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Legacy Retention: A tool for retaining biodiversity in managed forests

What is Legacy Retention?

A concept called *variable tree retention* was developed in the late 1980s and 1990s as a forest management tool designed to retain trees as key structural elements of a harvested stand for at least one harvest rotation (Franklin et al. 1997). The retention of such trees was hypothesized to help maintain species and forest processes well-distributed across forest landscapes. Either a few trees or many trees can be retained, and trees can be left uniformly dispersed or in patches (hence the name "variable"). Dispersed and patch retention represent two ends of a continuum of possible retention strategies in a stand.

Legacy retention is an evolution of the concept of variable tree retention (Carey 1998). The key modification is that, rather than focusing solely on trees as the retained features, *any* feature with high ecological value, or with high *vulnerability* to timber harvesting, becomes a feature to be retained. Such features might include small forest wetlands such as vernal pools, patches of rare or uncommon plant species, large hollow logs on the forest floor, and large old trees covered with mosses and lichens. The word "legacy" is used to imply that these features are to be transferred through time so that they are key functional, ecological elements in the subsequent stand.

Alternative Names

clear cutting with reserves ▪ clumps ▪ green tree retention ▪ islands ▪ leave trees ▪ legacy trees ▪ lifeboats ▪ maintaining stand legacies ▪ patch retention ▪ patches ▪ remnant trees ▪ wildlife tree patches ▪ wildlife tree retention ▪ wildlife trees

Why Use Legacy Retention?

Legacy retention is a tool foresters can use to retain vulnerable ecological features in a widespread fashion across managed forest landscapes. The original concept of variable tree retention was designed to contribute to biodiversity in four ways: (1) by maintaining a constant supply of structural features that are likely to be lost due to modern forestry practices but that are essential to biodiversity, such as large trees, snags, and woody debris, (2) by retaining individuals of sensitive species that can colonize the surrounding managed forest matrix as suitable conditions redevelop, (3) by maintaining habitat patches that can serve as stepping stones for dispersing individuals and propagules, and (4) by increasing the structural diversity of the future managed stand (Franklin et al. 1997).

Legacy retention focuses on retaining those biodiversity features of the forest that are most vulnerable to being lost due to timber harvesting. Timber harvesting affects forest species in different ways, depending on the biology of the species. One trait that determines a species' vulnerability in dynamic landscapes is its dispersal ability. Large organisms, such as birds and large-bodied mammals, are able to move and/or disperse readily into suitable habitat. Smaller organisms, such as herbaceous plants, lichens, mosses, invertebrates, and terrestrial amphibians may not fare as well in intensively managed forest landscapes because some have more limited dispersal capacity. Harvesting can locally extirpate many of these species (Ash 1997, Frisvoll and Presto 1997, Lesica et al. 1991, Petranka et al. 1993, Soderstrom 1988). Once lost from a stand or landscape, recolonization by poor-dispersing species can be slow (Bailey 1976, Brunet and von Oheimb 1998, Duffy and Meier 1992, Essen et al 1996, Halme and Niemela 1993, Matlack 1994, Tapper 1976).

In addition to problems associated with dispersal, suitable habitat conditions for some species may not develop until late in forest succession. Even if dispersal ability is high, suitable conditions must develop in a stand before it can be recolonized. Recolonization rates may be lower in young versus mature forest because young forests can lack the habitat structure necessary for young herbs, mosses, lichens, and beetles (Cain and Damman 1997, Chandler 1987, Metzger and Schultz 1981, Rose 1992). In some cases it may take decades, or longer, to fully restore these species and important elements of forest structure in managed stands (Ash 1997, Halme and Niemela 1993, Hansen et al. 1991, Meier et al. 1995, Petranka et al. 1993, Selva 1994). If conservation of these species is a goal, then *not* losing them to begin with is much more cost-effective than trying to restore them later.

In forest landscapes with long histories of intensive silviculture, such as in Scandinavia and the Pacific Northwest, many land managers have adopted retention as a tool to help avoid losing forest species from large areas. In Sweden, 100 years of increasingly intensive forestry has reduced the density of big trees and the volume of snags (Fig. 1). Many of Sweden's red-listed species (the legal analogy of U.S. threatened and endangered species) are associated with big trees, big snags, and fallen logs (Berg et al. 1994). It is estimated that Finland may lose up to 5% of its forest species (~1000 species) due to the loss of features that are commonly found only in late-successional and old-growth forest (Hanski 2000). Many of these are small, inconspicuous, species such as insects, fungi, lichens, and mosses. Thus, harvesting can affect poor dispersers *at the stand level* by temporarily changing structure and eliminating critical habitat features, and *at the landscape level* by creating large areas of unsuitable habitat, and that may present barriers to dispersal.

Ecological Basis

The scientific underpinnings of legacy retention are weak because very little research has been completed and results of these studies may only be relevant to a limited geographical area. We currently are studying the effectiveness of patch retention in Maine. Early results indicate that patches can effectively retain small and vulnerable elements of biodiversity. We also can learn about the potential role of small patches for maintaining biodiversity by looking at studies in agricultural and forested landscapes.

Agricultural landscapes

Most of the research on small patches and biodiversity has been conducted in the context of agricultural landscapes containing small forest remnants. Remarkably, small forest remnants (0.2 ac) in these severely altered environments have been found to contain a number of species of small mammals (Nupp and Swihart 2000), flowering plants, Honnay et al. 1999), and ground beetles (4 acres, Nilsson and Baranowski 1997) typically found in mature forest and old growth forest. Networks of small patches may be an important part of a larger strategy for maintaining forest biodiversity in highly fragmented landscapes (Fischer and Lindenmayer 2002). In reforested landscapes such as southern New England, small forest patches never cleared for agriculture support dispersal-limited species in these landscapes (Bellemare et al. 2002). In agricultural landscapes, small patches do not work well for larger-bodied species such as birds and mammals simply because the habitat patch is smaller than the minimum area needed by these species, or because of other negative effects associated with forest edges.

Forested Landscapes

Growing interest in legacy retention has precipitated many studies evaluating the ecological values maintained by retention in managed forest landscapes. Studies of shelterwood harvesting and selection harvesting also can help us understand the ecological values maintained by legacy retention. Evidence suggests that stand "legacies," such as large logs and big old trees and snags, help maintain biodiversity. In Maine, moderate partial cuts supported (1) the same set of bird species (Hagan and Grove 1996), (2) virtually all vascular plant species, and (3) many old forest lichen species (Whitman et al. 1999) that were detected in mature closed-canopy forest. Residual forest strips surrounded by clearcuts can retain ground beetle species at abundance levels similar to that of intact forest (Jennings et al. 1986).

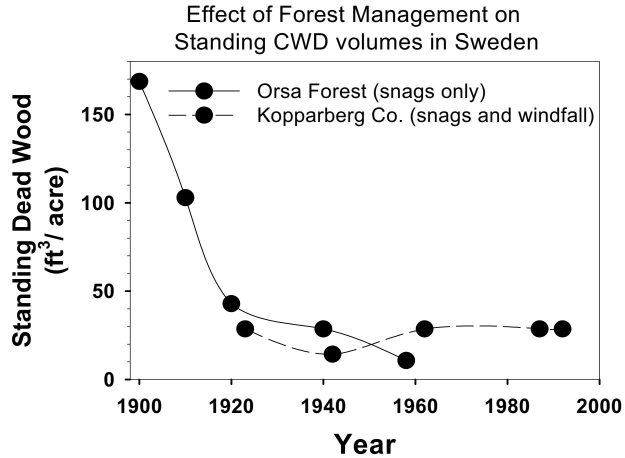


Figure 1. Trends in standing coarse woody debris (CWD) in two forest landscapes in Sweden (Linder and Östlund 1992).

Studies in regenerating clearcuts have shown that retaining mature trees helps to retain mature forest plant and animal species. Many lichens might be maintained on single, large trees within cutover areas (Sillet 1995), though survival may be improved with retention patches (Hazell and Gustafsson 1999). Small (0.8 -2 acre) undisturbed forest patches might be able to retain many rare and logging-sensitive "stubble" lichens (Order Caliciales, Kruys and Jonsson 1997). Three-acre patches may be sufficient to maintain all plant species (Beese and Bryant 1999). Some bird species tightly associated with large old trees or old forest might be maintained in younger forest landscapes simply by retaining a sufficient number of large old trees in the landscape as dispersed retention (Hansen et al. 1995, Schieck and Hobson 2000). As forest regenerates around patches (0.5-2 acres) in harvested stands, bird communities may more quickly change to resemble old forest bird communities than in harvest blocks without patch retention (Schieck and Hobson 2000). Carey (1995) found that the abundance of northern flying squirrels in naturally young stands *with old-growth legacies* was similar to abundances in old-growth forest. Our studies of retention trees left in 3-yr-old and 20-year-old shelterwood stands, forest buffers between 8-10 year-old clearcuts, and forest remnants in 80 year-old burns, suggest that variable retention may successfully maintain many late-successional forest species, including lichens, mosses, and vascular plants.

Legacy retention is not without shortcomings. It is too soon to tell whether legacy retention will work over the long-term (100s of years). One goal of legacy retention is to maintain species that disperse poorly, which are mostly small non-vertebrates. Larger-bodied, wider-ranging vertebrates such as deer or lynx may or may not benefit from legacy retention.

Other management strategies (e.g., reserves, riparian buffers) will probably need to complement the legacy retention tool. On the other hand, the absence of legacy retention as a biodiversity management tool could result in the failure of other strategies to maintain biodiversity in managed forest landscapes. What we *do* understand is that legacy features can be lost from managed forest landscapes unless an operational strategy is implemented to retain them.

A Summary of Current Guidelines for the Acadian Forest

Even though legacy retention is a relatively new forest practice, it is already widely used in North America and Europe. The retention of "legacy" (old) trees is often a condition of Forest Stewardship Council certification for landowners in the U.S. The U.S. Forest Service in the Pacific Northwest uses retention to attain specific habitat goals for spotted owls, marbled murrelets, and old-growth species.

Dispersed (or uniform) retention guidelines in the Northeast suggest retaining large trees at a minimum density of one 18" DBH tree / 2 ac (Elliot 1988) and at a maximum density of one 24" DBH tree / ac (Flatebo et al. 1999). Recommendations for overall density of retention trees range from 4 "wildlife trees" per acre to 67 trees per acre (including snags, Woodley and Forbes 1997). Patch retention guidelines in the northeast U.S. suggest leaving at least 5% of the harvest block in retention patches (Elliot 1988, Flatebo et al. 1999, New Hampshire Forest Suitability Standards Work Team 1997) with the recommended minimum patch size ranging from 0.01 acres (Woodley and Forbes 1997) to 0.25 acres (Flatebo et al. 1999).

A Minnesota survey of harvest sites provides the only systematic data on the use of voluntary guidelines for variable tree retention (Phillips 2001). Minnesota has two guidelines: (1) leave >6 scattered trees > 6" DBH per acre comprised of a mix of tree species on every harvest block, and (2) leave >5% of harvest area in patches in or adjacent to the harvest block. Compliance was 51% of sites for the first guideline and 49% of sites for the second guideline. Patches averaged 11.3% of the harvest area.

It should be understood that the recommended densities for retention trees or patches currently are based on very little data and no rigorous experimentation. However, specific numbers at least give managers a target value that can be pursued and adjusted as we learn more. At this point, definitive numbers for how much to retain are less important than taking some action to maintain ecological legacies throughout the landscape.

Box 1: Ecological legacies suitable for **patch** retention.

- large (> 18" DBH) snags,
- large (> 18" DBH) logs,
- cavity trees,
- large (> 18" DBH) shade-tolerant overstory trees,
- patches of old growth,
- rare and uncommon tree species and plant species,
- rare/endangered plant and animal species,
- beech trees with smooth bark or lacking many blocky, raised lesions,
- patches of oak or beech, especially if trees $\geq$ 8" DBH or areas with >30 ft. basal area are present,
- softwood inclusions in hardwood stands,
- hardwood inclusions in softwood stands,
- vernal pools (at least leave shade and a filter strip),
- woodland seeps and springs,
- patches that are representative of "climax" forest for the site, and
- undisturbed areas of forest in stands with a history of harvesting, agriculture, grazing, or fire.

Suggested Practices

When to use patch retention:

Use patch retention to retain any of the ecological features listed in Box 1. Patch retention is especially suitable for maintaining small, dispersal-limited species, including sensitive amphibians, plants (flowering plants, ferns, lichens, mosses, and liverworts) and invertebrates (see Fig. 2, and diagram, Pages 4,5). Patch retention can be used in clearcuts, shelterwood cuts, selection cuts, or in any stand in which the rotation period is less than 100 yrs (in n.e. U.S., s.e. Canada).

Special Considerations: Some old-growth/over-mature patches should always be maintained using patch retention regardless of harvest technique, wherever such stands occur. Partial cut areas with an intact forest understory and intact soil organic layers may function nearly as well as intact retention patches for some plant and invertebrate species. Riparian areas set aside as stream buffers can contribute toward patch retention goals but probably should not account for more than 50% of patch retention areas.

When to use dispersed retention:

Use dispersed retention to retain particular ecological features that can persist with little or no buffer (see Box 2). The biodiversity goal is to maintain forest generalists that require large trees, snags, and logs (some species of mammals, birds, amphibians, lichens, mosses, and invertebrates). Dispersed retention can be used in all harvesting techniques.

How much to retain?

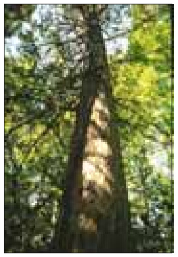
The answer to this question depends on the values that are used to establish management goals, what constitutes an acceptable risk to forest biodiversity, and the current limits of scientific knowledge. Maintaining all forest species across a

Box 2: Ecological legacies suitable for **dispersed** retention.

- rare and uncommon tree species,
- mature individuals of each species in or adjacent to each stand,
- beech trees with smooth bark or lacking many blocky, raised lesions,
- oak or beech $\geq$ 8" DBH,
- large (> 18" DBH) snags, cavity trees, and overstory trees.

Examples of Ecological 'Nuclei' for Legacy Retention

Large downed logs, especially hollow logs.



Large snags for woodpeckers, and as a source for future downed woody material.

Large living trees of low economic value. Such trees often have high ecological value.

Small retention patches (0.1 – 0.5 acres) can provide the same features as single trees, and provide habitat for sensitive mosses, lichens, insects. Small patches may be used by small and large vertebrates as "stepping stones."

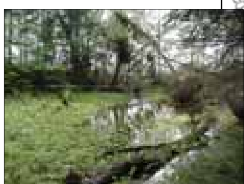
Single trees can provide nesting habitat for raptors and woodpeckers, provide substrate for tolerant lichens, and become future large snags and eventually fallen logs.

Den trees.

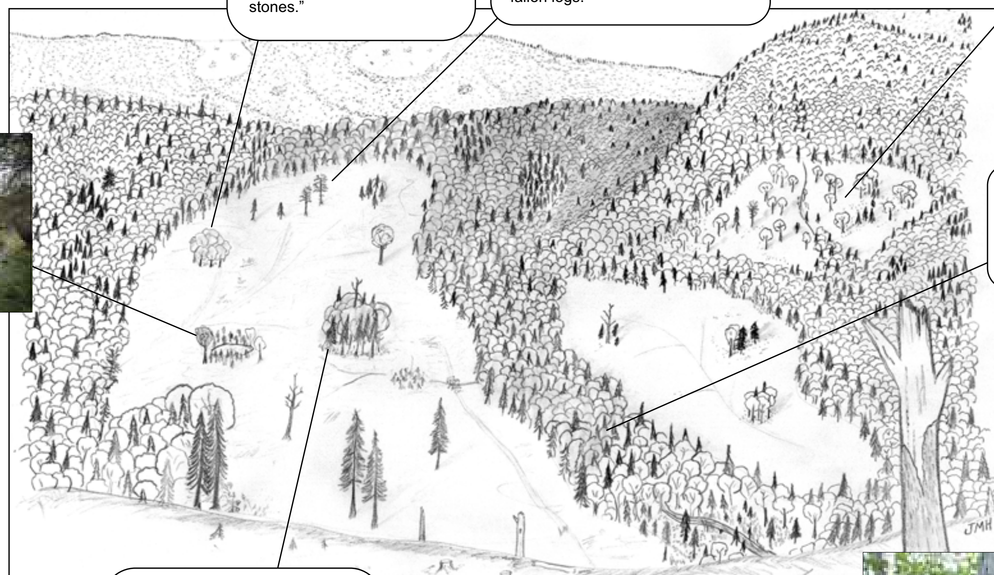
Even in shelterwood cuts or selection cutting systems, important ecological legacies can be conserved with legacy retention.

Pockets of softwood in hardwood stands (or pockets of hardwood in softwood stands). Alternatively (or in addition to), pockets of trees representative of the former stands.

Rare plants.

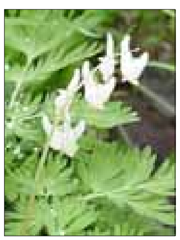


Forested wetlands, including vernal pools, woodland seeps and springs, and sections of small headwater.

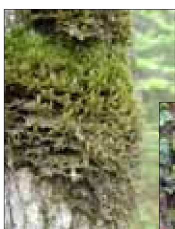


Riparian buffers can provide many of the same features as large patches, in addition to protecting water quality and perhaps serving as corridors for plant and animal dispersal.

Smooth-bark beech trees for mast and to help propagate disease-resistant strains of beech.



Uncommon plants that indicate a rich site with good soils.

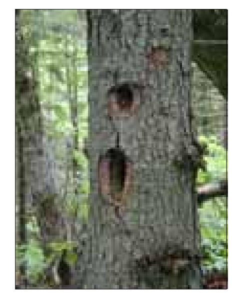


Large trees with mosses, lichens, or fungi that indicate old stand age. A few easily identifiable species can be used as a guide.

Large patches (>0.5 ac), "peninsulas," and buffer strips separating clearcuts can provide the same features listed for small patches, plus habitat for old-forest lichens, mosses, and insects. Large patches are ecologically efficient when there is a cluster of features of high ecological value.

Decaying trees with fungus.

Old decadent trees with a heavy epiphyte load.



Trees with fresh cavities indicating recent use by woodpeckers or other cavity-dependent species.

Manomet Center for Conservation Sciences landscape may require retaining about 5% of the stand or about 0.5 large (>24") trees per acre. We suggest a sliding scale where the amount (or percent) retained increases with harvest intensity at the landscape level (adapted from Coates and Steventon 1994):

$$\textit{\% Retention level in harvest block (\%)} = \frac{(A + B)}{C}$$

where **A** = % forest management unit (unit=forest stand for small woodlot owners; unit=25,000-100,000 ac for large landowners) that is operable timberland, **B** = % of A that has been harvested using even-aged management (or that has a rotation length of ≤ 80 yrs), and **C** = a unitless number that reflects the landowner's choice for biodiversity risk (we suggest C=10 if lower risk is desired, or C=40 if higher risk is acceptable). As an example, for a management unit that is 100% operable, and 100% even-aged management, choosing a C of 10 results in 20% retention, and a C of 40 results in 5% retention.

In the equation above, as the amount of operable timberland (A) decreases, % retention decreases. The equation assumes that inoperable land (e.g., set aside reserves, high-elevation areas) reduces the need for retention. If the inoperable land is not forestland (e.g., agriculture), then greater levels of retention are recommended and this equation is not applicable.

How many? How big?

It is worth briefly reviewing an old debate among ecologists about the geometry of conservation, termed "SLOSS" (for *single large or several small*), to understand the key considerations for the number and size of retention units (Jarvinen 1982, Hunter 1990). At a larger scale (at which the SLOSS debate has mostly focused) a single large reserve can (1) provide more habitat area away from forest edges, (2) provide for a greater array of natural disturbance processes, and (3) encapsulate the larger home ranges of larger-bodied species. However, a single large reserve also is vulnerable to a single catastrophic event (e.g., fire, hurricanes, disease) that might wipe out a species, or other values that the reserve was established to protect. By contrast, many small reserves spatially disperse the risk of any single catastrophic event. But many small reserves may not support as many species as a single large reserve. The tradeoff is clear. This conundrum can be scaled down to apply to legacy retention. Should many single trees be maintained, or fewer, but larger, retention patches? Species that do not fare well near edges may benefit more from a strategy of large retention patches while other species might benefit from the other extreme of scattered wildlife trees.

If a biodiversity goal is to maintain all forest species, then a diversified strategy is probably best: leave single large patches in some cuts, many small patches in other cuts, and dispersed retention in still other cuts. A strategy of single large patches makes the most sense in stands that still contain small (1-10 acre) patches of old growth forest (most often found in stands with only a long history of high-grading) where the most edge-sensitive species may still occur. A strategy of many small patches or wildlife trees makes the most sense in stands with a history of even-age management where old growth remnants are unlikely to exist. Patches should be ≥ 0.01 acre in size, but patches 0.5-2.0 acres can contain many forest species of vascular plants, mosses, lichens, and ground beetles and retain a microclimate similar to that of undisturbed forest. Patches > 1 acre may be suitable for small, forest species that are very sensitive to logging.

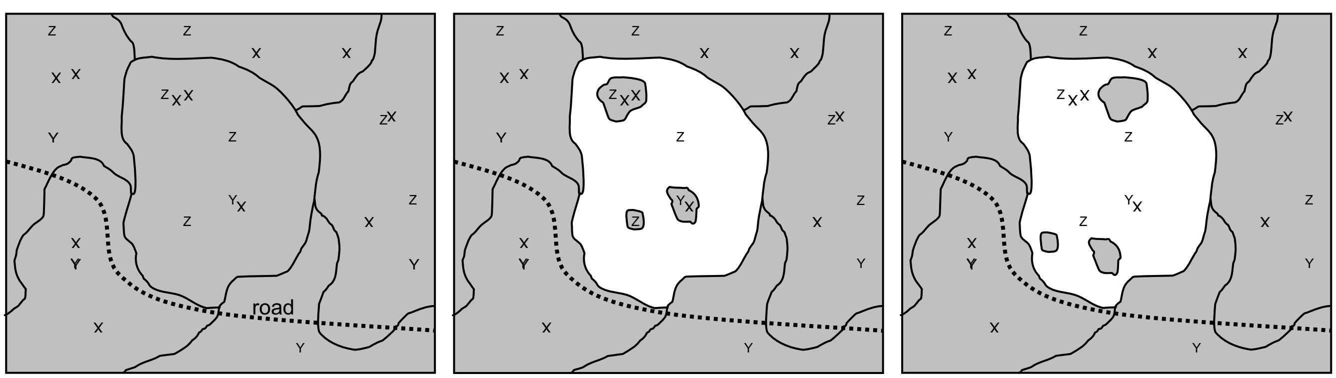
Retain for how long?

Retained trees and patches should be maintained for an entire rotation. Old forest remnants should be maintained until the regenerating stand has sites with similar structure and composition.

Other Considerations

Economic Issues

There are two key economic considerations for retention: (1) lost timber value due to leaving wood behind and (2) increased operational costs. Timber values can be lost through



(a) pre-harvest (b) post-harvest (good placement) (c) post-harvest (poor placement)

Figure 2. The strategy of patch retention is to retain patches around important ecological features. In (a) above, different types of ecological features are depicted as X's, Y's, and Z's. A good use of patch retention is shown in (b), whereby diverse features are retained in patches. A poor use of patch retention is shown in (c), whereby patches were retained, but they did not capture important ecological features. Rather, in (c), patches are placed near the logging road for visual effect, or near the back of the plot, perhaps due to skidding costs. Ecologically, much more is gained in (b) relative to (c) by careful attention to patch 'nuclei.' The retention tool can be used as effectively in selection cut operations as in clearcuts, although patches may not need to be as big to retain the particular feature or species of concern.

mortality due to old age, wind throw, insect damage, and disease, and simple failure to optimize harvests based on tree growth. Some of the economic value may not be lost if retained trees survive from the time of retention to the end of the next timber rotation. However, given that one goal of retention is to create large dead trees and logs, it is probable that the economic value of many retained trees will be lost. The retention of trees also imposes operational costs, especially in sites that are clearcut or managed using the shelterwood approach. Retention in clearcuts can reduce felling and skidding productivity by 8-27% and increase costs 2-47% (Blinn et al. 2000). Patches near landings impose a greater financial cost than patches in the back of the harvest block due to skidding distance (C. LeDoux, pers. comm.).

Wind throw

Single trees and small patches of trees, especially in clearcuts, are vulnerable to blowdown. Wind throw can be minimized by taking into account retained tree shape, tree species, soils, stand structure, and topography (Stathers et al. 1994). Retention trees with relatively small or open crowns and high bole taper (fat at the bottom and skinny at the top) are less susceptible to wind throw. Deeply rooted species (hardwoods and white pine) are less susceptible to wind throw than shallow rooted species (other conifers). Stands that have been open and uneven in canopy height for some time are less vulnerable to wind throw than stands that are dense and even in canopy height. Trees on soils that are shallow due to bedrock or high water table and/or heavy with clay are more susceptible to wind throw than trees in deep soils. Ridge tops are always most vulnerable to wind throw. Mid-slopes are moderately vulnerable. Valley bottoms are least vulnerable to wind throw if the prevailing winds blow at right angles to the valley bottom but are highly vulnerable when the prevailing winds blow with the orientation of the valley bottom. In clearcuts, retention trees and patches placed near edges closest to the direction of the prevailing winds are less susceptible to wind throw. Areas with little or no pit-and-mound topography (resulting mounds of soil being created by "tip-ups" of root masses) may be least vulnerable. In areas most vulnerable to wind throw, removing canopy dominants from the patch edge might increase wind firmness. At this early stage in the practice of legacy retention we need to learn through experience what patch size, and under what conditions, patches remain wind firm.

Aesthetics

No research has been conducted that focuses on the aesthetics of retention practices. Clearcutting is widely perceived as unsightly in Canada and the U.S. (Forestry Canada 1992). Partial harvesting is perceived aesthetically as a good method of logging forest (Robson et al. 1996). A survey in Nova Scotia indicated that 86% of the general public was in favor of forest management practices such as leaving clumps of trees to protect wildlife (Sanderson et al. 2000). Patches and wildlife tree retention near roads better reduce negative aesthetic impacts of harvesting than retention away from roads, but this placement may conflict with effective retention of specific ecological features (Fig. 2).

Summary

Legacy retention is one of several ecological prescriptions that can help maintain small, slow dispersing, substrate specific species in a well-distributed manner across managed forest. Retention should focus on ecological features known to be important and vulnerable so as to maximize the ecological value retained for the foregone economic value. However it will take time to learn how to confidently and efficiently apply legacy retention. To facilitate this learning process we encourage landowners to maintain a GIS database of retention patch locations and the ecological feature(s) that the patch was designed to maintain. With this information we can learn what circumstances make patches resilient to windthrow, and whether patches successfully maintain the ecological features of concern over the long term.

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