, food, and water are provided.

Deer Use: Despite the long list of animals that use cedar stands, we are drawn to consider the white-tailed deer as the principle user. White-tailed deer are recent immigrants to the region where white-cedar is native and are not able to survive the severe winters without seeking some type of shelter to conserve energy and evade predators. Many conifer stands can provide winter thermal cover, or a "green barn" as it is sometimes called, and indeed deer use these other conifer stands throughout much of cedar's range. But cedar is the premier winter food source for deer in this region [Ozoga and Verme, 1970] and this makes stands containing cedar the most popular and efficient winter yarding areas. In much of northern Michigan cedar stands are the only stands suitable as winter deer yards [Verme, 1965] and so their importance cannot be overemphasized.

Table 1.
Common Names of Wildlife species found in cedar stands in Northern Michigan
[from Doepker et. al., 1990]

BIRDS

Osprey
Green Heron
Spruce Grouse
Ruffed Grouse
Long-eared Owl
Great-gray Owl
Northern Saw-whet Owl
Pileated Woodpecker
Olive-sided Flycatcher
Yellow-bellied Flycatcher
Blue Jay
Gray Jay
Common Raven
American Crow
Black-capped Chickadee
Boreal Chickadee
White-breasted Nuthatch
Red-breasted Nuthatch
Brown Creeper
Winter Wren
Golden-crowned Kinglet
Swainson's Thrush
Tennessee Warbler
Nashville Warbler
Northern Parula Warbler
Yellow Warbler
Magnolia Warbler
Cape May Warbler
Yellow-rumped Warbler
Blackburnian Warbler
Black-throated Green Warbler
Chestnut-sided Warbler
Bay-breasted Warbler
Palm Warbler
Northern Waterthrush
Connecticut Warbler
Wilson's Warbler
Canada Warbler
American Tree Sparrow
Chipping Sparrow
White-throated Sparrow
Lincoln's Sparrow
Pine Grosbeak
Pine Siskin
Red Crossbill
White-winged Crossbill

MAMMALS

Arctic Shrew
Masked Shrew
Pygmy Shrew
Water Shrew
Short-tailed Shrew
Star-nosed Mole
Keen's Bat
Little Brown Bat
Hoary Bat
Eastern Cottontail
Snowshoe Hare
Least Chipmunk
Red Squirrel
Northern Flying Squirrel
Deer Mouse
Southern Red-backed Vole
Meadow Vole
Southern Bog Lemming
Meadow Jumping Mouse
Woodland Jumping Mouse
Porcupine
Coyote
Gray Wolf
Red Fox
Black Bear
Marten
Fisher
Ermine
Long-tailed Weasel
Bobcat
White-tailed Deer
Moose

HERPATILES

Wood Frog
Blue-spotted Salamander
Wood Turtle

Deer are large animals and they are numerous, thus they can have a great impact on their habitat. The deer herd in the Central Upper Peninsula of Michigan was estimated in 1987 to be approximately 72,000 animals. There is a total of 3626 km^2 of summer range in this region, which yields an average summer density of 20 deer/km^2. Winter range in the Central region (almost exclusively northern white-cedar) has been estimated to be 932 km^2 to 303 km^2 depending on the severity of the winter [Doepker et. al., 1990]. The winter density, then, ranges between 77 and 238 deer/ km^2. This deer herd obviously has an immense impact on northern white-cedar, especially when one considers that they share this winter food source with sometimes large populations of snowshoe hare.

Carrying Capacity: Calculating stand carrying capacity is a difficult, and some think impossible task. There are so many variables that change from place to place and year to year that these figures can be nothing more than general guides at best or educated guesses in the worst cases. For argument's sake, I will attempt an educated guess at the carrying capacity of the cedar stands in Michigan's central Upper Peninsula. The numbers are not as important as the method.

In order to make these calculations, several things have been assumed:

- The size of the central U.P. yard is 90 km^2 in mild winters and 30 km^2 in severe winters [Doepker et. al., 1990].
- Food availability is a critical factor limiting carrying capacity. It was assumed that the inventory information obtained from the 1980 forest survey of Michigan for shrub biomass[2] in northern white-cedar stands gives an adequate idea of the quantity of total browse available in these yards [Smith, 1982; Spencer, 1982].
- Another important factor limiting carrying capacity is the ability of the stand to recover from browsing. Although some authors are more conservative, it was assumed here that up to 20% of the foliage can be removed from cedar without adversely affecting its growth the following year [Aldous, 1941]. The same was assumed to hold true for hardwood brush.
- It was assumed that deer will spend about 90 days within the yards (January through March).
- It was assumed that the yards are being used only to feed and shelter deer. Use by snowshoe hare and other animals, such as man, is not considered. It is also assumed that deer are entering the yard in a well-fed condition which reduces their food requirements.
- The feed requirement varies for each deer with size, sex, age, and condition, but an average figure of 1.85 kg of cedar or 2.78 kg of hardwoods per day has been chosen loosely based on penned feeding trials [Ozoga and Verme, 1970]. Naturally this assumption does not account for the fact that deer will require more food during severe winters than during mild ones.

Calculations based on these assumptions are summarized in Table 2 and Table 3. From this it is estimated that the central U.P. deer yard can support about 102,000 deer in a mild winter but only about 34,000 in a severe one. The 1987 population of 72,000 can be easily accommodated in mild winters, according to these crude calculations. In a severe winter, however, this large population would be squeezed into a small area and it is likely that large numbers of deer would starve and that the yards themselves would be severely damaged. Recovery of deer herds and cedar following such a winter would take many years.

Here we see how fragile is the thread by which we hang. A forest resource that changes slowly and lethargically is heavily used by both man and animals that respond to changes in climate and policy; neither of which can be adequately predicted. As present yards age, they will become more unsuitable and need to be replaced. It should be clear that cedar regeneration and winter yarding are incompatible activities so provisions for alternate yards will need to be made. This leads to the complicated question of managing cedar stands that is addressed next.

[2] Shrub biomass is defined as: Total above ground weight (including bark) of trees and shrubs less than 2.5 cm at breast height.

Table 2. Food availability in central U.P. deer yards

	Total Biomass	Available Biomass	Feeding Rate	Days of Food Per ha
	---------- kg/ha ----------		kg/day	
Cedar	536	107	1.85	58
Hardwoods	593	119	2.78	43
TOTAL	1129	226	--	102

(Total Biomass x 20% = Available Biomass) / Feeding Rate = Days of Food

Table 3. Carrying capacity of central U.P. deer yards.

	Yard Size (ha)	Days of Available Feed Per ha	Million Deer Days	Days In Yard	Carrying Capacity
Mild	90,000	102	9.18	90	102,000 deer
Severe	30,000	102	3.06	90	34,000 deer

(Yard Size x Days of Feed/ha = Deer Days) / Days In Yard = Carrying Capacity

MANAGEMENT OF NORTHERN WHITE CEDAR

After almost 50 years of research, scores of research papers, technical notices, management guides, and the like, one would expect that managing cedar stands would be simple and automatic. Attempts to regenerate northern white-cedar seem to fail almost as often as they succeed though, so there must be something wrong. Most often it is because of what the other person did or did not do; wildlife managers blame silviculture and timber managers blame wildlife. Everyone knows of a stand that demonstrates the point they are making.

While attending graduate school I took a course from Dr. Anton Lang, a world renowned plant physiologist and senior scientist at the U.S. Department of Energy's Plant Research Laboratory at Michigan State University. We sat in his classes and hung on his every word. At the end of the term, one student asked Dr. Lang if he could summarize what he had learned during his 30-some years in plant science. I will always remember his earnest response; *"Different plants under different circumstances do different things."* That is to say, there are no generalities.

If there is one truth, it is that anyone who says managing northern white-cedar is easy -- is wrong. To paraphrase Dr. Lang, cedars under different circumstances do different things. We lack a thorough understanding of the differing responses however.

Current Management Guides : Cedar management guidelines are presently based on several traditional stand parameters including: Site index, stand age, stand size, associated species, and of course, management objectives. Since most cedar stands are predominately even-aged and given the difficulty of selection silviculture under swamp conditions, clearcutting is the harvesting method usually recommended.

Clearing of narrow (20 m wide) strips or small (1000 m^2) patches, down wind from the residual stand are often prescribed. The entire stand is harvested over 10 to 20 years by successively cutting more strips or patches. This system allows seed from the residual stand to be distributed onto the harvested area and is basically a modified seed tree system.

Strips and patches work well in areas with low deer and hare populations but are unworkable in yards. It has recently been recommended that regeneration in yarding areas can be accomplished using large clearcuts with isolated residual seed trees or direct artificial seeding. The large cuts eliminate thermal cover and overwhelm the deer with more food than they can use, thus increasing the chances that enough seedlings will remain to form a new stand.

These guidelines have been followed in many different areas across cedar's range with mixed results. It seems clear now that in order to achieve regeneration, a manager must consider more than just basic silvicultural site parameters mentioned in the guides. A more thorough system of site assessment is needed and should include physical site characteristics and external restrictions that may apply.

An Improved Stand Assessment Method: What type of stand characteristics might be important when prescribing management for cedar stands? A more thorough discussion of this question can be found in Miller, et. al. [1990] but a summary is presented below:

Detailed examination of site vegetation.

- Assessment of stand productivity.
- Inventory of crop and non-crop species.
- Interpretation of indicator species.
- Assessment of competition effects.
- Seed source evaluations.
- Evaluation of stand size and age.

Characterization of site physical characteristics.

- Examination of weather patterns.
- Assessment of micro-site variations.
- Investigation of access problems.

Characterization of soils

- Investigation of surface characteristics as they may effect establishment.
- Investigation of sub-surface characteristics as they effect growth potential.
- Assessment of soil chemistry affects on germination and nutrient cycling.

Characterization of groundwater

- Characterization of seasonal fluctuations in water table levels.
- Topographical drainage pattern assessments.

Assessment of animal pressure on the site

- Current use patterns of the site.
- Changes that might be expected at different times during stand management.
- Effects of activity in adjacent areas on animal use of the managed stand.
- Likely effects of unexpected fluctuations in animal populations.

Assessment of social concerns

- Legal restrictions against certain cultural practices.
- Political pressures that may exist against certain management decisions.

Financial analysis

- Complete accounting of all multiple use values.
- Assessment of the intensity of management system that is warranted based on stand value.

MANAGEMENT OPTIONS

It will probably be necessary for the cedar resource to be subdivided into management units, since it is so varied. Stand management can not be covered by blanket policies but rather needs to be done on a case-by-case basis.

An improved site assessment system might be used to determine the combination of cultural treatments that will achieve a desired ownership objective. Silvicultural and wildlife issues must be addressed jointly to ensure the success of any management plan and also to share the cost of the prescribed operations.

New cultural techniques need to be improved and developed to add to existing ones and so provide an arsenal from which managers can draw. Some of these techniques may be expensive and so it will be important to have a thorough understanding of the value of the stands being managed. This must include an assessment of both the traditional values of forest products as well as the less tangible values of wildlife, recreation, and watershed protection.

This paper concludes by presenting a brief summary of cedar management options. They are organized into groups: Pre-harvest Stand Treatments, Harvesting and Slash Handling, Site Modifications Before Regeneration, Regeneration, and Early Establishment and Growth Treatments.

Pre-harvest Stand Treatments

Eliminate undesirable species: Stands that contain species that are known to interfere or compete with cedar regeneration (tag alder and balsam poplar for example) could be treated to kill these species prior to harvest. This would effectively prevent them from competing with the regenerating stand. These operations would be expensive and so could only be justified in certain instances.

Encourage advanced regeneration: Cedar is shade tolerant so it might be possible in some areas to establish advanced regeneration prior to harvesting, using techniques similar to those now employed in hardwoods. This regeneration may be better able to withstand the competition of undesirable species after harvest and thereby improve the chances of success. These treatments would also be expensive and need to be carefully justified.

Harvesting and Slash Handling

Clearcutting: Although it may be possible to manage northern white-cedar using uneven-age management systems, the resulting stands may not provide quality winter deer yards. It is more likely that even-aged management systems will be required. Clearcutting in small strips or blocks is presently prescribed to take advantage of natural seeding from adjacent stands. If artificial regeneration systems are employed or deer herds are large, it may be better from an operations standpoint to increase the size of these cuts. Clearcutting is a profitable harvesting technique and creates large areas of cedar in the same stage of development.

Shelterwood: Shelterwood or seed tree regeneration systems can be employed in stands that are too small to accommodate strip or block clearcutting. Both of these harvesting systems leave scattered seed trees throughout the stand. Shelterwood also provides some of the benefits described above for advanced regeneration treatments: The shade of the shelter trees may tend to discourage regeneration of highly competitive hardwoods.

Slash handling: The accumulation of slash following a harvest operation is a problem for several reasons: It makes access to the site for subsequent cultural treatments difficult, it provides shelter for high populations of snowshoe hare, and may even prevent seed from germinating and establishing.

This slash is often the principle source of food for deer that are yarding in cutting areas. The slash acts to lure deer away from the young seedlings in previous year's cuttings. Anything done to eliminate slash must consider these positive effects.

Traditional slash handling techniques include windrowing, piling, or loping and scattering. Slash piles in cedar stand are usually the last areas to regenerate (although in some areas these piles act as natural exclosures and are the only spots that regenerate). It may be possible to use whole-tree skidding to remove the slash from the harvested area. The tops of trees

could either be fed to deer away from the site or sold for processing into wreaths or chemicals. Burning of slash will be discussed below.

Site Modifications Before Regeneration

Burning: Fires have probably played a key role in the natural establishment of cedar. Prescribed fires may have several beneficial effects: Reduce slash loading, remove undecomposed mosses on the swamp floor, blacken the surface and thus increase its temperature, and produce quantities of ash to raise the pH. Fire, then, removed competition and improved the seed bed. There are only a few cases where prescribed burning has been conducted in cedar stands [3], but it is generally thought to be a promising technique.

Cedar managers today have been hoping to use prescribed burning as part of their efforts to regenerate cedar, but have found that safe and effective burns in a swamp are even more difficult than in upland forest types. Burning windows are so narrow that only some stands can be treated this way each year. Without a serious commitment by the agencies that conduct prescribed burns, it is unlikely that burning will be used extensively in cedar management.

Mechanical scarification: The beneficial effects of burning (slash reduction and seedbed improvement) can be duplicated mechanically. Several machines are available commercially that grind woody material and mix the top layers of the swamp floor; like large rototillers or hammer mills. Machines like these are tremendously expensive and so their cost would need to be spread over many sites. In addition they tend to level the site, erasing all micro topography. This effectively places the entire site under water in the spring and makes seed germination difficult at that time of year.

Micro site modifications: As stated earlier, a primary cause of early seedling mortality is the soaking and drying cycles that occur over the year in a swamp. Operations that provide intermediate micro sites are common in the southeastern United States. Bedding, furrowing, and mounding are all examples of this type of treatment and have been used experimentally in this part of the country. These operations are also expensive, but costs vary among them. Mounding is one of the least expensive alternatives and creates a site that is analogous to an established hardwood stand; with the typical pit and mound topography.

Drainage: Recent public policy makes the drainage of wetland sites difficult to accomplish. It may be possible to develop a system that alternatingly drains areas during their regeneration phase and refloods them for the remainder of their life. A 1000 ha management area could be divided into ten 100 ha blocks. Each block might be drained for 10 years and then reflooded for the remaining part of the rotation (say 90 years). This would maintain the majority of the area as a wetland and would increase the health of the whole block.

pH and fertility adjustments: Soil pH has been implicated in the germination success of cedar seeds. Experiments are underway now to better define these relationships and it may be that lime applications on particularly acid swamp sites may greatly improve regeneration success. The beneficial effect of fertilization is obvious but the cost of this is frequently too high to justify. Quantitative measures of costs and benefits are lacking for cedar stands, however, so it is impossible to make any final determinations now.

Regeneration Methods

Regeneration from seed: Regenerating stands by natural or artificial seeding requires no or almost no investment. After harvest, one simply walks away or scatters some seed and waits. These methods have been used exclusively in the cedar resource and although the apparent costs are low, the actual costs may be very high indeed.

Cedar seed does not spread far from a seed tree so the current management system prescribes cutting in small strips or blocks. The distribution of these numerous small areas becomes a problem when the expensive machines, mentioned above,

[3] The well known work of L. J. Verme and W. F. Johnson at Cusino, MI demonstrated that broadcast burning produces more cedar regeneration than traditional logging or full-tree skidding techniques. It can be argued though that burning was not necessary on this site; traditionally logged plots had an average of 64,000 cedar per ha (2,600 cedar per acre) ten years after treatment -- certainly an adequate number.

are used to prepare the site, or when fire lines need to established around scores of 5-ha blocks. The cost of managing many small units is more than several larger ones.

Cedar plantations: Traditionally, when forest managers encounter problems with natural regeneration systems for important forest species, they establish artificial plantations. Although northern white-cedar is widely planted as an ornamental (arborvitae), plantation management of cedar swamps has not been adopted. Plantation silviculture is more expensive than natural regeneration systems but it is also more controlled.

Layering: Northern white-cedar is notorious for regeneration through layering on swampy sites. Trees of layered origin tend to have sweeping stems and are less desirable for posts and timber. Stands that reproduce by layering tend to have scattered, dense clumps of cedar that provide excellent wildlife habitat. The sweeping form of layered trees gives deer access to the foliage of older trees. Layering regeneration systems are as inexpensive as natural or direct seeding systems but may result in stands that are only suitable for wildlife objectives.

Type conversion: In certain instances the best course for management on a particular site may be to abandon the idea of growing cedar entirely. Some species, such as balsam fir, regenerate more easily and could provide some of the same thermal cover benefits to wildlife. This course of events has already taken place, unintentionally, on many sites.

Early Establishment and Growth Treatments

Competition control: Weeding operations are standard practice in many forestry operations and can be accomplished mechanically or chemically. The hardwood brush that frequently invades regenerating cedar stands can be controlled with the application of certain herbicides. Glyphosate, a broadleaf weed control chemical, is manufactured in a formulation that can be applied to open water (Accord ^{TM}) and might be effectively used in swamps. Another chemical, imazapyr (Arsenal ^{TM}) is currently being tested and is showing great promise. Some mechanical methods for reducing unwanted species have already been discussed but might also include girdling or felling of young unwanted saplings. Weeding operations can be expensive but have been shown in other applications to pay for themselves through improved stocking and growth.

Wildlife population control: Young cedar stands are susceptible to over-browsing by deer and hare. The number of animals using a regenerating stand might be altered in several ways:

- Lure animals away from sensitive areas by feeding them elsewhere. This could be done through harvesting operations in adjacent stands or by direct feeding of agricultural crops in areas remote from the managed stands.
- Reduce populations by increased hunting pressure through changes in the length of the season, type of seasons, or increased kill limits.
- Introduction of natural predators.

There is likely to be a great deal of public reluctance to employ the latter two suggestions above, so this must be considered as a cost.

Wildlife behavior modification: It may be possible to reduce the pressure exerted on young cedar stands by large deer and hare populations by changing their browsing preference. This might be accomplished by: Providing an alternate, more desirable food source at the stand; treating the cedar foliage with repellents that discourage browsing; or by breeding and planting cedar that contain natural repellents. Deer and hare have been shown to exhibit preference between cedar grown on different sites, and genetic links for this preference have been demonstrated in douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco). This approach to the cedar management problem will require more research and undoubtedly be expensive.

Wildlife exclosures: Excluding deer and hare from regenerating cedar stands has been shown to be an effective way of improving success. Many exclosure fences were erected as part of research projects over the last 30 years and have yielded

dramatic results. Large exclosures have never been used in cedar stands, although they have been used in hardwood stands in Pennsylvania. This may relate back to the growth potential of cedar stands when compared to other forest types; managers may simply not want to spend money on these projects.

An alternative to large area fencing has recently been introduced to the United States from Great Britain and a similar idea has been used in landscaping work for many years. This system involves erecting small, individual tree shelters around selected crop trees. These tubes have two advantages: First, they prevent animals from eating the trees and second, they have been demonstrated to increase the growth rate of some species' seedlings by a factor of 4 or more. Of course, they are not inexpensive.

SUMMARY

There is obviously no lack of ideas when it comes to managing cedar stands. The two principle deterrents to management, as stated by consensus at workshops held recently, are:

- Cedar responds differently to similar management methods on different sites. We lack an adequate way to predict this response, so our management success is also unpredictable.

- Although on-the-ground managers appreciate this, there is a general lack of support for finding answers about cedar and pursuing better management practices at the policy level in most agencies and governmental units.

We have a cedar resource that is aging, deer herds are larger now than ever before, and stumpage prices for cedar increase every year. The pressure on this resource has never been higher and if things continue as they are, it is certainly doomed.

I close, as I began, with the words of Gifford Pinchot*: "Perhaps no other natural agent has done so much for the human race and has been so recklessly used and so little understood."* The question we need to answer is this: Is the cedar resource (and its associated wildlife, watershed, and timber values) important enough that we make room on our list of priorities to save it?

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