PLANNING METHODS FOR ECOREGIONAL TARGETS: MATRIX-FORMING ECOSYSTEMS*

One of the goals of ecoregional planning is to identify viable examples of all types of ecosystems at appropriate scale to conserve their component species and processes. Natural terrestrial vegetation communities vary greatly in terms of their sizes and ecological specificity; some types cover large areas of varying topography, geology, and hydrology, while others occur only in small patches under very specific environmental conditions.

Matrix-forming (or dominant) ecosystems may extend over very large areas of 1000 to many millions of acres, often covering 80% or more of the undeveloped landscape. Matrix systems are generally forests in the Eastern United States; the terms *matrix forest*, *matrix community*, *matrix-forming community*, and *matrix site* are used interchangeably in the Northeast ecoregional plans. Matrix community types are often influenced by regional-scale disturbances such as hurricanes, insect outbreaks, or fire. They are important as “coarse filters”[1] for the conservation of most common species, wide-ranging fauna such as large herbivores, predators, and forest interior birds. The size and natural condition of the matrix forest allow for the maintenance of dynamic ecological processes and meet the breeding requirements of species associated with forest interior conditions. Nested within the matrix forests are the smaller *patch-forming ecosystems*,[2] with more specific ecological tolerances and often more restricted species.

Although differing in size and scale, matrix-forming systems were considered a special case of terrestrial ecosystem in the Northeast ecoregional plans. Most of the approaches and assumptions discussed under the terrestrial ecosystem chapter are directly applicable to matrix systems. However, the Natural Heritage Programs that provided the basis for identifying examples of patch-forming ecosystems had not, to date, developed a comprehensive method of identifying viable examples of the dominant forest communities that constitute the background “matrix” within which all other biodiversity is found.

Matrix forest assessment within ecoregional planning was developed in conjunction with the New England Natural Heritage programs to fulfill this need. The methodology has evolved significantly during the past several years, and has been applied to a broad range

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The standard methodologies sections created for this and all Northeast ecoregional assessment reports were adapted from material originally written by team leaders and other scientists and analysts who served on ecoregional planning teams in the Northeast and Mid-Atlantic regions. The sections have been reviewed by several planners and scientists within the Conservancy. Team leaders included Mark Anderson, Henry Barbour, Andrew Beers, Steve Buttrick, Sara Davison, Jarel Hilton, Doug Samson, Elizabeth Thompson, Jim Thorne, and Robert Zaremba. Arlene Olivero was the primary author of freshwater aquatic methods. Mark Anderson substantially wrote or reworked all other methodologies sections. Susan Bernstein edited and compiled all sections.

[1] The concept of coarse filter is discussed in the chapter on Terrestrial Ecosystems and Communities.

[2] Patch-forming ecosystems are discussed in the chapter on Terrestrial Ecosystems and Communities.

of ecoregions, from the Northern Appalachians where forests remain large, contiguous, and in good condition to the Chesapeake Bay Lowlands where forest remnants occur only in small areas and are in poor condition. The work to conserve the values of these formerly contiguous forested areas ranged from identifying areas within intact forests where old growth features can reemerge over time, to identifying areas for intensive restoration efforts to reclaim, reestablish and ensure the persistence of the matrix forest.

Most of the Northeast U.S. was cleared for agriculture or pasture in the mid to late 1800. As the region reforested, forests have been repeatedly logged for saw timber, pulp and firewood. Thus, although the matrix forest system is semi-contiguous across most of the Northeast ecoregions, the forests are young in age, have little structural diversity and lack important features such as large coarse woody debris or big standing snags. Moreover, they are densely crisscrossed with fragmenting features such as roads, powerlines, logging trails, housing developments, rural sprawl, agricultural lands, ski areas and mining operations. The Northeast's dominant tree species have lifespans ranging from a quarter to half a millennium. Historical effects of farming, pasturing and logging as well as current effects of climate change and pest/pathogen outbreaks suggest that they are unlikely to have reached any type of equilibrium state at this time.

Assessing viability criteria for matrix-forming forest ecosystems

To identify those areas where forest protection was most critical or where ecosystem restoration would most likely be successful it was necessary to develop clear *viability criteria* against which we could evaluate any given site's potential as a target for conservation activity.

In concept, a viable matrix forest ecosystem was defined as one that exhibits the qualities of *resistance* (e.g. the ability to dampen out small disturbances and prevent them from amplifying into large disturbances) and *resilience* (e.g. the ability to return to some previous level of productivity and structure following a catastrophic disturbance) leading to dynamic *persistence* over centuries. Additionally we required that the example of the forest ecosystem have a high probability of being a *source breeding habitat* for interior forest species (Anderson and Vickery, in press).

Matrix forests in the Northeast are large and dynamic ecosystems. Direct assessment of resistance and resilience requires a determination of the intactness of a forest's structure, biological legacies, composition and processes. As extensive ground-based inventory was beyond the scope of this work, we developed an estimate of viability based on three less direct but measurable characteristics:

- **Size**: based on the key factors of minimum dynamic area and species area requirements.
- **Condition:** based on the key factors of structural legacies, fragmenting features, and biotic composition.
- **Landscape context:** based on the key factors of edge-effect buffers, wide-ranging species, gradients, and structural retention.

After developing clear criteria for these three attributes we used a combination of expert interviews, GIS analysis, written descriptions and the study of aerial or satellite imagery to obtain the detail we needed to make a determination of viability. The criteria for each of the three factors are discussed below.

Size

The size of a contiguous forest example is particularly important with respect to the viability of matrix-forming ecosystems. To establish how large examples should be, two key factors were considered: the size and frequency of *natural disturbances* and the size of the habitat needed by selected *interior forest species* within the ecoregion in order to breed.

Natural disturbances and minimum dynamic area: Examples of matrix forest ecosystems should be large enough to withstand the full range of natural disturbances that influence the system. To estimate the critical area needed to ensure that an ecosystem could absorb, buffer, and recover from disturbance, we first listed the expected catastrophic disturbances typical of the ecoregion. In the Northeastern U.S., these disturbances include hurricanes, tornadoes, fires, ice storms, downbursts and insect/pathogen outbreaks. Sizes of these disturbances were established from historical records, vegetation studies, air photo analysis and expert opinion.

Numerically, most disturbances are small and frequent; however large, infrequent, catastrophic events have had the greatest impact on most of the present landscapes.[3] Thus, although Shugart and West (1981) suggested that minimum dynamic areas be scaled to the mean disturbance patch size, Baker (1992) emphasized that it should be scaled to the maximum disturbance size to account for the disproportional influence of catastrophic disturbances. Likewise, Peters et al. (1997) suggested scaling the minimum dynamic area to the largest disturbance event expected over a 500-1,000 year period.

Damage from catastrophic natural disturbances is typically dispersed across a landscape in a uneven way such that severe damage patches are embedded in a larger area of moderate or light damage. We focused on this pattern and determined the maximum size and extent of *severe damage patches* expected over a one century interval for each disturbance type (see examples in Table MAT1 and Figure MAT1).

Table MAT1. Comparison of characteristics among infrequent catastrophic disturbances in the Northern Appalachian Ecoregion (adapted from Foster et al. 1998)

Disturbance characteristic	Tornado	Hurricane	Down-bursts	Large Fires	Insect outbreak	Ice Storm	Flood
Duration	Minutes	Hours	Minutes	Weeks /months	Months	Days	Week /months
Return interval in years	100-300	60-200	?	400-6000	10	2	50-100
Maximum size of severe damage patches (acres)	5000	803	3400	57-150	?	<5	?

[3] Oliver and Stephens 1977, Turner and Dale 1998.

How much larger than the severe damage patch size should a particular ecosystem example be to remain adequately resilient? Presumably this is a function of disturbance return intervals, the condition of each example and the surrounding landscape context. Rather than develop a model for each specific place, we assumed that if we replicated the presettlement proportions of disturbed to undisturbed forests at a matrix scale, the example should be of adequate size to accommodate natural disturbance events. Information on historic vegetation patterns suggested that recently disturbed systems accounted for 11-35% of the landscape in New England. We used this information to develop a guideline that an individual instance of a matrix forest ecosystem should be about *four times* the size of the largest severe damage patch within the forest[4]. This estimate of the *minimum dynamic area*[5] should insure that over time each example will express a range of forest successional stages including recently disturbed areas, areas under recovery, mature and old-growth areas.

The upper half of Figure MAT1 below illustrates how we applied this logic to estimate the size of contiguous forested area needed to accommodate a variety of regional-scale disturbances. For example, based on historical records, hurricanes tend to create a mosaic of disturbance, with patches of severe damage ranging up to about 1000 contiguous acres. From this we estimate that an ecosystem example or a forest reserve would need to be at least four times that size, or 4000 acres, to remain viable with respect to hurricanes.

Breeding territories and area sensitive species: The size of matrix forests needed to support characteristic and area-sensitive species was determined by an assessment of the female breeding territory sizes of specific animals that utilize interior forest condition. In the Northeast, these species include many birds (broad-winged hawk, barred owl, neotropical warblers), mammals (pine marten), herptiles and insects.

In developing the methodology to estimate minimum area needs we compiled the mean female breeding territory for a variety of interior-forest dwelling birds and mammals in the ecoregion (Table MAT2 shows examples for birds in one ecoregion) using the generalization that these species typically establish and make use of mutually exclusive territories during the breeding season. Furthermore, to address the actual habitat size needed for a matrix forest to support a genetically diverse population, we multiplied the mean female home range by 25 to reflect the so-called "50/500" rule[6].

The 50/500 rule, which was developed for zoo population, suggests that at least 50 genetically-effective individuals are necessary to conserve genetic diversity within a metapopulation over several generations. We did not use this guideline to address needed population sizes but rather as a reasonable order-of-magnitude estimate of the *minimum area* required to ensure a genetically effective local population[7] embedded in a larger regional population. In using the guideline we assumed that all the available habitat within the ecosystem example was suitable for breeding, and that the occurrence was semi-isolated. The first assumption is not particularly realistic, but, again, we were not

[4] Anderson 1999, based on Foster and Boose 1992, Canham and Loucks 1984, and Lorimer 1977
[5] Pickett and Thompson 1978.
[6] Franklin 1980, Soule 1980
[7] Lande 1988, Meffe and Carroll 1994

advocating for an actual population size of 50 individuals, we were approximating the absolute minimal area needed to accommodate 25 breeding females.

Table MAT2. Example of nesting territory sizes for some deciduous tree nesting birds in Lower New England. The literature-derived mean for 25-female breeding territory in shown in column 2. (See complete table with references at end of chapter.)

SPECIES	Acres x 25	Mean Territory (acres)
Broad-winged hawk	14225	569
Cooper's Hawk	12500	500
Northern Goshawk	10500	420
Eastern Wood-Pewee	300	12
Yellow-throated Vireo	185	7.4
Philadelphia Vireo	87.5	3.5
Warbling Vireo	82.5	3.3
Baltimore Oriole	75	3
Cerulean Warbler	65	2.6
Blue-gray Gnatcatcher	42.5	1.7

Many species avoid small patches of forest for breeding even if the patch size is theoretically large enough to accommodate many female territories. Thus, as the full table indicates, we also investigated the literature to identify any species for which *minimum area requirements* have been identified. For species with such requirements we used the larger of the two area requirements (25 female territories or minimum area requirements) for our critical size estimates.

Combining size factors: After developing a list of characteristic breeding species and deriving an estimate of area requirements, we plotted the area needs of the more space-demanding species against the minimum dynamic area estimate derived from the disturbance scales. The lower half of Figure MAT1 indicates, for one sample ecoregion, how large a matrix site should be to expect multiple breeding populations of interior forest species, while the upper half indicates minimum dynamic area.

As the size of a matrix forest increases, it has a higher probability of viability as defined above. For each ecoregion, an acceptable size threshold was set by the ecology team to serve as the criterion for evaluating potential matrix forest systems (shown as a dark black arrow – 15,000 acres in Figure MAT1). Presumably an occurrence size above the threshold is likely to accommodate all the disturbance and species to the left of the arrow but be vulnerable to factors shown to the right of the arrow. In the High Allegheny example an occurrence size of 30,000 acres has a higher probability of accommodating all factors than our minimum threshold of 15,000 acres.

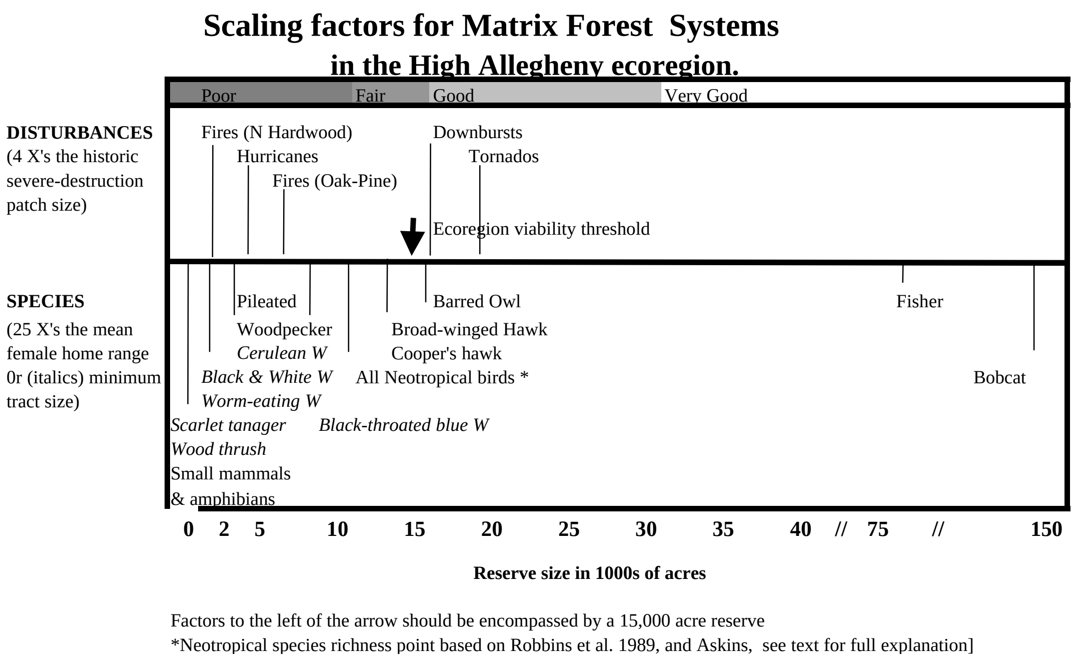

Figure MAT1. Scaling factors for matrix forest systems in the High Allegheny Ecoregion. Note: Fisher and bobcat are included in the figure for context; they were not considered to be interior-forest-requiring species.

Current condition

In describing and evaluating the condition of an ecosystem, ecologists often group the ecosystem's characteristics into structure, composition, and processes: *Structure* is the physical arrangement of various live and dead pieces of an ecosystem. Examples of structure include standing trees, snags, fallen logs, multilayered canopy, soil development. C*omposition* is the complex web of species, including soil microorganisms, arthropods, insects, spiders, fungi, lichens, mosses, herbs, shrubs, trees, herptiles, breeding birds, and mammals. Internal *Processes* are the dynamic activities performed by species such as energy capture, biomass production, nutrient storage and recycling, energy flows, and disturbance responses. (External processes are considered under "landscape context.")

Identifying reliable indicators of ecosystem "health" is still in its early stages.[8] Symptoms of stress on a community include changes in species diversity, poor development of structure, nutrient cycling, productivity, size of the dominant species, and a shift in species dominance to opportunistic short-lived forms.[9] Viability is affected by human activity, such as fragmentation, alteration of natural disturbance processes, introduction of exotic species, selective species removal, and acid deposition. Many of these symptoms are subtle and hard to detect, particularly in the absence of good benchmarks or reference examples. Our criteria for current condition revolved around three ecological

[8] Odum 1985, Waring 1985, Rapport 1989, Ritters et al. 1992.
[9] Rapport et al. 1985

factors: *fragmenting features*, *ecosystem structure and biological legacies*, and *exotic or keystone species*.

Fragmenting features: Fragmentation changes an ecosystem radically by reducing total habitat area and effectively creating physical barriers to plant and animal dispersal. Highways, dirt roads, powerlines, railroads, trails — each can fragment an ecosystem. Most have detrimental effects on at least some species and populations. Road kill is familiar to most people. In the U.S., one million vertebrates per day are killed by direct vehicle collision. Less obvious, perhaps, are the cumulative effects of fragmenting features for certain species. Species that are naturally rare, reproduce slowly, have large home ranges, depend on patchily distributed resources, or in which individuals remain with their parent populations are disproportionately affected by fragmentation.[10]

A critical factor in measuring fragmentation is the judgment of which features and at what density reduce the integrity of the system to an unacceptable degree.[11] We focused particularly on roads, which became an integral part of locating examples (see below).

In forested regions, the degree to which a road acts as a selective barrier to species is a function of its width, surface material (contrast), traffic volume, and connectivity, and also of the size, mobility, and behavior of the species in question.[12] Beetles and adult spiders avoid 2-lane roads and rarely cross narrow, unpaved roads.[13] Chipmunk, red squirrel, meadow vole, and white-footed mouse traverse small roads but rarely venture across 15-30 m roadways.[14] Amphibians may also exhibit reduced movement across roads.[15] Mid-size mammals such as skunks, woodchuck, raccoon and eastern gray squirrel will traverse roads up to 30 m wide but rarely ones over 100 m.[16] Larger ungulates and bears will cross most roads depending on traffic volume, but movement across roads is lower than within the adjacent habitat and many species tend to avoid roaded areas.[17] A variety of nesting birds tend to avoid the vicinity of roads.[18]

Roads also serve to reduce the core area of an ecosystem by making it more accessible. Small, rarely driven, dirt roads are used for movement by ground predators, herbivores, bats, and birds (especially crows and jays[19]). Open roadside areas are well-documented channels for certain (often exotic) plants and small mammals.[20] Roads allow access into the interior regions of a forested tract, and brings with it a decrease in forest interior area. For forest dwelling birds high road densities are associated with increased nest predation and parasitism,[21] increased resource competition and a decrease in adequate nesting sites.[22]

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[10] Forman 1995; Meffe and Carroll 1994
[11] Forman and Alexander 1998.
[12] Forman and Alexander 1998.
[13] Mader 1984, Mader et al. 1988.
[14] Oxley et al. 1974.
[15] Hodson 1966, van Gelder 1973, Langton 1989.
[16] Oxley et al. 1974.
[17] Klein 1971, Singer 1978, Rost and Bailey 1979, Singer and Doherty 1985, Curatolo and Murphy 1986, Brody and Pelton 1989.
[18] Ferris 1979, van der Zande et al. 1980, Reijnen et al. 1987.
[19] Forman 1995.
[20] Verkaar 1988, Wilcox and Murphy 1989, Panetta and Hopkins 1992, Huey 1941, Getz et al. 1978.
[21] Paton 1994, Hartley and Hunter 1997, Brittingham and Temple 1983.
[22] Burke and Nol 1998.

Roads are also source areas for noise, dust, chemical pollutants, salt, and sand. Traffic noise, in particular, may be primary cause of avoidance of roads by interior-breeding species.[23] Presumably, the conduit function of roads is not tightly associated with road size as larger roads tend to have more "roadside" region that may be utilized like a small-unpaved road. Although powerlines share some of the same features as low use roads, the filter and barrier effects may be softened if they are allowed to obtain a shrub cover and the conduit effects appear to be reduced.[24]

Ecosystem structure and biological legacies: Forest structure refers to the physical arrangement of various live and dead pieces of an ecosystem, such as standing trees, snags, fallen logs, multilayered canopy, and soil aggregates. Because many of these features take centuries to develop and accumulate, they are often referred to as *biological legacies*. Emphasizing their role in ecosystem viability, Perry (1994) defines legacies as anything of biological origin that persists and through its persistence helps maintain ecosystems and landscapes on a given trajectory. In Northeastern forests, legacies also include a well-developed understory of moss, herbs and shrubs, and reservoirs of seeds, soil organic matter and nutrients, features that were widely decreased during the agricultural periods of the 1800s. The development of many of these "old-growth characteristics" may take considerably longer than the life span of a single cohort of trees.[25] Although there may be ways to speed up or augment the development of legacies[26] it is probably more economical and strategic to locate those ecosystem examples that have the longest historical continuity and focus reserve development around them whenever possible. As few current restoration efforts can guarantee success over multiple centuries, it was crucial to identify ecosystem examples that currently contain the greatest biological legacy.

Although not well studied in the Northeast, the presence and persistence of biological legacies has a large effect on the resistance and resilience of an ecosystem. For instance, moisture stored in big accumulations of large downed logs provides refuges for salamanders, fungi and other organisms during fires and droughts. Moreover, "young forests" that develop after natural disturbances often retain a large amount of the existing legacies in contrast to "managed forests" where many of the legacies are removed or destroyed.[27] Thus, although disturbance removes and transforms biomass, the residual legacies of organisms influence recovery and direct it back towards a previous state.[28] Some biological legacies may even function to increase particular disturbances that benefit the dominant species (e.g. fire-dependent systems).

Accumulating legacies and forest structure also have a large effect on the density and richness of associated species. Insects such as the ant-like litter beetles and epiphytic lichen are both more abundant and richer in species in New England old-growth forests.[29] Breeding bird densities are significantly higher in old growth hemlock hardwood forests

[23] Ferris 1979, van der Zande et al. 1980.
[24] Schreiber and Graves 1977, Chasko and Gates 1982, Gates 1991.
[25] Duffy and Meier 1992, Harmon et al 1986, Tyrrell and Crow 1994.
[26] Spies et al. 1991.
[27] Hansen et al 1991.
[28] Perry 1994.
[29] Chandler 1987, Selva 1996.

when contrasted with similar forest types managed for timber production.[30] Pelton (1996) has argued that many mammal and carnivore species in the East benefit from forest components such as tip-up mounds, snags, rotted tree cavities. Most of the above patterns were correlated with more abundant coarse woody debris, more developed bark textures and differences in snag size and density. Identifying examples of forest ecosystems that have intact structure and legacy features is important in insuring that the examples function as *source habitat* for many associate species.

Exotic or keystone species: The species composition of an entire ecosystem is a difficult thing to measure as it may consist of hundreds to thousands of species. Relative to all species in a forest system, vascular plant vegetation and vertebrates together probably account for less than 15% of the total biota.[31] The majority of species are the smaller but overwhelmingly more numerous types (invertebrates, fungi, and bacteria) that carry out critical ecosystem functions such as decomposition or nitrogen fixation.[32] Additionally, ecological lag-times, internal system dynamics and the temporally variable nature of ecosystems makes determining the "correct" composition of an ecosystem example an intractable problem (as does the lack of reference sites and an abundance of conflicting perspectives from opinionated ecologists!).

Consequently, we focused on certain individual species (harmful exotics or keystone species) whose presence or absence may signal, directly or indirectly, a disproportionately large effect on the viability of an ecosystem. Total loss of a dominant species or a keystone predator may have a large direct effect. The presence of exotic understory species or forest pathogens may indirectly suggest something about the human history of the site, and so help us to judge the likelihood of successful restoration outcomes.

Condition factors summarized: In summary, our criteria for viable forest condition were: low road density with few or no bisecting roads; large regions of core interior habitat with no obvious fragmenting feature; evidence of the presence of forest breeding species; regions of old growth forest; mixed age forests with large amounts of structure and legacies or forests with no agricultural history; no obvious loss of native dominants (other than chestnut); mid-sized or wide-ranging carnivores; composition not dominated by weedy or exotic species; no disproportional amount of damage by pathogens; minimal spraying or salvage cutting by current owners.

Our condition criteria were more descriptive than quantitative. We could evaluate some attributes like roads and known old-growth sites directly from spatial databases, but the complexities of how the features were distributed and the unevenness of their severity and size were difficult to reduce to a single measure. Most of the detailed information on structure came from state foresters, Natural Heritage ecologists, literature and other expert sources. These descriptions are now stored in text databases for reference. Finally, as we assessed hundreds of potential areas throughout the Northeast, we discovered much that we did not anticipate such as the presence of prisons, abandoned nuclear reactors, streams made sterile from nearby mine tailing, or hunt-club "zoos" with African

[30] Haney and Schaadt 1996.
[31] Steele and Welch 1973, Falinski 1986, Franklin 1993.
[32] Wilson 1987, Franklin 1993.

ungulates. We simply discussed these cases and made a judgment on their potential effects.

Landscape context

The general condition of the landscape surrounding a particular forest was relatively easy to determine from land cover and road density maps in combination with air photos and satellite imagery. More difficult to resolve were the potential effects of the patterns on the viability of the ecosystem. During the planning process we thought of landscape context mostly in reference to buffers against edge effects, evidence of disruption in ecological processes, possible isolation effects on island-like forest areas, and the position of the area relative to landform features. Some evidence in the literature points to isolated reserves that have lost species over time, but most of these refer to much smaller reserves than meet our size criteria. Large reserves that have lost species are, conversely, often in very good landscape settings. Until we have a better grasp of the long term implications of landscape settings, and until we better understand the need for buffers around and connections between ecosystems, we cannot make reliable judgments about landscape context. At the end of this chapter, we discuss new work that has begun on these thorny issues.

Planning teams evaluated and recorded information on the surrounding landscape context for all matrix communities. As a viability criterion, we generally considered areas embedded in much larger areas of forest to be more viable than those embedded in a sea of residential development and agriculture. However, use of this measure as a threshold was complicated by the fact that the matrix forests in many of the poorer landscape contexts currently serve as critical habitat for forest interior species and are often the best example of the forest ecosystem type as well. Thus, no area was rejected solely on the basis of its landscape context. Rather, this criterion was used to reject or accept some examples that were initially of questionable size and condition.

Viability factors summarized

Each ecoregion had somewhat different criteria based on disturbance patterns, species pools, forest types, and anthropogenic setting of the region. Based on the analysis and concepts discussed above the general guidelines for all ecoregions were as follows:

- **Size**: 10,000 – 25, 000 acre minimums
- **Current condition:** low road density, large regions of core interior habitat, large patches of old growth forest, large amounts of structure and legacies features or continuous forest history. Composition dominated by native non-weedy species, confirmed evidence of forest breeding species and mid-sized carnivores. Minimal spraying or salvage cutting by current managers.
- **Landscape context:** examples surrounded by continuous forest or natural cover or, if isolated amidst agriculture and residential development, area clearly meeting the size and condition criteria.

Locating examples of matrix-forming forests

With the matrix forest viability criteria established, the next step of the process was to comprehensively assess the ecoregion to identify and delineate forested areas that met our criteria with respect to size, condition and landscape context. Patch systems had been delineated in a standard way by the state Natural Heritage programs[33] but no 10,000 – 25,000 acre examples of any system types were contained in the current Natural Heritage databases. Thus, an independent assessment of large contiguous forested areas in the ecoregion was needed to determine where the viable matrix-forming forest examples were.

In recent years, a variety of methods have been developed to assess the location and condition of large unfragmented pieces of forest. These methods include delineating contiguous areas of forest on aerial photos, identifying forest signatures on satellite images / land cover maps, or using arbitrarily bounded polygons or "moving windows" in conjunction with road density.[34] Additionally, other conservation site selection projects have used watersheds, regular grids, or political jurisdictions as sampling and selection units for large areas.[35]

Matrix blocks

The surface area of each Northeast ecoregion is effectively tiled into smaller polygons by an extensive road network. The method we used to delineate matrix community examples built on the discrete polygons created by roads, which we referred to as *blocks*. Each block represented an area bounded on all sides by roads, transmission lines, or major shorelines (lake and river polygons) from USGS 1:100,000 vector data. All roads from class 1 (major interstates) to class 4 (local roads) and sometimes class 5 (logging roads) were used as boundaries (see Table MAT3). The blocks could have "dangling" roads within them as long as the inner roads did not connect to form a smaller block. Subsequently, we combined these road-bounded polygons with 30 meter land cover maps and delineated potential forest block areas as those blocks that met a certain size threshold and a certain percentage of forest cover as specified by the ecoregion matrix criteria (e.g., 25,000 acres and 98% natural cover for the Northern Appalachian ecoregion). These forested blocks of land were subsequently evaluated by experts during a series of state by state interviews.

Using road-bounded blocks to delineate matrix examples had practical advantages. They were based on easily accessible public data, which are updated regularly by various organizations. They were easy to register with remotely sensed data. Further, because blocks partition a landscape into boundaries and interior area, they have meaningful area and boundary attributes such as size, shape, and core area. Blocks can be hierarchically nested based on road class, or grouped into larger blocks for spatial analysis. Unlike watersheds, blocks include, rather than divide, peaks and ridges, allowing mountainous areas to be treated as whole units. Additionally, blocks are an effective census unit because they are easy to locate in the field and their locations are recognizable to most people. They are well correlated with parcel, zoning, census, and conservation site boundaries, placing appropriate emphasis on the impact that humans have on nature and biodiversity. Blocks can be used as *draft* conservation site boundaries for regional scale analysis. However, to actually implement conservation at a site, a detailed site

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[33] See the chapter on Terrestrial Ecosystems and Communities methods.
[34] D. Capen, pers. com.
[35] Stoms et al. 1997.

conservation plan must be done to refine boundaries and define internal protection and management zones.

Table MAT3. Road and trail classes used in matrix forest delineation.

Class	Designation	Description
1	Primary route	Limited access highway.
2	Secondary route	Unlimited access highway.
3	Road or street	Secondary or connecting road.
4	Road or street	Local road, paved or unpaved. Includes minor, unpaved roads useable by ordinary cars and trucks.
5	4-wheel drive vehicle trail	Usually one-lane dirt trail, often called a fire road or logging road and may include abandoned railroad grade where the tracks have been removed.
6	Other trails and roads	Not part of the highway system and inaccessible to mainstream motor traffic, includes hiking trails.
20, 30, 50, 70	Other bounding features	Stream or shoreline, railroad, utility line, airport or miscellaneous

Data sources: Macon USA TIGER 94; GDT Major Roads from ESRI Maps and Data 1999.

The core idea behind the road-bounded block, however, was not their practicality but that roads have altered the landscape so dramatically that block boundaries and attributes provide a useful way of assessing the size and ecological importance of remaining contiguous areas of forest.[36] Roads subdivide an otherwise homogenous area into smaller areas. Their effect on the surrounding forest was discussed earlier under the topic of fragmenting features.

Blocks have some limitations for matrix forest delineation. Although they include lake and river polygons, which hold different attributes than land blocks, they do not work as well for aquatic elements as for terrestrial ones because they tend to dissect watersheds, and run parallel to streams. For this reason, we developed an equivalent census of watersheds using similar indices and attributes meaningful for aquatic elements.

Collecting expert information on the matrix blocks

Once all the potential forest blocks were identified using a GIS analysis of roads and forest cover, we gathered more information on the critical characteristics of each block in state-by-state expert interviews with Natural Heritage ecologists, Nature Conservancy staff, and state and federal foresters. The objective of the expert interview process was to refine the boundaries of the blocks using local knowledge, collect information on the types and condition of features occurring within the block boundaries, determine which blocks qualified as matrix examples, and rank them according to their potential as conservation areas.

During the expert meetings, a wide variety of supplemental paper maps, atlases, imagery, and reports were used. Every block larger than the size threshold was examined and the boundaries and interior roads assessed to determine the degree to which they should be

[36] Forman and Alexander 1998.

considered barriers. We discussed road width, traffic volume, surface composition, gates, and other aspects of roads that could be significant. Based on these assessments and field knowledge we accepted, split or aggregated blocks to form new block boundaries.

Experts added supplementary information on the dominant forest types, forest condition, forest composition, land use, forestry practices, hydrologic features, rare species, patch communities, presence of old growth forest, and forest diversity. Information was collected and stored in a systematic way for each block using a questionnaire. After discussing each proposed block, the group scored it on a 5-point scale as to whether it met the viability criteria. Blocks receiving a low score of 2 ("unlikely") or 1 ("no") were discarded from further analysis. Site boundaries for each block were revised as determined at the expert workshops and comments about each block were entered into a permanent database.

Representing forest blocks across all landscape types

Our goal was to identify and conserve forest ecosystems across all types of landscapes typical of the ecoregion. The expert interview process eliminated a large number of areas on the first cut, leaving a smaller subset of potential large forest blocks for detailed evaluation. In every ecoregion, however, the smaller subset was composed of heterogeneous sets of forest areas situated across a variety of landscapes. For example, some forest blocks encompassed mostly conifer forests on high-elevation, resistant granite mountains; others encompassed deciduous forests in lowland and valley settings underlain by rich calcareous and sedimentary soils. In some blocks the dominant forest types were similar, but one set of blocks might be situated so as to contain extensive steeply cut rivers, while another set occurred within a landscape of moist flats with low rolling hills. Thus, our next step was to determine the ecological characteristics of each potential forest area to evaluate which blocks could be considered interchangeable replicates of the same forested landscape and which blocks, or groups of blocks, were not interchangeable.

Ecoregion-wide representation is a critical part of the strategy of conserving forests in the face of severe region-wide threats such as climate change, acid deposition or suburban sprawl. Another reason for representing forests across all types of landscapes was to maximize the inclusion of various patch-forming communities or focal species within the blocks. In the previous examples the high-elevation, high-relief areas might be studded with acidic cliffs, alpine meadows, rocky summit ecosystems and Bicknell's thrush populations while the lowland calcareous areas would tend to contain rich fens, floodplain forests, rivershore grasslands and rare freshwater mussels.

To assess the landscape diversity and ensure the protection of forest areas over ecological gradients we developed a comprehensive ecoregion-wide data layer or map of physical features that we termed *ecological land units* or ELUs. Development of ELUs is the subject of a separate chapter, Ecology of the Ecoregion, and details may be found there.[37] Briefly every 30 square meters of the ecoregion was classified[38] as to its topographic

[37] Incomplete as of July 2003.
[38] While the variables that we used are physical ones, the classes were based on biological considerations (e.g., tree distribution, for Elevation Zone).

position, its geology and its elevation zone (Table MAT4), identifying units such as “cliff on granite in the alpine zone” or “north facing sideslope on sedimentary rock at low elevations.”

Table MAT4. Ecological Land Unit variables

ECOLOGICAL LAND UNITS: generalized example. An ELU is any combination of these three variables		
TOPOGRAPHY	GEOLOGY	ELEVATION ZONE
Cliff	Acidic sedimentary	Very Low (0-800’)
Steep slope	Acidic shale	Low (800-1700’)
Flat summit or ridgetop	Calcareous	Medium (1700-2500’)
Slope crest	Moderately Calcareous	High (2500-4000’)
Sideslope –N facing	Acidic granitic	Alpine (4000+’}
Sideslope – S facing	Intermediate or mafic	
Cove or footslope-N facing	Ultra mafic	
Cove or footslope–S facing	Deep fine-grained sediments	
Hilltop flat	Deep coarse-grained sediments	
Hill / gentle slope		
Valley bottom or gentle toeslope		
Dry flat		
Wet flat		
Flat at bottom of steep slope		
Stream		
River		
Lake or pond		

By overlaying the potential forest blocks on the ecological land unit data layer, and tabulating the area of each ELU, we summarized the types and amounts of physical features contained within each forest block. Subsequently we used standard quantitative classification, ordination, and cluster analysis programs (PCORD) to aggregate the forest matrix blocks into groups that shared a similar set of physical features. The resulting groups may be thought of as identifiable *forest-landscape combinations*. To continue the previous examples, one such group might be blocks that are composed of conifer spruce-fir forests on high-elevation, resistant granite mountains, while another group might be oak-hickory and rich mesic deciduous forests in lowland and valley settings underlain by sedimentary soils. Each forest-landscape combination, which we referred to as “ELU-groups,” contained a set of blocks that were relatively interchangeable with respect to their dominant forest types and landscape or physical features. Based on this methodology each ecoregion had anywhere from five to twenty forest-landscape groups, depending on the range of forest types and physical features within the ecoregion. Additional tests using Natural Heritage element occurrences[39] indicated that many patch-

[39] An Element Occurrence, or EO, is a georeferenced occurrence of a plant, animal, or natural community contained in a Natural Heritage database.

forming ecosystems and focal species locations were highly correlated with the types and diversity of the ELUs. Thus, we assumed that the forest-landscape groups were a useful surrogate for the biodiversity contained within each matrix block.

	Example 1	**Example 2**
Identified forest block	conifer forest on high-elevation, resistant granite mountains	deciduous forest in lowland and valley setting underlain by rich calcareous and sedimentary soils
Associated patch-forming communities or focal species	acidic cliffs, alpine meadows, rocky summit ecosystems, Bicknell's thrush populations	rich fens, floodplain forests, rivershore grasslands, rare freshwater mussels
	ELU Group A	*ELU Group B*
Resulting forest-landscape group	Conifer spruce-fir forests on high-elevation, resistant granite mountains	Oak-hickory and rich mesic deciduous forests in lowland and valley settings underlain by sedimentary soils

Figure MAT2. Development of forest-landscape groups. These examples illustrate the result of analyzing and clustering forest blocks by physical features in order to represent all types of landscapes in the conservation portfolio.

Prioritizing and selecting matrix forest areas for the portfolio

The final step in the analysis of matrix forest areas was to individually evaluate each forest-landscape group and prioritize the set of forest sites within them for conservation. Recall that all blocks under consideration had passed the viability criteria, so the purpose of this final selection was to focus our initial conservation actions, rather than to eliminate non-viable examples.

A final workshop was held in which a group of core team members, TNC state directors, and local experts met to complete the task. Initially the members reviewed the forest-landscape groupings to ensure they captured the logical range of diversity within the ecoregion. Subsequently, within each forest-landscape group, participants prioritized the included blocks based on their *relative biodiversity values*, the *feasibility of protection* and the *urgency of action*.

After prioritizing the blocks within each group they were sorted into two tiers. Tier 1 blocks were identified as the best possible block or set of blocks to represent the forest-landscape group of which it was a member. Tier 2 blocks were less ideal but considered to be acceptable alternatives to the Tier 1 blocks. Experts used their judgment as to how many Tier 1 blocks were needed to represent each landscape group. If, for example, the blocks in a given group were in close proximity and very homogeneous in their ELU composition, then one Tier 1 block was often thought to be enough. On the other hand, if the blocks in a landscape group were geographically dispersed and less homogeneous in ELU composition, then the experts often recommended two or three Tier 1 blocks to represent that group.

The experts were provided with block reports[40] and comparison tables that summarized the features within each block, including comments from the previous expert review of

[40] Block reports are one- or two-page formatted documents that summarize all important descriptive and quantitative information about a matrix block. They are included on the ecoregional data distribution CDs

this block, miles of streams, dams and toxic release points, miles of roads, number and types of ground-surveyed patch ecosystems and rare species, acres of conservation lands, number of ownerships, types and numbers of ELUs, and acres/percents of various landcover classes. A 30 meter resolution satellite image was provided for each block. Maps showing features such as plant hardiness zones allowed the experts to investigate the spatial arrangement of the blocks and determine whether any one block was situated in a particularly important location or if two blocks complemented each other in a particularly useful way.

Overall, however, most of the Tier 1 blocks were identified because they were not only areas with the highest forest integrity but they were also full of embedded patch-forming ecosystems, aquatic features, and focal species populations that were likely to pass their respective viability criteria. Because conservation action would already be targeted for these places due to the clusters of patch features, the addition of a large forest target was a particularly effective way to concentrate biodiversity protection as well as ensure good landscape context for the smaller scale targets. In these cases the Tier 1 and Tier 2 distinctions were obvious but in other cases (parts of northern Maine, for example) in spite of all our collected information the set of alternative blocks all appeared roughly identical and the choice of the Tier 1 block was a somewhat arbitrary judgment.

The set of Tier 1 matrix blocks was our best estimate of the ideal set of matrix forest sites on which to focus conservation action. It is this "optimum" set that was selected for the first iteration of the portfolio. There are, however, a number of alternative solutions that would be very acceptable and the final, implemented, solution may differ from the optimal solution. The identification of Tier 2 blocks should allow us to be flexible but still scientifically rigorous in meeting the conservation mission of the Conservancy.

Numeric goals and total acreage

Our methodology required that we comprehensively assess every possible large scale, unroaded forested area. Unlike the patch-forming ecosystems and focal species work we did not set a quantitative numeric goal for matrix forest sites in the ecoregion. Rather, we assessed the entire region first for potentially viable forest areas, then for representation of landscape features and ecological diversity within those viable sites. Within each forest-landscape combination we prioritized all areas in the set and selected 1 to 4 Tier 1 blocks for inclusion in the portfolio based on the heterogeneity of the group.

Our minimum goal was to identify the number of forest blocks recommended by the team, with at least one block for each forest-landscape group. We set no maximum, but the largest number recommended for any group was 4; most were in the 1 to 2 range. For a few forest-landscape groups even the best forest block was of questionable size and condition. In those cases, our selection was identified as "the best site for restoration." In some plans these restoration sites were included with several caveats. In other plans they were omitted, leaving the issue to be addressed in subsequent updates of the plan.

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for all plans in which they were used. When block reports were not generated, expert teams were given tables containing similar data. See a sample block report page at the end of this chapter.

Assumptions and future needs

The set of forest matrix blocks identified in each ecoregional plan is intended as a minimum set that, if protected, will have a huge impact on biodiversity conservation. We do not know if it is enough. Several outstanding assumptions require further research.

All the plans assume that the current land cover status of the ecoregion remains the same, or becomes more forested. It was necessary to develop the plans relative to the current status of the ecoregion, but now that we have completed this first assessment we can begin to model threats and future change scenarios that will inform a broader strategy of forest protection.

Some TNC ecoregional plans have developed baseline percentages for each matrix system target, such as 10% of the existing cover. We examined these methodologies but did not find them suitable for the Northeast. One reason is that the existing cover is not representative of the historic cover. Diminishing and degrading ecosystems, such as red spruce forests in the Central Appalachians, are already just a fraction of their previous extent.

A second more theoretical issue in using percentages as a basis for goal setting is that the percentage figures are typically derived from species-area curves and island biogeography theory. We used this same body of research to examine isolated or fragmented *instances* of forest. *Ecoregions*, however, are both contiguous with each other and completely permeable. Thus, they do not meet the assumptions of being “island-like” in character.

As an alternative we approached the question of “how much is enough?” by breaking it into two parts: How large and contiguous does a single example have to be to be functional and contain multiple breeding populations of all associated species? And how many of these are needed to represent all the variations of landscape types across the ecoregion? By multiplying the size of the matrix blocks by the number of blocks, we obtained an estimate of the minimum land area needed for conservation. These summaries may also be done by individual forest types or for other groups of targets.

Northeastern ecologists think that we will have to take measure to ensure that these critical areas continue to reside within a larger forested landscape. To address this we have formed a working group, hosted a conference, and produced an initial literature summary document (Anderson et al. 2000) that begins to untangle these issues. In our current protection work we are beginning to identify protection zones along the model shown in Figure MAT3, such that, for example, high protection and land purchase (Gap status 1) is focused on core regions, somewhat lower protection status (Gap status 2) is developed for areas directly surrounding the cores, even lower protection status — forest easements (Gap status 3) — has been enacted on the surrounding landscape, which in turn is embedded in harvested land with forest certification (Gap status 4).

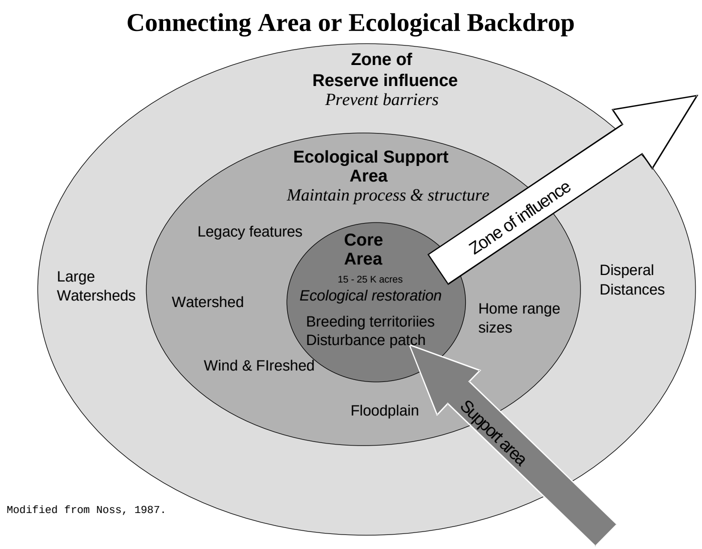

Figure MAT3. Model of protection zones, based on Noss (1987).

Table MAT2-Expanded. Example of nesting territory sizes for some deciduous tree nesting birds in Lower New England. The literature-derived mean for 25-female breeding territory is shown in column 2. Column 5 is Robbins et al. 1989 estimate of minimum area requirements (MAR). Columns 6 and 7 illustrate Partners-in-Flight (PIF) importance score for the species within the ecoregion.

SPECIES	Acres x 25	Mean territory (acres)	Mean Home Range	MAR acres	PIF 10 score	PIF 27 score	References
Broad-winged hawk	14225	569		0	3	4	.89miles between nests (569acres) Goodrich et al 1996, 1-2 square miles (Stokes)
Cooper's Hawk	12500	500	2718	0	3	2	densities 0.2 pairs/100 acres (Stewart & Robbins 58)// Little information on territoriality but minimum distance between nests is 0.7-1.0 km
Northern Goshawk	10500	420	5028	0		3	1-2 square miles (Stokes). // 170 ha surrounding the nest BNA =420 acres
Eastern Wood-Pewee	300	12		0	5	4	1.4-3.1: Fawver 1947, 2-6 (Stokes)// 2.2 ha Iowa, 7.7 ha in Wisconsin averages BNA =12.2 acres
Yellow-throated Vireo	185	7.4		0	3	2	3 males/100 acres in MD floodplain, 8/100 in riparian swamp, 19/100 in deciduous forest, (Stewart & Robbins 1958 //Populations are sparse and little competition evident but most activity occurs within 100 m of nest or 3 ha area. (BNA)
Philadelphia Vireo	87.5	3.5		0		2	0.3-0.8 ha Ontario, 0.5-4.0 NH. Overlap with red-eyed Vireo.
Warbling Vireo	82.5	3.3		0	2	3	10 males/100 acres in MD riparian and field, (Stewart & Robbins 1958)// 1.2 ha AZ, 1.45 ha CA, 1.2 IL, 1.2-1.5 Ontario, 1.5 ha Alberta =avg 1.34 ha=3.3 acres
Baltimore Oriole	75	3	1.6	0	4	5	3 acres (Stokes). //Varies with habitat quality, food availability, population density and time of breeding. Only nesting area defended (BNA)
Cerulean Warbler	65	2.6		1729	2		5 males per 50 acres in birch basswood forest (Van velzan) //Mean breeding territories 1.04 ha SD 0.16 BNA =2.6 acres
Blue-gray Gnatcatcher	42.5	1.7	9.8	91	4	1	7 pairs/100 acres in MD floodplain, (Stewart & Robbins 1958)// Mean territory size: 0.4 ha FL.1.8 ha CA, 0.7 ha VT, (=1.7 acres VT) Difference may reflect environment. Territory size decrease over season and adults tend to stay within 50 meters of nest.

MATRIX SITE: 26
NAME: Merry Meeting Lakes
STATE/S: NH

RANK: Y
SUBSECTION: 221Al Sebago-Ossipee Hills and Plains

COMMENTS:
collected during potential matrix site meetings, Summer 1999

Old growth:	unknown; mature forest
Logging history:	less of an agricultural history here because higher elevation and rougher topography. 3rd and 4th growth or more.
Other comments:	invasives, two 10-15K blocks. Divided by rt. Kings Highway – local road, paved and canopy covered for large portions and just a little development.
Road density:	low (maybe moderate) mixed paved and gravel except the two larger. A number of class six trails. A number gated.
Unique features:	some neat geology; some mining. Some active low bush blueberry management on the peaks. Period burning. Ledges – ravens, turkey vultures, bobcat. Fairly uneven terrain.
Aquatic features:	headwaters of the cocheco River, number of lakes and ponds. Some of Merrymeeting marsh emergent wetland.
General comments/rank:	YES, great blue blocks.
Landscape assessment:	contiguous to south with a block NW and east chewed up.
Ownership/ management:	State F and W – 4,000, hunting and wildlife improvement cuts; Forest Society has 600+ - forest management, recreation and hunting. Large woodlot ownership.
Boundary:	
Cover class review:	0.93

Sample Block Report

Ecological features, EO's, Expected Communities: Isotria, acidic pondshore communtiy, acidic rocky summit; spruce-fir in lowlands.Pinus strobus-Quercus-Fagus alliance

SIZE:
Total acreage of the matrix site: **49,738**
Core acreage of the matrix site: **39,015**

Total acreage of the matrix site:	49,738
Core acreage of the matrix site:	39,015
% Core acreage of the matrix site:	78
% Core acreage in natural cover:	98
% Core acreage in non- natural cover:	2

(Core acreage = > 200m from major road or airport and >100m from local roads, railroads and utility lines)

INTERNAL LAND BLOCKS OVER 5k: 42 %

Average acreage of land blocks within the matrix site:	1,333
Maximum acreage of any land block within the matrix site:	11,567
Total acreage of the matrix site that is part of 5000 + acre sized land blocks:	20,870
% of the total acreage of the matrix site that is made up of 5000 + acre sized land blocks:	42

Internal Land Block Size Distribution:

Acres	# Blocks
<100	12
100 - 500	9
500 - 1000	3
1000 - 2000	5
2000 - 5000	5
5000 - 10000	1
10000 - 15000	1
15000+	

MANAGED AREAS: 7 %
(Conservation and other Federal / State managed parcels > 500acres)

	# Parcels in block	Percent	Acres
Managed Area Total	17	7	3,564

15 Largest managed area parcels within site

	Name	Acres	Type
1	Jones Brook WMA	1,547	STA
2	Jennings Forest	358	PVT
3	Merrymeeting Marsh WMA	302	STA
4	Beaver Brook WMA	255	STA
5	Marks Memorial Forest	240	PVT
6	Seavey	236	STA
7	Eley	184	STA
8	UNH - Jones Property	156	STA
9	Powdermill Fish Hatchery	101	STA
10	Abbotts Grant - Farmington Town Forest	53	PVT
11	Middleton Park	50	MUN
12	Middleton Town Forest	31	MUN
13	New Durham Ballfield	20	MUN
14	Hoopes	14	STA
15	Milton Mills WMA	10	STA

LANDCOVER SUMMARY:
Natural Cover: 96 %

	Percent
Open Water:	4
Transitional Barren:	0
Deciduous Forest:	39
Evergreen Forest:	11
Mixed Forest:	34
Forested Wetland:	6
Emergent Herbaceous Wetland:	1
Deciduous shrubland:	0
Bare rock sand:	0
TOTAL:	96

Non-Natural Cover: 4 %

	Percent
Low Intensity Developed:	1
High Intensity Residential:	0
High Intensity Commercial/Industrial:	0
Quarries/Strip Mines/Gravel Pits:	0
Hay Pasture:	0
Row Crops:	3
Other Grass (lawns, city parks, golf courses):	0
Orchards, Vineyards, Tree Plantations:	0
Plantations:	0
TOTAL:	4

(Landcover summary based on total area of the matrix site)

ROADS, ETC.:
Miles / 1k acres: **2**

Internal Transportation Linework

	Miles	Miles / 1,000 Acres
Major Roads (Class 1-3):	7	0
Local Roads (Class 4):	97	2
Railroads:	0	0
Utility Lines:	0	0
4-Wheel Drive Trails		
Foot Trails:		
Other (ski lift, permanent fence, airstrip)	0	0
TOTAL:	105	2

Boundary Linework

% Of site boundry which is made up of major roads: 32