Conservation Issues

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Selection Criteria for Forested Natural Areas in New England, USA[1]

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ABSTRACT: The selection of forested natural areas for research and educational purposes is discussed. Five factors are important: sufficient size; representation of typical communities and sites; documented disturbance histories; acceptable current condition in terms of age, tree size, and successional stage; and administrative feasibility.

INTRODUCTION

The criteria for selecting and evaluating natural areas depend upon proposed usage. Natural areas are recognized and set aside for a variety of reasons related to the protection or preservation of rare, sensitive, or unique species and ecosystems. But another objective of natural area designation is to establish areas for ecological research and education. This approach, which requires a fairly carefully developed set of selection criteria, is the one emphasized in the Research Natural Area (RNA) program of the U.S. Department of Agriculture, Forest Service. A number of other U.S. Forest Service designations apply to areas set aside for their unique characteristics; examples include historical areas, scenic areas, botanical areas, and national primitive areas.

The primary reason for establishing research natural areas is to enable the study of natural processes in unmanaged ecosystems and thereby provide a baseline for comparison with managed areas. Research natural areas also contribute to the understanding of managed-stand dynamics. Two examples illustrate the sorts of research done in the past and the reasons why selection criteria are needed.

Example 1: One of the basic requirements for the uneven-aged management of forest stands is the development of a sustainable or balanced stand structure defined by numbers of trees by age or size class. This requirement simply assures that trees will be available to take the place of those that die or are cut. Since there are few forests in the United States that have been managed long enough to develop a balanced stand structure and sustained timber yields, research on this question has been done in old-growth stands that have developed stand structures in balance with natural trends in mortality (Meyer and Stevenson 1943, Meyer 1952). This sort of research must be conducted in areas large enough to minimize fluctuations that occur from cycles of natural disturbances such as wind, fire, and pests.

Example 2: Nutrient losses from managed forests are a major, fairly recent concern, particularly in New England. To separate the influence of timber management from the effects of natural disturbance and environmental impacts, the availability of natural, unlogged area is of prime importance. Nutrient cycling studies in The Bowl Research Natural Area and the Hubbard Brook Experimental Forest indicated that nitrogen outputs from old-growth hardwoods and a cutover 55-year-old stand were similar, but were much higher than nitrogen outputs from a 3-year-old clearcut (Martin 1979), where biomass and organic matter accumulation retained available nutrients. Critical research of this type, based on streamwater nutrient outputs, requires entire watersheds or subwatersheds in a natural old-growth condition; furthermore, chemical additions from insecticides or fertilization must be avoided or carefully monitored.

Based on our experience with research studies similar to these, we suggest that five selection criteria be considered in establishing natural areas to be used for research and education.

SELECTION CRITERIA

Sufficient Size

Size is one of the most important criteria because it relates so closely to the potential of a natural area for several types of research. Size of area and disturbance dynamics are closely related. Very small areas are less likely to be touched by a dis-

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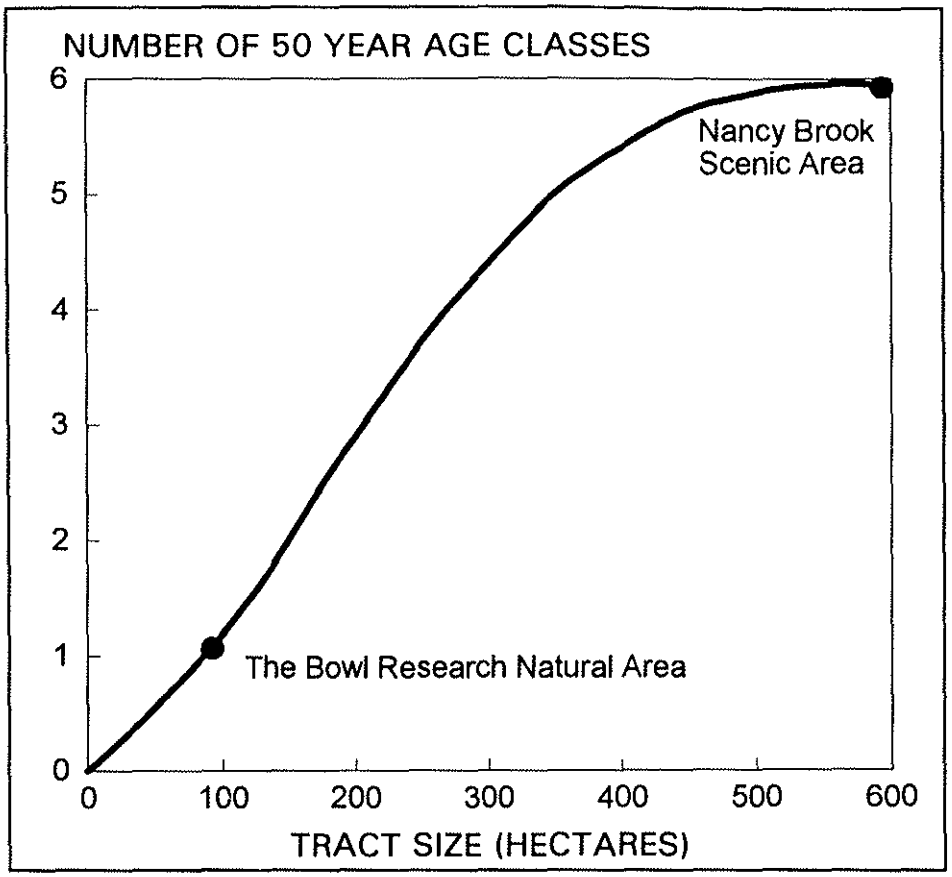

Figure 1. Hypothetical graph of numbers of different age classes in a forested natural area as tract size increases. The example represents spruce-fir with six 50-year age classes. At the plateau, there would be equal areas by age class and an inverse J-shaped diameter distribution. Curve dimensions would vary with natural disturbance regime as influenced by cover type, soils, and site diversity. Two areas are plotted for illustration. Note that small areas will have only one or two age classes; large areas will have the full range of age classes required for sustainability.

turbance event such as a windstorm; but if such an area is hit, the damage will be total. Large areas are more likely to be affected by any given event, but the damage will be partial. This intuitive truism results from the diversity associated with large areas — diversity in soils, aspect, tree condition, wind currents, and more. The end result is that tree size, age, and condition in a natural area tend to follow something equivalent to a species-area curve (Figure 1): the more area you examine, the greater the likelihood of finding a complete range in tree size, age, and condition up to the point where there is little gain in examining more area (see Hunter 1990). The point where this plateau is reached no doubt varies greatly with cover type, soils, and so on. For example, in "wind-firm" stands (stands on deep soils, in unexposed location, consisting of well-rooted trees of typically not brittle species), where disturbance impacts are small, the area required at any point in time to find a full range in tree size, age, and condition will be small. In "wind-prone" types on shallow, wet soils, a large area will be required (Figure 1).

An ideal natural area should be large enough so that it maintains a fairly steady (though dynamic) age distribution, structure, species mix, biomass, and level of biodiversity throughout time, consistent with the natural disturbance cycle that typifies the area. Natural areas below this critical size will exhibit great variation in structure and process, providing only an extremely variable benchmark for comparison with managed landscapes. In other words, small areas that vary greatly over time in age or size structure will exhibit variable physical, chemical, and biological properties that cannot readily be compared with managed landscapes. For example, The Bowl Research Natural Area, an area of about 200 ha, was set aside in 1931, reportedly because of the "fine stand of pure, virgin spruce. . . . The virgin spruce runs about 4 logs per tree. . . . It occurs in practically pure stands which are overmature" (Stuart 1931). While a few large, old (250 years or more) individual trees remain today as well as much second-growth red spruce (*Picea rubens* Sarg.) and balsam fir (*Abies balsamea* [L.] Mill.), little remains of this outstanding 80- to 120-ha tract of spruce following heavy windthrow in 1938 and 1957. On the other hand, a 20- to 40-ha tract of old-growth northern hardwoods at a lower elevation remains intact owing to the lower disturbance intensities characteristic of deciduous stands on deep soils (Runkle 1982). This tract is now the featured stand in The Bowl and serves as a valuable site for a wide variety of research studies. Apparently, The Bowl is too small to maintain a spruce-fir ecosystem but approaches adequate size for northern hardwoods. A similar situation exists at Mountain Pond, a proposed research natural area in the southeastern portion of the White Mountain National Forest. Only about 50 ha in size, this tract contains northern hardwoods over a full range of age classes up to the maximum longevity of the species.

The spruce-fir forest of the Nancy Brook Scenic area — a nearby virgin spruce-fir tract of about 600 ha — is very different in character from the stand of spruce that once occupied The Bowl. The Nancy Brook tract still contains many examples of large, old-growth spruce communities with trees over 400 years old. The disturbance intensity here appears to be at least as severe as in The Bowl. However, the area is larger and more diverse, and appears to be maintaining a full range of age and size classes in spruce, fir, and mountain paper birch (*Betula cordifolia* Regel) (Hill 1989).

Little specific information is available on natural disturbance regimes in New England to help us estimate how large a research natural area should be for a given community-site combination. Some stud-

ies suggest that catastrophic fire and windthrow are relatively rare in the spruce-hardwood forests of Maine — at intervals of 800 to 1150 years, for example (Lorimer 1977). However, experience in New Hampshire indicates at least two heavy windthrows since the 1930s and a couple of lighter disturbances; adjacent portions of Maine experienced, in addition, at least one drastic fire season. On average, then, significant natural disturbances have occurred approximately every 30 years in the hardwood-hemlock forests of mid- to southern New England, with lighter ones occurring in between. Curtis (1943) summarized literature suggesting that there have been 22 storms of hurricane intensity in New England over the last three centuries — a 14-year cycle.

In the most severe recent windthrow — the 1938 hurricane — the mortality on U.S. Forest Service experimental forests was moderate in most types except white pine (Table 1). On the Gale River Experimental Forest (530 ha of spruce-fir), "about 25% of the growing stock was windthrown, damage being complete over large areas." On the Bartlett Experimental Forest (1050 ha of northern hardwood and mixed hardwood-conifer), "hardwoods were damaged to the extent of about 9% and softwoods about 11%. . . . Heaviest damage occurred on the high slopes where losses by compartments reached a maximum of 35% for softwoods and 18% for hardwoods" (Northeastern Forest Experiment Station 1938). Small areas of white pine (*Pinus strobus* L.) in western Maine were 88% seriously damaged, while oak (primarily *Quercus rubra* L.) stands in western Massachusetts were only 13% destroyed. On the Harvard Forest, Massachusetts, the hurricane destroyed about 82% of the 80 ha occupied by the white pine type (Spurr 1956).

Losses of 10% every 30 years or so in hardwood and mixed hardwood-conifer stands implies that some stands regularly will attain ages of 300 years or so. Losses of 25% in 30 years in softwood stands similar to those at Gale River implies that the oldest stands will reach only 120 years of age. Apparently, natural areas in softwood types need to be somewhat larger than Gale River in order to accommodate a fairly regular disturbance cycle with stands consistently reaching old-growth ages of 200 years or more. Areas composed primarily of hardwoods or mixed hardwoods and conifers can be much smaller.

Configuration also may be important. For hydrologic or nutrient-cycling studies, entire well-defined watersheds are useful or required; these often are 400 ha or larger in mountainous areas of New England. However, subwatersheds of less than 40 ha are readily available and have proven useful for watershed studies at Hubbard Brook and elsewhere.

The potential value of natural areas for genetics and wildlife studies also relates to size. A question commonly asked in New England is whether timber management practices, especially those that remove the better trees, lead toward a change in genotype of the remaining tree populations. To answer this question, natural areas must be large enough to remain at least somewhat isolated from outside seed and pollen sources. Pollen dispersal studies in the Northeast indicate that pollen concentrations drop off rapidly within 100 or 200 m from the source, although some move much further (Wright 1952). Seed dispersal is much more limited. Both are influenced significantly by wind currents and topographic factors and are restricted by closed canopies and unbroken forest cover as opposed to patchy landscapes (Foster et al. 1992). This indicates that well-defined watersheds, as mentioned above for hydrologic studies, might be at least partially effective in isolating forested areas for population genetics studies.

No terrestrial vertebrate wildlife species (and no vascular plant species as well) are considered obligate inhabitants of old-growth forests in New England at the present time (DeGraaf et al. 1992). But additional research is needed to compare habitat quality and species abundance in managed versus unmanaged landscapes, and much additional research is needed on mosses, lichens, fungi, and invertebrates. Meaningful comparisons would require that natural areas be larger than the home ranges of the species under study, otherwise there would be some confounding between inhabitants and visitors. The majority of vertebrate species in New England have home ranges less than 20 ha (Table 2), although large mammals have ranges of a few thousand hectares or more. On the White Mountain National Forest, habitat management units of about 1200 ha — home range of the moose (*Alces alces*) — are considered adequate to accommodate the needs of most species.

Some allowance should be made for buffer strips around a designated area, especially small tracts adjacent to areas that

Table 1. Percentage of area blown down in the 1938 hurricane by forest type, tract, and tract size.

Forest Type	Tract	Area (ha)	Approximate % Blowdown
Spruce-fir	Gale River, NH	530	25
	Bartlett, NH	80	35
	Bowl, NH	80-120	total
	Nancy Brook, NH	610	partial
Northern and mixed hardwood	Bartlett, NH	1050	9-11
	Bowl, NH	40	light
	Mountain Pond, NH	50	light
	Hopkins, MA	660	13
White Pine	Massabesic, ME	—	88
	Harvard Forest, MA	80	82

Table 2. Numbers of species by taxonomic class and average home range in New England (DeGraaf et al. 1992).

Taxonomic Class	Average Home Range (ha)				
	Unknown	<5	5-20	>20	Total
Amphibians	0	25	1	0	26
Reptiles	0	21	7	2	30
Birds	17	141	30	32	220
Mammals	9	31	5	17	62
Total	26	218	43	51	338

will be managed actively. On natural areas following watershed boundaries, buffers of about 100 m or so should be sufficient to protect hydrologic and genetic properties of the natural area, but many questions still remain about the impacts of human usage and, of course, the impacts of adjacent conversions to nonforest conditions.

Representative Communities

In selecting and ranking research natural areas, it is important to include areas that represent the major communities, sites, and disturbance regimes in the region, especially those that are subject to intensive management. Many natural areas in New England are remote, high-elevation sites where both access and logging have not been feasible. The real challenge is to find natural area benchmarks in highly productive, lower elevation sites that have been subject to heavy use. Unique areas and unusual sites are perhaps less important for research and educational purposes than the forest types and sites that are commonly used for intensive timber management and recreational activity. A carefully designed set of community-site categories will minimize the amount of acreage set aside as natural areas yet will ensure that the most important site conditions are represented. In northern New England, a minimal set of research natural area categories might be a list, such as the following, that includes the major forest associations (cover types) and types of parent material as well as a range in disturbance regimes and climatic-edaphic conditions (Table 3):

- High-elevation spruce-fir on shallow bedrock; subject to heavy natural disturbance from windthrow, drought, fire, and insects.
- Low-elevation spruce-fir and spruce-hemlock (*Tsuga canadensis* [L.] Carr.) on shallow, imperfectly drained hardpan; subject to natural disturbance primarily from windthrow and insects.
- Low-elevation spruce-hemlock-pine on well-drained outwash; drought-prone and nutrient-poor sites.
- Northern hardwoods on well-drained till.
- Sugar maple (*Acer saccharum* Marsh.)—ash (*Fraxinus americana* L.) on somewhat enriched or moderately well-drained tills.

Several categories may be represented in a single natural area; this is especially true in the entire watersheds and other large areas discussed above. A case can be made for applying this list to each of the major recognized ecoregions for a state or region (McMahon 1990). In addition to these categories, there are many unique forested areas and wetlands that deserve protection, but which are not common enough to serve as important benchmarks for monitoring management activity.

Documented Disturbance History

In New England, emphasis in natural area selection has been on forests that have never been logged. This approach has been a reasonable one since these unlogged areas are rare and deserve to be given first priority. However, from a research/educational point of view, certain important questions are left unanswered if selection is restricted to untouched areas. Do areas disturbed by agriculture, heavy logging, or fire ever return to a pristine condition? How long does it take? Which forms of disturbance impose the greatest impacts and why?

To answer such questions in the short term it appears necessary to include major categories of disturbance as one of the selection criteria. For example, for each of the five community-site categories listed above, it would be useful to have old stands that are (a) unlogged; (b) farmed, then abandoned; (c) heavily logged, then untouched; and (d) burned over. It is very likely that present communities would vary under these past disturbance regimes, and selection would be based on soil-topographic

Table 3. Proposed research natural area categories for northern New England.

Cover Type	Site	Past Disturbance	Area (ha)	Current Condition
Spruce-fir-hemlock	Bedrock	Burned	600	Young to old
		Unburned	600	Old
	Hardpan	Logged	600	Young to old
		Unlogged	600	Old
Spruce-pine-hemlock	Outwash	Burned	600	Young to old
		Logged	600	Young to old
		Unlogged	600	Old
Northern hardwood	Till	Logged	40	Young to old
		Unlogged	40	Old
Sugar maple-ash	Rich till	Logged	80	Young to old
		Unlogged	80	Old

conditions and historic vegetation records. The primary need in implementing this sort of selection criterion is to document the type, extent, severity, and date of the past disturbance.

Acceptable Current Condition

Old-growth stands have been given first priority during the selection of forested natural areas in New England. These areas offer immediate opportunities for studying conditions and processes characteristic of unmanaged stands. Furthermore, they are unique and interesting areas. However, as the number of selection criteria increase, it becomes more difficult to find old-growth stands, especially on productive, accessible sites. Furthermore, since one purpose of natural area designation is to establish a time line for recovery from disturbance, it is important to have potential natural areas established across several age classes or successional stages. One argument against this approach is that we can always find young stands on managed lands. However, such stands frequently do not meet the necessary criteria for size, configuration, and community-site condition discussed above. In addition, we need to have potential natural areas established in younger stands so that these areas can be remeasured and monitored in perpetuity.

Administrative Feasibility

Readily identifiable boundaries are important not only in locating the area for study purposes but to guide adjacent management activities such as cutting, fire protection, pest management, and recreation. Natural watershed boundaries, as discussed above, are useful as are roads and brooks. The question of accessibility is difficult to answer. On the one hand, difficult access in terms of distance and topography helps relieve recreational pressure on the area. On the other hand, we have found that areas with difficult access are less used for research/educational purposes, especially if equipment and repeated visits are needed.

Table 4. Current research natural areas in the Northeastern Forest Experiment Station territory (14 states from Maine to Kentucky and west through Ohio).

Principal RNA Name	National Forest	State	Area (ha)	Date Established	Cover Types
Alpine Gardens	White Mountain	NH	40	1989	Alpine tundra
The Bowl	White Mountain	NH	206	1931	N. hardwood, Red spruce
Nancy Brook	White Mountain	NH	601	1991	Spruce-fir
Reas Run	Wayne	OH	32	1974	Virginia pine
Rock Creek	Daniel Boone	KY	77	1939	Mixed mesophytic
Tionesta	Allegheny	PA	855	1940	Hemlock-beech

MANAGEMENT ACTIVITIES

If we accept the premise that the primary purpose of research natural areas is to serve as a basis for comparison with managed stands, then it follows that, ideally, no resource use should be permitted in natural areas — no timber cutting, intensive recreation, fire control, pest management, hunting, fishing, and so on. In practice, we compromise this ideal by allowing most forms of light recreational use, including hunting and fishing, that will not materially diminish the values of the natural area. The most difficult questions relate to fire and insect control. The policy within the boundaries of natural areas probably should be no controls for the following reasons. First, insects and fire are among the most common forms of natural disturbance in certain New England forests, yet neither will usually cause complete devastation of a natural area. Specific insects seldom damage all plant species, so an outbreak will simply cause a shift in species composition. The question of native versus introduced insects and diseases is difficult; but it would appear logical to regard introduced pests that are widespread and naturalized as an integral part of the environment. The gypsy moth (*Lymantria dispar*) and beech-bark disease (*Nectria coccinea* var. *faginata*) are examples. Fires generally are most damaging on certain dry sites and frequently will not destroy an entire natural area that contains a diversity of community-site conditions. Although some of the postsettlement fires in New England burned large areas, these were often related to logging operations and were more severe than we might expect in a natural area. Certainly, there are exceptions to these generalities that must be considered in framing a fire and insect control policy for a given natural area.

STATUS OF RESEARCH NATURAL AREAS

Selection criteria for the U.S. Forest Service RNAs currently are somewhat different from those suggested above. The main criteria follow: 120 ha minimum size in the West, with allowances for smaller areas in the East; entire small drainages where possible; no evidence of human disturbance (e.g., timber cutting) in the past 50 years, but preference given to "pristine" conditions (areas never manipulated). Progress to date has been modest at best under the current set of selection criteria, and there has been little success in meeting the broader range of criteria outlined in this paper (Table 4). However, many additional proposals are under consideration, and the climate appears right for significant progress in natural area establishment in the near future.

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LITERATURE CITED

Curtis, J.D. 1943. Some observations on wind damage. Journal of Forestry 41:877-882.

DeGraaf, R.M., M. Yamasaki, W.B. Leak, and J.W. Lanier. 1992. New England wildlife: management of forested landscapes. General Technical Report NE-144, U.S. Department of Agriculture, Forest Service, Radnor, Penn. 271 p.

Foster, D.R., T. Zebryk, P. Schoonmaker, and A. Lezberg. 1992. Post-settlement history of human land-use and vegetation dynamics of a *Tsuga canadensis* (hemlock) woodlot in central New England. Journal of Ecology 80:773-786.

Hill, J.D. 1989. Mountain paper birch (*Betula cordifolia* Regel) regeneration in an old-growth spruce-fir forest, White Mountain National Forest, New Hampshire. M.S. thesis, University of New Hampshire, Durham. 76 p.

Hunter, M.L., Jr. 1990. Wildlife, Forests, and Forestry. Prentice Hall, Englewood Cliffs, N.J. 370 p.

Lorimer, C.G. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. Ecology 58:139-148.

Martin, C.W. 1979. Precipitation and streamwater chemistry in an undisturbed forested watershed in New Hampshire. Ecology 60:36-42.

McMahon, J.S. 1990. The biophysical regions of Maine: patterns in the landscape and vegetation. M.S. thesis, University of Maine, Orono.

Meyer, H.A. 1952. Structure, growth, and drain in balanced uneven-aged forests. Journal of Forestry 50:85-92.

Meyer, H.A. and D.D. Stevenson. 1943. The structure and growth of virgin beech-birch-maple forests in northern Pennsylvania. Journal of Agricultural Research 67:465-484.

Northeastern Forest Experiment Station. 1938. Annual report of the Director for 1938. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Radnor, Penn. 34 p.

Runkle, J.R. 1982. Patterns of disturbance in some old-growth mesic forests of eastern North America. Ecology 63:1533-1546.

Spurr, S.H. 1956. Forest associations in the Harvard Forest. Ecological Monographs 26:245-262.

Stuart, R. 1931. R-NE Natural areas. Unpublished report on file at U.S. Department of Agriculture, Forest Service, Forestry Sciences Laboratory, Northeastern Forest Experiment Station, Durham, N.H.

Wright, J.W. 1952. Pollen dispersion of some forest trees. Station Paper 46, U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Upper Darby, Penn. 42 p.