Annotated Bibliography of Selected Literature Related to Vegetation and Wildlife Management in Lowland Conifer Stands of The Lake States Region

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“We’re meeting here to exchange information on the management of swamp conifers. I don’t believe we’re doing so with the feeling that we know all of the answers. The swamps have not been the simplest area for foresters, wildlife biologists, hydrologists, ecologists, and botanists to understand. It is more likely that many of us have a sense of inadequacy in tackling this subject. Most of the forces with which a forester deals push him toward the upland. That’s where the people are with whom he works. There are the roads he travels. It is only with extra effort that he pushes his way into the swamp environment.”

Robert D. McCulley
Chief, Division of Forest Management Research
Lake States Forest Experiment Station

At the third annual seminar of the Lake States Council of Industrial Foresters,
Eagle River, Wisconsin
May 24, 1963

These words from Robert McCulley are as true today as they were 35 years ago. We do know more now than we did then, but the ecosystem we seek to describe and understand is among the most complex in the region.

This document has been complied to provide a cross-section of the literature produced by people working in many fields. It is by no means exhaustive. Some of the articles summarized here are included in the binder that was distributed at this meeting. Other articles are available from libraries or from their authors or editors. When an article’s source is obscure, we have tried to provide the information you will need to obtain a copy for yourself.

A copy of this document is available at the Upper Peninsula Tree Improvement Center’s WEB site. That document will be updated based on suggestions made by conference participants. Check the library there for updates and corrections:

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Animal exclosure design and effectiveness

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Stand Origin and Distribution

Archambault, S. and Y. Bergeron. 1992.
Discovery of a living 900 year-old northern white-cedar, *Thuja occidentalis*, in northwestern Quebec.
The Canadian Field-Naturalist 106:192-195.

> Thirty 500-900 year-old specimens of Northern White Cedar, *Thuja occidentalis*, were discovered growing on xeric rock outcrops in the Quebec boreal forest, seven more than 700 years old. The oldest has an 869-year tree-ring sequence and an estimated germination age exceeding 900 years; this makes them among the oldest individuals for the species thus far noted in the literature. Such long tree-ring series offer great potential to extend the dendrochronological record in eastern Canada.

Gustafson, E.J. and T.R. Crow. 1996.
Simulating the effects of alternative forest management strategies on landscape structure.
Journal Of Environmental Management 46: 77-94.

> Quantitative spatial tools are needed to assess the long-term spatial consequences of alternative management strategies for land use planning and resource management. We constructed a timber harvest allocation model (HARVEST) that provides a visual and quantitative means to predict the spatial pattern of forest openings produced by alternative harvest strategies. HARVEST was used to investigate the effect on landscape structure of alternate management plans formulated for the Hoosier National Forest (HNF) in southern Indiana, U.S.A. The 1985 Forest Plan for the HNF specified primarily clearcutting across most of the forest, and the 1991 Amended Forest Plan specified primarily group selection (removal of small groups of trees), limited to a much smaller portion of the forest. We assessed the relative importance of variation in the extent and intensity of timber harvest on landscape spatial pattern. We simulated 150 years for each alternative and calculated several measures of forest spatial pattern. The total area of forest interior and the mean size of forest interior blocks declined more under the 1985 Plan than under the 1991 Plan, primarily because of the greater area dedicated to timber production in the 1985 plan. Despite the 65% decrease in timber production in the 1991 Plan, that Plan produced almost as much forest edge as the 1985 Plan due to heavy reliance on small harvests with large perimeter-to-area ratios. Both Plans resulted in an even distribution of age classes up to the age equal to rotation length, a dramatic decline in mid-age classes, and a large area of mature forest. The restriction of harvest activity to more limited areas in the 1991 Plan appeared to have a greater effect on forest spatial pattern than did the differences in harvest intensity of the two Plans. HARVEST provides a tool to link planning alternatives with potential changes in landscape structure, commodity production, and other resource values that are spatially dependent.

Heitzman, E. 1997.
A comparison of pre-European settlement and present-day forests in Delta County, Michigan. 🕮
p 3.1 – 3.27. IN Heitzman, E. The origin and development of northern white-cedar (Thuja occidentalis L.) forests in northern Michigan. Houghton, MI: Michigan Technological University.; 1997. Dissertation.

> General Land Office (GLO) survey records from 1841-53 were compared with data collected in 1991-92 from Forest Inventory and Analysis (FIA) plots to quantify changes in forest species composition in Delta County, northern Michigan. Northern white-cedar (*Thuja occidentalis*) was the most common species in 1841-53 and 1991-92. It comprised 25% of the trees measured in the GLO survey and 27% of the trees measured in the FIA plots. Hemlock (*Tsuga canadensis*), tamarack (*Larix laricina*), and yellow birch (*Betula alleghaniensis*) were frequently recorded in pre-European settlement forests, but were rarely represented in present-day forests. They were replaced as abundant species in the contemporary landscape by aspen (*Populus* spp.), red maple (*Acer rubrum*), and balsam fir (*Abies balsamea*). The changes observed in species composition most likely resulted from changes in the type, frequency, and severity of disturbance regimes. As Delta County became settled by people of European descent, logging, slash fires, and land clearing replaced wind and wildfire as the predominant disturbance regimes. These newer disturbances favored the establishment of early-successional species adapted to frequently disturbed conditions. Human influences also resulted in increases in the white-tailed deer population, decreases in the number of seed sources of commercially valuable tree species, and suppression of forest fires, all of which contributed to changes in species composition.

Heitzman, E., K.S. Pregitzer, and R.O. Miller. 1998.
Origin and early development of northern white-cedar stands in northern Michigan. 🕮
Canadian Journal of. Forest Research 27: IN PRESS. The version included here is from: p 1.1 – 1.28. IN Heitzman, E. The origin and development of northern white-cedar (Thuja occidentalis L.) forests in northern Michigan. Houghton, MI: Michigan Technological University.; 1997. Dissertation.

Stem analysis was used to reconstruct establishment and development patterns in seven mature northern white-cedar (*Thuja occidentalis* L.) stands in Michigan's Upper Peninsula. Stands originated after single or repeated disturbances, probably timber harvests, that occurred between 1870 and 1935. These disturbances were essential for successful cedar recruitment into the overstory. Stands developed as single or multiple cohorts, depending upon the severity and frequency of disturbance. Duration of the establishment period following single disturbances ranged from less than 10 years to 50 years. Seedlings in some multiple cohort stands established almost continuously for 100 years. Cedar overstory trees, saplings, and seedlings that survived disturbances exhibited highly plastic height growth responses to suppression and release. All study areas developed stand initiation and stem exclusion stages. Only 3% of all stems >=2.54 cm DBH established after 1945. Cedar germination beneath the mature canopy was abundant, but cedar seedlings taller than 30 cm were completely absent from most sites. Successful cedar establishment and recruitment following the initial wave of timber harvesting contrasts with widespread regeneration failures after present-day cutting practices. Factors influencing the cedar recruitment process have apparently changed over the past century.

Kudray, G.M. and M.R. Gale. 1996.
Relationships Between Groundwater Characteristics, Vegetation, and Peatland Type in the Hiawatha National Forest, Michigan.
IN: Northern Forested Wetlands: Ecology and Management, Trettin, C. C. *et al.*, Eds., CRC Press Lewis Publishers, Boca Raton, Fl., pp. 89-96.

Vegetation and ground water chemistry data from 61 peatland plots in the Hiawatha National Forest, Michigan were analyzed in the context of the bog, fen, and swamp concept. Plots were identified as to bog, fen, or swamp based on vegetation composition and physiognomy; a discriminant analysis based on ground water chemistry, water table depth, and water temperature data was then used to examine these types. The variables pH, Ca, groundwater temperature, and Mn, listed in order of best discriminating ability (decreasing F - value), were significant at the 5% level and entered into the discriminant model. A prediction accuracy of 80% was achieved using these variables. Mn could be dropped from the model with no loss of prediction accuracy. Misclassified plots were often intermediate in vegetation as reflected in a DCA ordination of vascular and bryophyte species. Bogs, fens, and swamps in this area appear to represent peatland types that are reasonably distinct in vegetation. and ground water characteristics. The view that only two types of peatlands, bogs and fens including swamps, can be recognized depends on a narrow definition of bogs and a broad concept of fens. Swamps and fens were often no more alike in vegetation and water chemistry than swamps and bogs. Swamps were highest in Ca, Mn, Al, Mg, Zn, P, and Fe. Bogs were generally lowest in ground water mineral content but had P, N, and K levels comparable to fens and swamps. The presence of a dense tree or shrub layer in swamps could be better related to water chemistry than to mid - season depth to water table. Vegetation composition, as reflected by DCA axis scores using vascular and bryophyte species in separate ordinations, was most strongly correlated with Ca and Mg levels.

Van Deelen, T.R., Pregitzer, K.S., Haufler J.B. 1996.
A comparison of presettlement and present-day forests in two northern Michigan deer yards.
American Midland Naturalist. 135(2)181-194.

In northern Michigan, deer yards (wintering areas) used by white-tailed deer (*Odocoileus virginianus*) typically consist of extensive stands of cedar-dominated (*Thuja occidentalis*) or mixed conifer swamps where thick evergreen overstories provide shelter from winter conditions. Forest and wildlife management in and around cedar-dominate swamps of the upper Great Lakes have created a nearly optimum interspersion of early-seral summer range and mature conifer winter range. For a variety of reasons, deer populations today are larger than those of presettlement conditions. General Land Office survey records from the 1840s were used to compare presettlement forest composition with present-day forest composition in two important deer yarding areas in Michigan's Upper Peninsula. Except for tamarack (*Larix laricina*), woody plant species that are unpalatable to deer or tolerant of browsing have increased. Species that are palatable and intolerant have decreased. Ages of extant mature cedars indicate establishment during a period of low deer populations. Change in forest composition has many causes, but deer populations encouraged by forest and wildlife management may contribute to a changing ecology in northern Michigan's conifer swamp communities, and may change the structure of plant communities in areas where deer use is concentrated.

Stand Development

Heitzman, E. 1997.
Establishment and development of northern white-cedar forests following strip clearcutting. 🕮
p 4.1 – 4.11. IN Heitzman, E. The origin and development of northern white-cedar (Thuja occidentalis L.) forests in northern Michigan. Houghton, MI: Michigan Technological University.; 1997. Dissertation.

Difficulties in regenerating northern white-cedar have prompted concerns among resource managers regarding the long-term sustainability of cedar forests. We studied three 20-30 year old cedar stands that successfully regenerated following strip clearcutting to determine patterns of establishment and height growth. Cedar, balsam fir, and black and white spruce grew over a broad range of height classes and comprised more than 94% of the stems in each stand. Paper birch and balsam poplar were less abundant and usually survived only in the overstory. Most trees of all species established prior to or within a 15 year period after clearcutting. Dominant and codominant trees established before or soon after harvest. Stems which originated relatively late in the establishment period remained suppressed beneath older trees. Since harvest, the tallest trees in each stand were species other than cedar. However, cedar was abundant in codominant crown positions. It took 16 to 19 years after logging for the study areas to become fully stocked with cedar taller than the over browsing reach of deer. This interval may last longer if deer are able to browse the tops of cedar >2 m tall. Cedar's successful regeneration on these strip clearcuts can be attributed to its aggressive colonization, the lack of faster-growing competitors, and limited herbivory.

Maples, T.E. and G.J. Soulliere. 1996.
Forest regeneration after harvesting white cedar in eastern Upper Michigan deer yards. 🕮
Michigan Department of Natural Resources Wildlife Division Report Number 3241. 9pp.

Regeneration was examined in several 7-year-old and 20-year-old strip cuttings in two eastern Upper Michigan deer yards. Cedar was present in 93% of all plots. Balsam fir and cedar were equally numerous (22,000 stems per hectare) throughout the area. Balsam fir was taller (averaging 2.5 m in the older strips) than cedar (averaging 0.5 m in the older strips) but cedar's shade tolerance and longevity ensures that it will be a dominant member of the developing stand in the absence of over browsing by deer.

Nelson, T.C. 1951.
A reproduction study of northern white cedar.
Game Division, Department of Conservation, Lansing, MI. 1951. 100 pp.

A detailed study was made of natural reproduction of Thuja occidentalis in swamps, and of the incidence and effect of browsing by deer, small rodents and hares. Field and laboratory observations and experiments showed that germination of seed from swamps is low, though there is usually enough seed to assure adequate reproduction. Temperatures of 18°C. and below had an adverse effect on germination and seedling vigour. A trend of increase in germination with a decrease in hydrogen-ion concentration above pH 6.0 was apparent. Full sunlight inhibited germination, and partial light was more satisfactory than darkness. In field conditions logs in various stages of decay are the preferred germinating medium and seedlings upon them developed better root systems than those upon the swamp floor. About 8.5% of the seedling population was found to be killed, and 11.5% damaged by small-rodent and snowshoe-hare browsing. Of the mortality of advanced reproduction 2-8 ft. in height, 45% was due to deer and 20% to snowshoe-hare browsing. Other subjects studied were natural regeneration by layering (aided by the presence of sphagnum moss), and the microclimate within decaying logs, and management to favour layering is suggested.

Swamp conifer management guides.

Johnston, W.F. 1977.
Manager's handbook for black spruce in the north central States. 🕮
U.S.D.A. Forest Service Gen. Tech. Rep. NC-34, 18p. N.C. Forest. Experiment. Station., St. Paul, MN.

Presents the resource manager with a key for choosing silvicultural practices to manage black spruce stands, especially for pulpwood on organic soil sites. Discusses control of growth, establishment, composition, and damaging agents; also discusses managing for Christmas trees, wildlife habitat, water, and esthetics. Includes yield and growth data, and broadcast burning techniques.

Johnston, W.F. 1977.
Manager's handbook for northern white-cedar in the north central States. 🕮
U.S.D.A. Forest Service Gen. Tech. Rep. NC-35, 18p. N.C. Forest. Experiment. Station., St. Paul, MN.

Presents the resource manager with a key for choosing silvicultural practices to manage northern white-cedar stands especially for timber and deeryards on organic soil sites. Discusses control of growth, composition, establishment, and damaging agents; also discusses managing for other wildlife habitat, water, and esthetics. Includes yield data and broadcast burning techniques.

Schaffer, W.W. 1996.
Silvicultural guidelines for the eastern white-cedar.
Ontario Ministry of Natural Resources, Southern Region Science and Technology Transfer Unit Technical Report TR-006. 62pp.

This management guide for northern white-cedar was drafted to reflect the unique conditions of the southern region of Ontario. It includes a summary of cedar's silvics, distribution, genetics, values, wildlife use, management systems (in an area where attempts are underway to increase the deer herd size), ecological site classification, and site index estimation methods. Cutting methods are suggested that maintain maximum wildlife travel corridors around harvested areas. Unlike the strip-cuts suggested in the U.S. management guides, cuttings suggested here would create an area that resembles a checker board with squares of various ages.

Swamp conifer silviculture and stand management.

Black Spruce

Burns, J., K.L. Puettmann, and D. Perala. 1996.
Strip thinning and spacing increases tree growth of young black spruce. 🕮
Northern Journal of. Applied Forestry 13(2): 68-72.

Two different thinning methods were applied to three 6- or 7-yr-old black spruce stands in northern Minnesota which were measured after 20 years. Overall, thinning improved the growing conditions for crop trees. Strip thinning with a 0.6 m leave strip and three widths of cleared strips (1.5 m, 2.1 m, and 2.7 m), and spacing to 1.5 m, 2.1 m, and 2.7 m resulted in reduced numbers of crop trees, but with larger diameters and, in the spacing thinned plots, greater heights. Because of these contradicting trends, stand volume was unaffected by thinning. Crop tree growth was not affected by the width of the cleared strip, but the distances between the leave trees in the square spacing were positively related to the increased growth response after thinning. The study is still too young to evaluate the economic feasibility of both shinning treatments, but shorter rotations or substantially increased volume seem possible by early thinnings of black spruce.

Frank, R.M. and E.L. Putnam. 1972
Seedling survival in spruce-fir after mechanical tree harvesting in strips.
USDA Forest Service N.E. Forest Experiment Station Research Paper NE-224. 16 pp.

The stocking of seedlings surviving on strips logged during winter conditions with a Beloit Tree-Harvester and a rubber-tired skidder is apparently adequate under most conditions at the end of 2 years. A sample of ¼-milacre plots measured I and 2 growing seasons after harvest indicated that heavy slash accumulations contributed most to both spruce-fir and maple-birch seedling mortality. Survival was greater off skidroads than on skidroads.

Groot, A. 1995.
Harvesting method affects survival of black spruce advanced growth. 🕮
Northern Journal of. Applied Forestry 12(1): 8-11.

Careful harvesting to preserve advance growth is an attractive regeneration option for many peatland black spruce stands. Success of this option depends on enough well-distributed trees surviving harvesting. This study examines the fate of black spruce advance growth following overstory harvesting by three methods. About 80% of the original advance growth stocking remained after winter harvesting, 70% after summer harvesting using wide-tired skidders, and 60% after summer harvesting using narrow-tired skidders. Mortality of advance growth occurred mainly during harvesting and in the first growing season after harvesting.

Johnston, W.F. 1980.
Full-tree skidding favors black spruce reproduction under certain peatland conditions
USDA Forest Service, N.C. Forest Experiment Station Research Note NC-252. 4 pp

Two trials on different sites indicate that clearcut black spruce reproduces well after full-tree skidding only on nonbrushy sites that have fairly abundant sphagnum seedbeds and adequate natural seeding.

Johnston, W.F., 1982.
Direct seeding lowland conifers. 🕮
P. 299 – 303 IN: Artificial regeneration of conifers in the upper Great Lakes Region. Mroz, G.D. and J.F. Berner Editors. Proceedings of a conference held in Green Bay, WI October 26-28, 1982. Published by Michigan Technological University, Houghton, MI. 435 pp.

Direct seeding of black spruce is used extensively on clearcut peatlands in northern Minnesota, especially on large burns and other areas where it has important advantages over natural seeding or planting. Satisfactory stocking from direct seeding requires an adequate amount of suitable seed and seedbeds. Depending on various peatland conditions, black spruce is generally direct seeded on sites prepared by broadcast burning of slash or full-tree skidding. Different reproduction and site preparation alternatives need to be developed before the best combinations can be recommended for reforesting lowland conifers, especially northern white-cedar and tamarack.

Reynolds, P.E. and M.J. Roden. 1995.
Growth of multipot black spruce seedlings planted after site preparation with liquid dry-flowable hexazinone.
Northern Journal of. Applied Forestry 12(2): 75-79.

Liquid (VELPAR L) and dry-flowable (VELPAR ULW) hexazinone (2 kg ai/ha) were aerially applied to a northern New Brunswick clearcut to reduce raspberry competition. Treatments were applied in June 1987; planting with containerized (multipot) black spruce was conducted 2 and l 4 months after treatment in August 1987 and August 1988, respectively. Seedling survival and growth were measured yearly through August 1991. Five growing seasons after treatment, raspberry competition was generally less in treated plots than in controls. Hexazinone formulation did not affect raspberry control, seedling survival, or growth. Seedlings planted 14 months after hexazinone treatment grew poorly compared with those planted 2 months after herbicide treatment. Both height and stem diameter of seedlings planted 2 months after hexazinone treatment remained greater than that of control seedlings through 1991. Diameter of treated seedlings exceeded that of control seedlings in the first growing season after planting; height of treated seedlings exceeded control seedlings 3 growing seasons after planting. Fourth-year stem diameter of seedlings planted 2 months after hexazinone treatment was correlated with raspberry cover ($r^2 = 0.383$) and with raspberry height ($r^2 = 0.379$). As raspberry competition increased, black spruce growth decreased.

Verry, E.S. and A.E. Wiling, 1978.
Two years necessary for successful natural seeding in nonbrushy black spruce bogs
USDA Forest Service, N.C. Forest Experiment Station Research Note NC-229. 3 pp.

Natural seeding in a strip-cut black spruce bog was adequate, averaging 1,800 stems per acre and 80 percent milacre stocking. Natural seeding in a completely cut bog was inadequate, averaging 630 stems per acre and 40 percent milacre stocking. Slash was removed to expose sphagnum seedbeds in both cases. Progressive cutting every other year is recommended.

Tamarack

Davis, A., K. Puettmann, and D. Perala. 1996.
Site preparation treatments and their effects on establishment and growth of tamarack. 🕮
U.S.D.A. Forest Service. N.C. For. Expt. Sta. Res. Pap. NC-328. 8p.

Investigates the effects of site preparation on tamarack regeneration. Site preparation treatments used were broadcast burning, full-tree skidding and full-tree skidding with subsequent burning. Reports the effects of these site preparations on distribution and quality of seedbed types as well as density and initial growth of seedlings.

Both site preparation treatments (burning and skidding) resulted in germination rates adequate to establish fully stocked tamarack stands. The burn treatments altered the seedbed and increased the proportion of Burn-type Bryophytes. The highest tamarack densities coincided with the presence of Burn-type Bryophytes. When burning is not possible, full tree skidding can provide adequate seedbeds. The higher density in the burn treatment resulted in greater competition between the seedlings. The slower growth rates on the burn treatments compared to the skid treatments suggest the need for earlier thinning in higher density tamarack stands.

Northern white-cedar

Foltz, B.W. and W.F. Johnson. 1968.
Gross basal area growth of northern white-cedar is independent of stand density over a wide range. 🕮
USDA Forest Service, N.C. Forest Experiment Station Research Note NC-61. 4pp.

A 20-year study in a Wisconsin swamp stand of northern white-cedar indicates that after a second thinning gross basal area growth is independent of stand densities ranging from 90 to 225 square feet of basal area per acre. Mortality, net growth, and ingrowth were also independent of density in the thinned plots.

Johnson, W.F. 1972.
Balsam fir dominant species under rethinned northern white-cedar. 🕮
USDA Forest Service, N.C. Forest Experiment Station Research Note NC-133. 4pp.

A 20-year thinning study in a Wisconsin swamp stand of middle-aged northern white-cedar indicates that advance tree reproduction and shrubs grow little until after a second thinning to less than 150 square feet of basal area per acre. Balsam fir will probably dominate this undergrowth, particularly if the area is used heavily by snowshoe hare or white-tailed deer.

Miller, R.O. 1992.
Ecology and management of northern white-cedar. 🕮
p 1-14. IN Regenerating conifer cover in deer yards. Proceedings of a workshop held is North Bay Ontario, December 4 & 5, 1990. B. Naylor and L. Thompson Editors. Central Ontario Forest Technology Development Unit Technical Report No. 28. October 1992. 117 pp.

This article is a summary of the current state of knowledge surrounding northern white-cedar in the Lake States including its: range, climate and soils, associated species, growth, pests, stand development, wildlife uses (with a discussion of carrying capacity). A summary of management practices is also presented including a proposed system of stand assessment prior to assigning a prescription. Management methods summarized include: pre-harvest stand treatments, harvesting systems, site modifications prior to regeneration, regeneration systems, and early establishment and growth treatments.

Thornton, P.L., 1957.
Problems of managing Upper Michigan's coniferous swamps.
Journal of Forestry 55(3): 192 – 197.

To summarize briefly, the following points are reiterated:

1. The forest resource is absolutely vital to the economic well being of the Upper Peninsula, and coniferous-swamps are one of the most valuable segments of that resource.
2. Several separate cover types are included in these coniferous swamps, but for practical purposes they are best discussed and treated as a single, broad type, having considerable variation.
3. The chief value of these swamps is the production of pulpwood and cedar products. Their value as habitat for deer and other wildlife is also considerable.
4. Present cutting practices, in general, preclude the attainment of the maximum sustained yield that the swamps are capable of producing. Public and private foresters are currently engaged in cooperative efforts to develop improved cutting methods.
5. Reproduction of cutover swampland is generally adequate, but the composition of the new stand is greatly inferior to the original stand in most cases. The proportion of hardwoods has increased on all soil types. White cedar and spruce are poorly represented in the reproduction on areas where they formerly grew best.
6. About one-fourth of the coniferous swamp forests are not restocking naturally to coniferous species. They are, in most cases, denuded and must be reforested artificially if a very long nonproductive period is to be avoided.
7. The spruce budworm and the larch sawfly are the two most important insect enemies of these swamps. If sawfly epidemics can be controlled, one of the best opportunities to increase production on swamp lands will be through converting unstocked or poorly stocked areas to tamarack wherever possible.
8. Many rots cause considerable loss of volume in coniferous swamps, particularly in balsam and cedar. Salvage or sanitation cutting at short intervals and harvesting balsam fir at not later than 70 years will reduce losses considerably.
9. Loss from windthrow after partial cutting is definitely a problem, but there are some indications that it may be overrated and the cause of more alarm than is justified.
10. Swamp drainage has been observed to accelerate tree growth on stagnant or extremely wet swamps. Although excessive costs have prevented any large drainage projects in the Upper Peninsula for forestry purposes a new tool, the "Kesko-Oy plow," offers some promise of reducing costs of drainage ditch construction.

The problems of managing Upper Michigan's coniferous swamps are complex, and their solution will require considerable study. However, the reward for developing management practices to meet these problems, as expressed in terms of a steady, increased production of high-value swamp products will make the task well worthwhile.

Fire

Doepker, R.V., D.E. Beyer, L.J. Visser, F.C. Short, and F.M. Short., 1996.
Northern white-cedar regeneration in Menominee County, Michigan. 🕮
Michigan Department of Natural Resources Wildlife Division Report 3255.

In the Upper Peninsula of Michigan, many cedar stands have been strip clear-cut to promote cedar regeneration. This study found clear-cutting of cedar on a seasonally wet mineral site failed to regenerate cedar, unless it was followed with a burn. Zasada (1952) and Nelson (1951) reported poor cedar reproduction following clear-cutting without burning on poorly drained mineral soil sites and suggested an increase in hardwood reproduction was at the expense of cedar. Cedar seedlings were abundant on the burned strip, however, browsing by herbivores, probably white-tailed deer, reduced the number of cedar seedlings on unprotected plots. Differences in the number of cedar seedlings between protected and unprotected plots were statistically significant 7-9 years following burning. Strip clear-cuts juxtapose food (clear-cut strip) with shelter (leave strip) for species such as deer and snowshoe hare, and may exacerbate the impact of browsing on reproduction. In addition, the presence of abundant cedar seedlings in exclosures, immediately adjacent to control plots, may attract deer to the exclosures and intensify browsing pressure on controls.

Given the existing habitat conditions, deer population density and distribution, and behavioral patterns of deer, it seems prudent to delay efforts to regenerate cedar in EMU-30. The mean number of deer pellet groups deposited per pellet course ranged from 17-32 over the course of this study. Efforts to regenerate cedar may be fruitless if regeneration efforts are undertaken in other areas with deer pellet group indices approximating those in this study, if the impact of browsing found in this study is representative.

Verme, L.J. and W.F. Johnson. 1986.
Regeneration of northern white cedar deeryards in Upper Michigan. 🕮
Journal of Wildife Management 50(2): 307-313.

This study tested the effectiveness of 3 silvicultural treatments for regeneration of northern white cedar (or eastern arborvitae, Thuja occidentalis) in an Upper Michigan deer yard. Following clearcutting on 9 plots, slash disposal consisted of broadcast burning, full-tree skidding and delimbing at a landing, or slash left as felled. Advance reproduction was killed by broadcast burning; but 2 years after clearcutting, only 30 and 46% of such stems remained alive on the full-tree skidded and slash-left plots, respectively. After the 5th growing season, white cedar <=60 cm tall averaged 33.3 trees/quadrat on the burned plots vs. 115 and 22.2 on the full-tree skidded and slash-left units, respectively. The 10-year analysis showed a continued increase in number of stems/quadrat (40.7) on burned plots but no change for the 2 other treatments. Fire appears to favor white cedar regeneration; thus, broadcast burning following clearcutting would be desirable where:

1. there is little advance reproduction;
2. thick slash deposits occur;
3. a large amount of deciduous "brush" is present, or
4. the site may convert naturally to other conifers.

Silvicultural and other considerations for rehabilitating white cedar deeryards are discussed.

Wildlife use and habitat management.

Doepker, R.V. and J.J. Ozoga. 1991.
Wildlife values of northern white-cedar. 🕮
p 15-34. IN Northern white-cedar in Michigan. Proceedings of a workshop held in Sault Ste. Marie, MI on February 21-22, 1990. D.O Lantagne, Editor. Michigan Agricultural Experiment Station Research Report 512. 122 pp.

In Michigan, northern white-cedar communities provide especially valuable breeding habitat for certain birds, especially the wood warblers, and as preferred habitat for permanent residents (birds and mammals) in winter. Considerable species variation exists regarding seasonal use of the various developmental stages of cedar. The presence and abundance of snags and dead and downed woody material, found in greater abundance in more mature stands, are important habitat features influencing wildlife habitat suitability. In addition, the proportion and spatial arrangement of the northern white-cedar community relative to other forest communities (landscape vegetation pattern) also are important. Clearly, all developmental stages of the northern white-cedar community must be well represented to satisfy the basic needs of all cedar associated wildlife species and to assure perpetuation of the forest community.

An anticipated increase in timber harvest from Michigan's forests suggests that more emphasis will be placed on harvesting northern white-cedar. In fact, annual cedar harvest volumes have already increased 199% in the western Upper Peninsula, 128% in the eastern Upper Peninsula, and 32% in the northern Lower Michigan since 1977. A long-term decrease in all developmental stages of northern white-cedar habitat is anticipated unless a concerted effort is made to regenerate this type. Northern white-cedar growing on the more productive sites may be in great jeopardy, because of the tendency of these sites to convert to hardwoods following harvest.

There is a definite need for additional research into aspects of northern white-cedar regeneration, particularly as applied to the diversified habitat characteristics of the western U.P. and those areas which receive insufficient snowcover to protect seedlings from excessive deer browsing. Nonetheless, the guidelines provided by Johnston (1977) and Verme and Johnston (1986), are adequate to assure successful regeneration of northern white-cedar in the Lake Superior watershed and other areas of extensive lowland conifer habitat. The most serious deficiencies we see are the current lack of comprehensive long-range planning, and the lack of dedicated commitment to natural conifer regeneration by the biologists and foresters involved.

Donovan, M.L. 1998.
Inventory of deer habitat in Michigan's Upper Peninsula utilizing Landsat Thematic Mapper data. 🕮
Special report written for this conference and included in this binder.

This brief article reviews the project undertaken in 1991 to identify habitats in the Upper Peninsula that are suitable as deer yarding areas. The process used images taken by satellite and processed by Maclean Consultants Lts. for the Michigan Department of Natural Resources. Type maps are not included here but may be obtained from Mike Donovan at Michigan DNR Wildlife Division. P.O. Box 30444 Lansing, MI 48909-7944.

Johnson, H.E. 1960.
Controlled deer feeding experiments.
Michigan Dept. of Natural Resources Game Management Research Project No. W-95-R-3 (Job Number A-4) Completion Report. January 15, 1960.

This an interesting report of one of the only deer feeding studies to use cedar. Because it is so obscure, we are including an extended summary of the findings below.

ABSTRACT: This progress report covers three years of winter diet feeding trials. Aspen, jack pine, sweet fern, and willow were the principal species tested. In general, all four rated quite poorly as winter foods. Feeding tests of aspen branches, aspen tips, aspen stem remains, and aspen sprouts are still inconclusive and are being continued. Control diets of cedar continued to demonstrate its high nutritional quality and value to deer. Palatability tests of cedar from limestone and swamp areas showed deer preferred swamp cedar, although both were equally nutritious to them.

SUMMARY OF FINDINGS: This comprises a progress report on feeding and represents a mere scratching of the surface to solutions in deer nutrition. We are not presenting here the details of feeding food consumption, weight analysis, and blood test techniques and ratings. The data is being studied by the Game Division biometrician and pathologist. There are many aspects of the experiments that at present are inconclusive and can only be summarized with general statements. Much of the data is still too limited for conclusive analysis and reinforcement through further work. Some of the results could not be reconciled and some could not be interpreted.

However, a number of generalizations and conclusions can be safely made. They are summarized as follows:

1. Cedar continues to demonstrate its high nutritional quality, sustaining deer well below the 30 per cent weight loss index. In comparison aspen, jack pine, willow, and sweet fern are inferior.
2. The 30 percent level of weight loss still provides the best yardstick for evaluating diets. Experience has shown that some deer starting the tests in good condition can lose 30 percent or more of their weight in the 90-day tests and still survive. But since 30 percent loss is the average maximum for young growing animals and pregnant does, that figure is still used as the dividing line between satisfactory and unsatisfactory diets.
3. The sweet fern, willow, jack pine, and total aspen diet values are in doubt. What apparently carried some animals through the experiments and not others is not known. Why some deer relished these diets and others did not is unclear. There is an unexplainable variation in deer tastes for the same browse species.
4. Analysis of blood samples has given contradictory results. Some deer who should have lived, died; some who should have died, lived. Blood protein and hemoglobin values varied greatly and fluctuated between animals and within individual animals. As the deer became weaker, erratic clotting times were evident. It was hoped that some blood factor might prove to be a reliable index to the relative degree of winter malnutrition. So far none has been consistent enough for this.
5. Weight loss could not be correlated concretely with weather or food consumption.

Ozoga, J.J. 1968.
Variations in microclimate in a conifer swamp deeryard in northern Michigan. 🕮
Journal of Wildife Management 32(3): 574-585.

Wide differences in winter microclimate were found in 1965 and 1966 among six habitat types within a single conifer swamp used by white-tailed deer (Odocoileus virginianus) as a winter yarding area in Upper Michigan. No compartment of cover provided both optimal shelter and adequate food. A densely stocked even-aged stand of mature swamp conifers offered deer the best protection from cold weather and the least hazardous snow conditions. This site exhibited the narrowest thermal ranges, warmest average temperatures during the coldest weather, highest and most stable relative humidity, least amount of wind flow, minimal snow depths, and best snow support conditions. The other habitat types consisted of pole-size and sapling conifers, mixed hardwood-conifers, northern hardwoods, and upland opening. Since deer normally seek the best shelter available from adverse climatic factors, management of conifer swamp deeryards should strive to maintain blocks of even-aged mature timber as prime winter cover, interspersed in an ideal pattern near younger stands providing abundant food.

Ozoga, J.J. and L.J. Verme. 1967.
Small mammals of conifer swamp deeryards in northern Michigan. 🕮
Papers of the Michigan Academy of Science, Arts, and Letters. Vol. 53: 37 – 49.

White-tailed deer (Odocoileus virginianus) in the Great Lakes region commonly congregate in well-protected sites during the winter to gain relief from harsh weather. Conifer swamps provide deer the best physical comfort, and thus are preferred wintering grounds. However, Verme (1965) noted wide differences in utilization and carrying capacity of northern Michigan deeryards which superficially appear similar. From all indications, availability of heavy cover rather than of good food supplies governs the selection and use of conifer yards by whitetails. Because of the complex nature of Upper Peninsula swamps, analysis of such environments poses a major problem. The purpose of this study was to determine whether appreciable variation in small mammal populations occurred among conifer yards and microhabitats. In that event, sample trapping data might be a simple means of detecting more or less discrete ecological niches important to the winter welfare of deer. We report here some results of an investigation to determine the feasibility of appraising yarding sites on the basis of species of small mammals present and their density.

At this time, we would hesitate to recommend using small mammal censuses as a clear-cut means of differentiating coniferous swamps in terms of present or future deeryard value. However, there is little doubt that the number of species and of individual animals inhabiting swamps actually does vary according to type of microhabitat.

Schad, Dave, et al. 1997.
1996 Emergency deer feeding program evaluation.
Minnesota Department of Natural Resources Section of Wildlife, St. Paul, MN. 59pp.

A comprehensive case study of emergency deer feeding during the 1995-1996 winter was prepared by the Minnesota DNR to help assess the impact on deer populations. The 1995-1996 winter season was one of the most severe on record. Public concern about deer starvation prompted the Minnesota legislature to appropriate $750,000, in addition to a $260,000 biennial DNR appropriation, for an emergency feeding program. The report evaluates program and the effects on deer populations including population impacts, potential behavioral changes, risk of disease transmission, public understanding of deer biology, methods to improve program effectiveness, policy recommendations, relevant literature, and more.

Verme, L.J. 1965.
Swamp conifer deeryards in Northern Michigan. 🕮
Journal of Forestry 63: 523 – 529.

A study of winter range use by white-tailed deer (Odocoileus virginianus) in conifer swamps of Michigan's Upper Peninsula indicated that all-age forests were uninhabited, despite an abundance of browse, because shelter requirements were lacking. Interspersion of food and cover on small, diverse tracts promptly led to overuse of white-cedar (Thuja occidentalis), followed by herd dieoffs. Habitat of high carrying capacity was characterized by various large even-aged stands. Findings suggest deeryard management should aim at creating, within a compartment, five age classes of timber with 15 to 20 years between classes and a rotation cycle of 80 to 100 years. Clearcutting by the alternate-strip method, on blocks between 40 and 160 acres, is recommended. Units supplying browse or shelter must be arranged to regulate winter deer activity and minimize forest damage.

Animal exclosure design and effectiveness.

Craven, S. and S. Hygnstrom. 1992.
Controlling deer damage in Wisconsin. 🕮
University of Wisconsin Cooperative Extension Bulletin G3083. 12pp. An almost identical document (Controlling Deer Damage: C728) was placed in the public domain by the Kansas State University Cooperative Extension Service and is included in this binder. It is also available on the internet at:
http://www.oznet.ksu.edu/__library/pub/library/wildlif/wldlfpub.htm

A brief review of deer damage control techniques is reviewed. Methods include: herd management through hunting and birth control, scare devices, repellents (8 types are reviewed), and fencing (6 fence types are described including construction tips). Additional sources of information are included as well.

Cummings, C. and G.K. Yarrow. 1996.
Reducing deer damage at home and on the farm.
Clemson University Cooperative Extension Service Publication AFW6, August, 1996. 20pp. Contact: Bulletin Room, Room 82, Poole Agricultural Center, Clemson, SC 29634-0311.

This document is a short summary of the benefits of and problems with the deer herd in South Carolina. It reviews a range of measures to control deer damage. Control methods discussed include: (1) living with the damage, (2) habitat modification, (3) herd management, (4) scare tactics, (5) repellents, and (6) physical barriers. Benefits and drawbacks of each method are discussed along with instructions for their application.

Curtis, P.D., M.J. Fargione, and M.E. Richmond. 1994.
Preventing deer damage with barrier, electrical, and behavioral fencing systems. 🕮
IN: Proceedings of the 16th Vertebrate Pest Conference. Halverson and Crabb Editors. University of California, Davis.

White-tailed deer (Odocoileus virginianus) are responsible for damage to a variety of horticultural crops. Economic losses often require growers to implement one or more damage management methods including repellers, scare devices, hunting to control deer numbers, and fencing. A relatively small proportion of producers currently use fencing as their primary deer damage management technique due to high initial costs and other perceived shortcomings. Several fencing systems, including baited single wires, three-dimensional outriggers, and slanted and vertical fences up to 3.3 m (11 feet) in height have successfully excluded deer under some conditions, but simple designs are effective only under light deer pressure, or for relatively small (< 5 ha) areas. Low-cost fences are seldom satisfactory for protecting commercial orchards or ornamental plantings during winter, especially if snow restricts normal deer foraging opportunities. Combining electric fences with either attractants or repellents can enhance their effectiveness. Recent experiments with invisible electronic fencing systems and dogs have resulted in reduced deer damage to crops, however, additional research is needed to determine dog density per unit area for reliable protection during winter. Actual costs for fence installation vary depending on site characteristics, labor quality and costs, and sources of materials. It is important for growers to calculate the annual fencing costs for an orchard or nursery based on the anticipated life-expectancy of the fence design.

Hygnstrom, S.E. and S.R. Craven. 1988.
Electric fences and commercial repellents for reducing deer damage in cornfields.
Wildlife Society Bulletin 16:291-296.

We evaluated the efficacy and cost-effectiveness of 3 single-strand electric fences (smooth wire baited with peanut butter [PB], yellow polytape [VGS], and aluminum foil ribbon LOG]) and 2 commercial repellents (Hinder and Magic Circle) used to control deer damage in cornfields. Deer damage was less in fields protected by single-strand electric fences (x = 277 kg/ha) than in unprotected control fields (x = 2,573 kg/ha). There were no differences in efficacy among the 3 fence treatments and all had 1- and 5-year benefit:cost ratios > 1.0; however, we recommend only the PB and VGS fences. Both are durable, easy to construct, and relatively inexpensive (average material and labor costs were $0.35 and 0.07/ m, respectively). The GG fences were costeffective, but they were the least durable and most expensive and difficult to work with. Hinder and Magic Circle were inconsistent in controlling damage and had unacceptable benefit:cost ratios.

Kiwi Fence company
Product Catalog. 🕮
Contact: Kiwi Fence Company: 1145 East Ray Furman Hwy. Wanesburg, PA 15370-8070 *or* Delta Fence Co. PO Box 394 Escanaba, MI 49829.

This catalog is included as a reference not as an endorsement. Several brochures are also included with the catalog that cover information about the wire, fence charges, voltmeters, and other tools. This is promotional material and should be used with that in mind.

Pennsylvania Game Commission
Electric deer deterrent fence instructions. 🕮
A manual of the Pennsylvania Game Commission, Bureau of Wildlife Management. 2001 Elmerton Ave. Harrisburg, PA 17110-9797. 34pp.

This is one of the few documents available without copyright restrictions that describes high-tensile wire fence construction methods in detail. These techniques are tailored to commercial forest applications and are part of the Pennsylvania Game Commission's program of paying landowners for fence parts and installation. All phases from lay-out to corner construction, wire stringing and fastening, wire tensioning, gating, grounding and charging, and lightning protection are covered. There are numerous documents like this but this one was available and is included here.

Selders, A.W. and J.B. McAnich. 1987.
High-tensile wire fencing.
Northeast Regional Agricultural Engineering Service Publication NRAES-11. 23pp. Contact: 152 Riley-Robb Hall, Ithaca, NY 14853-5701. (607)-255-7654. nraes@cornell.edu.

This publication provides a thorough guide to the construction of high-tensile wire fencing (including vertical and slanted smooth wire fences and woven wire fences) for the purpose of excluding deer. Diagrams and written explanations are included to provide a range of options for the design, construction, and maintenance of effective exclosures. Although the publication is 10 years old, basic fence designs are explained well.

Water quality and hydrology.

Bay, R.R. 1963.
Watershed management relationships of bog lands. 🕮
P 8-17 IN: Some recent research in swamp management. Proceedings of the third annual seminar of Lake States Council of Industrial Foresters. Eagle River, WI. May 24-27, 1963. 36pp.

Although this is an older article, so little research has been done in this field that it still serves as a fairly good summary of current understanding. Most water is discharged from swamps and bogs as surface run-off in early spring during snowmelt and as a result of early season rains. This occurs while the soil is frozen and the plants are dormant. Water discharge diminishes during the growing season when most water is lost from the site by evapotranspiration. The influence of bogs and bog management on ground water flow and recharge may be most important, but is poorly understood. Lowland conifer forests and management systems have a significant impact on snow pack and the discharge of this water into streams during snowmelt. More snow accumulates in cut swamps than in uncut swamps. Snowmelt is delayed if the cuttings are made in narrow east-west strips. This has the effect of ameliorating spring flooding. Snowmelt is accelerated if cuttings are large or strips are oriented in a north-south direction. This concentrates run-off and exacerbates spring flooding. Forest management can directly effect the hydrologic cycle of these wetlands.

Chimner, R.A. and J.B. Hart. 1996.
Hydrology and microtopography effects on northern white-cedar regeneration in Michigan's Upper Peninsula.
Canadian Journal of. Forest Research 26: 389-393.

Many harvested northern while-cedar (Thuja occidentalis L.) sites have not regenerated to cedar but have become dominated by other species such as balsam fir (*Abies balsamea* (L.) Mill.) and tag alder (*Alnus rugosa* (Du Roi) Spreng.) A regenerating cedar fen near Escanaba, Mich., was used to study factors related to regeneration success and failure. Twelve plots (6.1 x 6.1 m) were established on the site to collect data on hydrology, microtopography, stand composition, and stem density. Abundance of cedar regeneration was positively correlated with percentage of hummocks. There were more cedar on microsites with drier conditions (numerous hummocks) while more shrubs and hardwoods were found on the wetter areas (fewer hummocks) of the fen. The shallow depth to groundwater and unsaturated soil thickness early in the growing season are suggested to be factors.

Dube, S., A.P. Plamondon, and R.L. Rothwell. 1995.
Watering up after clear-cutting on forested wetlands of the St. Lawrence lowland.
Water Resources Research 31(7): 1741-1750.

Clear-cutting on wetlands of the St. Lawrence lowlands, Canada, raised the water table levels on seven of the eight studied sites encompassing five forest types and four soil subgroups. Soil types were a mineral soil, a peaty gley soil, a fen and a bog. Water table levels dropped 3 cm after clear-cutting (an eastern white cedar stand) on the eighth site, which was the wettest site with precut water levels within the top 10 cm. This was explained by evaporation from exposed water surfaces. The magnitude of the water table rises increased with the depth of the precut water table. The seasonal mean and maximum rise were respectively 20 and 52 cm on a poorly drained mineral soil which had the lowest precut water table levels. The smallest rises, with means around 7 cm, were associated with high precut water table on bogs and on fens. The watering up was not reduced on fens where a lateral flow occurs. This study indicated that transition sites between the bogs or fens and the uplands were most susceptible to hydrologic changes after clear-cutting. Watering up was caused by reduced evapotranspiration, of which the major component was interception. The rise of the water table observed in the clear-cut and the bordering forest indicates that clear-cutting in narrow strips is not an effective solution to preventing water table rise. Silvicultural treatments to maintain interception and transpiration by leaving logging debris, small trees, and pre-established regeneration would be more effective.

Verry, E.S. 1996.
Effects of forestry practices on physical and chemical resources.
IN At the water's edge: the science of riparian forestry. Conference Proceedings, June 19-20, 1996, Duluth, MN. University of Minnesota St. Paul, MN. p 101-106.

Forestry practices in the riparian management zone will influence its future condition. Broadly speaking, favoring natural or human disturbances, early of late successional stages, and native or nonnative species (plants and animals) will shape future condition. Access to riparian management zones may induce the delivery of fine sediment (mostly sands) to streams, which reduces fish spawning capacity. The traditional sediment filter strip recommendations for roads are updated and expanded to about 50 feet on sites with little slope. Roads at stream crossing are major sources of redd-smothering sand to streams. Paving the road sloping to the channel or surfacing it with six inches of one and one-half inch crushed rock will reduce sediment loads to the stream. On high water table areas, enter only on frozen soils and cease operation if rutting to a six-inch depth occurs. Keep heavy logging equipment at least 50 feet from channels, and favor long-lived conifer and hardwood forest communities in the near bank region where most of the shading and large woody debris recruitment function are met within 30 meters (100 feet) of the bank.

Wetland and stream crossings.

Anonymous. 1995.
Protecting water quality and wetlands in forest management: Best management practices in Minnesota.
Available through the Minnesota Department of Natural Resources, Division of Forestry – R. Dahlman, 500 LaFayette Road, St. Paul, MN 55155-4044, (612)-296-6502. 140 pp.

This guidebook was developed for Minnesota land managers and woods operators to outline the best management practices for protecting water resources during forest management. Each state has a guidebook like this, but this one covers wetland road building and crossing particularly well. Among other things, the manual includes: (1) guidelines for crossing mineral wetlands, (2) guidelines for crossing peat wetlands (both shallow and deep), and (3) guidelines for crossing wetlands in winter. Pages 49-63 are included in the binder.

Blinn, C.R., R. Dahlman, and D. Oshkosh. 1998.
Options for accomplishing temporary stream and wetland crossings when conducting forest management activities.
IN PRESS. USDA Forest Service, North Central Experiment Station General Technical Report.

Presents a review of current temporary stream and wetland crossing techniques and regulations. Methods include fords, culverts, bridges, corduroy, wood and geotextile mats, gratings, chunkwood, pipe bundles, and other systems. A summary of the environmental impact issues and the regulations and statutes that effect the Lake States and northeastern U.S. as well as Quebec and Ontario, Canada are included. Photographs of various crossing systems are also included.

Ellefson, P. and A. Cheng. 1996.
North Central States nonpoint source program review. 🕮
National Council of the Paper Industry for Air and Stream Improvement, Inc. Technical bulletin No. 710. P.O. Box 13318, Research Triangle Park, NC 27709-3318. 62pp.

This report reviews state nonpoint source (NPS) control programs in the thirteen North Central states. Agricultural land uses cover 69 percent of this region, with forests covering another 20 percent. State assessments show that forest practices are among the more modest sources of nonpoint source pollution. Every state in the region has some type of NPS control program, and seven of the thirteen states have developed Best Management Practices (BMPs) specifically for silviculture. There have been few attempts to monitor rates of BMP implementation in this region.

The sections of this report dealing with Michigan, Minnesota, and Wisconsin have been reproduced in this binder.

Hislop, L.E. 1996.
Improving access and environmental sensitivity with portable surfaces on low volume roads.
USDA Forest Service, San Dimas Technology and Development Program, Publication 9624 1211-SDTDC. 11pp.

Mason, L.E. 1990.
Portable wetland and stream crossings.
USDA Forest Service, San Dimas Technology and Development Program, Publication 9024 1203. 110pp.

This document includes descriptions of several matting systems designed for military purposes but adapted here for forestry use. It also includes detailed information about the construction and use of temporary timber bridges for stream crossing with heavy equipment. Detailed design data is provided for each system.

Mason, L.E. 1992.
Gratings with geotextile as wetland crossings.
USDA Forest Service, San Dimas Technology and Development Program, Tech Tip Publication 9224 1310-SDTDC. 4pp.

Mason, L.E. and J.E. Moll. 1995.
Pipe bundle and pipe mat stream crossings. 🕮
USDA Forest Service, San Dimas Technology and Development Program, Tech Tip Publication 9524 1301-SDTDC. 4pp.

This publication is a summary of a new wetland crossing system that takes advantage of inexpensive and easily worked PVC pipe. Instructions for construction and use are provided along with observations of the tests performed on this crossing system in a field trial in Florida.

Moll, J.E. and R. Hiramoto. 1996.
The plastic road.
USDA Forest Service, San Dimas Technology and Development Program, Publication 9624 1206-SDTDC. 11pp.

This booklet provides complete instructions for the construction, installation, and use of PVC pipe matting for crossing wet or soft areas for temporary access. Detailed material lists and construction drawings are included. It can serve as a complete guide for woods supervisors and operators.