CHAPTER 3

BIOPHYSICAL ASSESSMENT OF THE NORTHERN APPALACHIAN ECOREGION

Introduction

Objectives

The objectives of this chapter were: (1) to develop a comprehensive and quantitative assessment of the biophysical features and gradients within the ecoregion and, (2) use this information to develop a stepwise hierarchical partitioning of the ecoregion into sequentially smaller subregions.

In representing examples of communities in a conservation reserve system, it is important to protect them across the full range of conditions within which they occur (Soule and Sanjayan 1998, Noss and Cooperrider 1994). Representation may be approached by distributing targeted examples of each community across ecoregional *subregions* that exhibit a variety of contrasting biophysical characteristics (Avers et al.1994). The representation of community occurrences across subregions of the ecoregion also helps to buffer against degradation in one portion of its range, allows for possible geographic shifts over time and, in some cases, may be used to compensate for coarse-scale conservation targets (Hunter 1991)**.**

The extent to which a community needs to be represented across the biophysical gradients of the ecoregion is largely a function of how restricted the community is to the ecoregion, as well as its distribution and variability within the ecoregion (see chapter 5). Restricted or endemic communities require a more thorough and finer-scale stratification of the ecoregion as their entire range of conditions are represented within the ecoregion. Conversely, widespread communities require less intensive stratification within an ecoregion, since they are already partially stratified among other ecoregions. Because of these differences in scale and resolution needs, a flexible, hierarchical partitioning of the ecoregion into increasingly finer eco-graphic subregions was developed. The hierarchy was used as a tool to determine the placement, number and distribution of community occurrences across the ecoregion.

Approach to Developing the Biophysical Subregions

To insure that the subregions could be explicitly related to communities, it was essential to compile information on the distribution of physical features across the ecoregion. In this chapter, I develop a comprehensive spatial data-layer of 580 fine-scale ecological land units (ELUs) composed of topographic features distributed across elevation and bedrock classes. These units were constructed based on specific relationships, albeit complex ones, to the communities. Subsequently, in a GIS format, I sampled and tabulated the area of each ecological land unit within each USFS subsection (Keys et al. 1995). Subsections were chosen as the basic unit for sampling the ecoregion as they were defined based on consistent landscape patterns (Smith and Carpenter 1996). Additionally, the subsection boundaries were readily available in a digital form, have received and incorporated wide critical review and were developed from a logical conceptual background based on climatic and edaphic patterns (Avers et al. 1994, Bailey et al. 1994). It is likely that the published subsection boundaries will change and improve over time making this analysis more-or-less specific to the 1995 units. (See chapter 1).

Finally, using a combination of classification (TWINSPAN; Hill 1979a), ordination (DECORANA, Hill 1979b), ocular inspection, and comparison with vegetation patterns, I produced a multi-scale hierarchical partitioning scheme for the ecoregion. The hierarchical model subdivides the ecoregion into increasingly finer eco-geographic units, separating or aggregating the subsections depending on their similarity in biophysical features and the scale of the variation being examined. Later in this document the subregion framework will be used to distribute occurrences across the ecoregion.

Overview of the Biophysical Setting

The Northern Appalachian ecoregion consists of 26 subsections (Table 3.1) extending over 31 million acres of primarily forested land. In total, it comprises the largest expanse of forest remaining in the eastern United States. Its boundaries extend from the Tug Hill and Adirondack ranges of New York, across the Green Mountains of Vermont and White Mountains of New Hampshire then stretching northward, encompassing most of Maine, to the Canadian woods and southward to the scenic island-studded coast of Maine. Located within an eight hour drive of 70 million people, it is also the largest expanse of forested ecosystem near major population centers (Trombulak 1995).

The landscape has endured extensive periods of volcanic activity, mountain building, erosion, sedimentation, and at least four major glaciations. The last of these, which occurred 12-14 thousand years ago, is responsible for the present landforms of sculpted mountains, flat plateaus, and carved valleys (Carpenter et al. 1999). Elevation ranges from sea-level to over 6000 feet. The extensive but ancient mountain ranges are composed of granites and metamorphic rocks overlain by a thin veneer of glacial till. Most of the glacially broadened valleys are plugged with till or deep outwash deposits giving rise to thousands of swamps, bogs, lakes and ponds. Figure 3.1 illustrates the U.S. boundaries of the ecoregion along with topographic relief and USFS subsections. Figure 3.2, the multi-resolution land cover (MRLC) map, illustrates the distribution of major land-cover classes across the region.

Table 3.1 Northern Appalachian subsection names and attributes (Keys et al. 1995)

SUBSECTION CODE	*NAME*	*Ann. Precip. (in.)*	*Ann. Temp. (F)*	*Growing season (days)*
212Aa	Aroostook hills and lowlands	36	39	109
212Ab	Aroostook lowlands	38	40	110
212Ba	Central Maine foothills	41	42	131
212Bb	Maine/New Brunswick lowlands	42	42	141
212Ca	Maine Eastern Interior	44	42	139
212Cb	Maine Eastern Coastal	47	43	152
212Da	Central Maine Embayment	39	44	125
212Dc	Casco Bay	48	45	143
M212Aa	International Boundary Plateau	38	38	108
M212Ab	St. John Upland	38	38	113
M212Ac	Maine Central Mountains	40	40	123
M212Ad	White Mountains	47	41	116
M212Ae	Mahoosuc Rangely Lakes	38	40	115
M212Af	Connecticut Lakes	41	39	107
M212Ag	Western Maine Foothills	44	42	125
M212Ba	Vermont Piedmont	39	42	114
M212Ca	Northern Green Mountains	49	41	121
M212Cd	Southern Green Mountains	48	45	143
M212Da	Adirondack Hills and Flats	39	42	125
M212Db	Western Adirondack Foothills	44	42	123
M212Dc	Adirondack Highlands and Lakes	45	40	108
M212Dd	Central Adirondack Mountains	39	40	98
M212De	Eastern Adirondack Low Mountains	39	43	140
M212Df	Adirondack Peaks	38	40	98
M212Fa	Tug Hill Plateau	60	42	140
M212Fb	Tug Hill Transition	50	44	147

Figure 3.1 Shaded relief map of the Northern Appalachian ecoregion.

Figure 3.2. Multi-resolution land-cover map for the Northern Appalachian ecoregion.

The ecoregional climate is characterized by warm summers and long cold winters with an average annual snowfall of over 100 inches and other precipitation averaging 35 inches per year. The dominant vegetation is made up of combinations of deciduous and coniferous forest interspersed with a variety of swamps, marshes, fens, bogs, rocky ridges, alpine mountain tops, calcareous outcrops, ice scoured river banks, salt marshes, and rocky coastal cliffs (Keys et al. 1995 and see chapter 1). Additionally the region includes over 68,000 miles of rivers and streams, and at least 8000 lakes and ponds covering over a million acres (Buttrick et al. 1998)

Development of the Ecological Land Units:

There are a variety of useful approaches to defining the biophysical environments of a large area (Austin and Smith 1989). Approaches that utilize broad correlations between vegetation and environment to delineate plant communities have been critiqued for relying too heavily on indirect factors (soils, landforms etc.) without explicitly stating the ecological relationships between the biotic and abiotic components (P. Bourgeron pers. com). Recent approaches to describe pattern in bio-environments (patterns in ecological space defined using direct variables such as radiation, thermal, moisture, and nutrient regime) have been differentiated from biophysical environments based on indirect geographical variables or natural landscape units (Belbin 1993, Mackey et al. 1988).

Previously, I developed an approach for assessing the Connecticut River watershed which began by constructing models of community distributions across elevational, topographic, and geologic gradients and then reducing the available continuous or catagorical data into a few classes which maximized their relevance to community distribution patterns (Anderson et al. 1998). In that study, an elevation range from sea level to 6000 ft, a limitless variety of slope positions, slope degrees, and aspects, and 230 bedrock types, were reduced to 4 elevation classes, 15 topographic features (steep slopes, dry flat, cove etc.) and 5 bedrock classes (acidic granitic, calcareous etc.). These 3 factors were then intersected to produce 300 ecological land units (e.g., low elevation calcareous wet flat, high elevation acidic-granitic upper slope) which fully tessellated the ecoregion. In the Connecticut River study, I modeled community distributions by further intersecting the ecological land units (ELUs) with USFS subsection polygons, narrowing down the potential list of community types to those occurring within the subsection. A multi resolution land cover map to was then used to isolate specific vegetation signatures. Thus the “full” model for a community, such as northern white cedar swamps might read “conifer forest on low elevation calcareous wetflats in subsections M221Bb or M221Ca”. In this thesis I develop and expand this approach for the Northern Appalachians, focusing on three primary factors: *Elevation*, *Topography* and *Lithology*. Along with climate and time the influence of these factors on vegetation and on soil formation has long been recognized (Jenny 1941, Siccama 1974, Leak 1982).

Methods

Overview

In the following sections I detail how I approached, reduced, and developed the data layers on elevation, topography, and lithology for the ecoregion. Each had to be assembled in a digital format. Elevation and lithology required relatively straightforward regroupings of existing digital data. The topographic feature data were derived primarily from a digital elevation model (DEM) and required substantial conceptual and spatial analysis. The DEM used was produced and distributed by USGS for one arc second cells for the entire conterminous United States (approximate scale of 1:250K). The cell size on the ground was approximately 74 m per side. I was greatly assisted with the technical GIS work by Mike Merrill of the TNC regional office.

Elevation

Elevation has a major influence on vegetation distribution in the Northern Appalachians particularly as it relates to microclimates and exposure (Bormann et al. 1970). Air temperature drops an average of 3 degrees F for every 1000 ft gained in elevation and the amount of precipitation collected at higher elevations is often double that of lowland stations (Marchand 1987). I based the elevation categories on the general distribution of dominant forest types in the region. Vegetational zonation in New England and New York has been clearly recognized by ecologists since the turn of the century (Chittenden 1905, Hawley and Hawes 1912, Bray 1915, Egler 1940, Oosting and Billings 1951, Westveld et al. 1956, Bormann and Nelson 1963, Siccama 1968, Braun 1950, Cogbill and White 1991). Generally, the transitions between zones are defuse and defined by a gradual acquisition or loss of certain species as one moves across an elevational and latitudinal gradient (Bormann et al. 1970). An exception to this is the fairly abrupt and generally agreed upon transition from deciduous northern hardwood forest to coniferous spruce-fir forest at about 2,500 ft. This transition corresponds closely with the upper elevational limit of sugar maple and American beech (Demers et al. 1997, Bormann et al. 1970). Other generalized elevation limits of important trees in the Northern Appalachians are eastern hemlock and white ash at 2000 ft, white pine and red oak at 1500 ft, and white oak and butternut at 500-900 ft (Bormann et al. 1970).

There is little agreement on the precise zonal boundaries of most forest types described in the literature partially because the forest communities themselves have been defined in different ways by different individuals (Cogbill and White 1991, Sneddon et al. 1994). Additionally, the zonal limits of vegetation types are modified by specific latitude, exposure, growing season, and other localized factors, that are not homogenous across the entire ecoregion (Sabo 1980). I used the synonymies developed in the regional classification (Sneddon et al. 1996), with tabular comparisons of the elevational distribution of dominant forest types as described by 13 different authors [in Bormann et al. (1970) and Cogbill and White (1991)], to compare and contrast the various types and arrive at some general elevational zones for the ecoregion.. Additionally, I tested and refined the zonation scheme by examining the distribution of 1321 Natural Heritage element occurrence points for communities across the proposed elevation zones. Generally, this analysis agreed with the literature and supported the zones listed below. However, after examining the element occurrences for alpine communities, I lowered my original (literature derived) alpine limit by 300 ft (from 4300- 4000). The 5 classes in my final model were:

Very low	0-800 ft	Oak, pine-oak, pine-hemlock, maritime spruce, floodplains
Low	800-1700 ft	Hemlock-N.hardwoods, N. hardwoods, lowland spruce
Mid	1700-2500 ft	Northern hardwoods. (spruce-hardwoods)
High	2500-4000 ft	Spruce-Fir (spruce – hardwoods)
Alpine	4000+ ft	krumholtz, montane Fir, alpine communities

Topography

Topography, or local relief, controls much of the distribution of soils and vegetation types in a landscape (Birkeland 1984, Leak 1976, Leak 1982). In particular there are many soil/vegetation properties influenced by position and gradient of a slope. Ruhe and Walker (1968) proposed a 5-part hillslope model for explaining soil formation dividing hills into flat summit, convex shoulder, backslope, concave footslope, and concave toeslope. Conacher and Darymple (1977) developed a nine-unit land surface model defined by process. Leak (1982) provides useful information relating site habitat types to topographic features for the Bartlett experimental forest in the White Mountains.

The topographic model I developed was based primarily on how communities were distributed in the landscape. It is similar to the Ruhe and Walker (1968) model but is more expansive as it is intended to cover all the significant topographic features in the ecoregion not just those found on hillslopes. As with the elevation zones, I tested and refined the model by overlaying, in a GIS format, 1321 Natural Heritage community occurrences and examining the correlation patterns between community type and topographic features. Quantifying the correlation in a tabular fashion was possible, but due to the coarse, 90 m resolution of the DEM and error in the spatial positioning of the element occurrences, it was not pursued at this time. For instance, when examined visually, mid elevation, upper slope, red spruce woodlands very clearly clustered around mid elevation, upper slope features. However, when the points, however, were tabulated pixel by pixel, a proportion of the occurrences landed on pixels classified as sideslope, cove or flat, often ones that were one or two pixels away from a upper slope pixel. This was true even when the occurrence was described in the supporting documentation as occurring on an upper slope suggesting some error in the point positions.

The final model had 5 primary units that I differentiated further into 17 total units (Figure 3.3, Table 3.2). I integrated SW or NE aspect into the model only for the “sideslopes and coves” where the influence of snowmelt and solar radiation is at its greatest. Likewise I integrated surficial sediment into the model only for the “dry flats” that were further subdivided into dry flat on tills or shallow soils, dry flats on deep coarse soils, and dry flats on fine grained lake sediment. The latter two categories covered only a small proportion of the ecoregion (1% and 4% respectively) but I assumed that, as they are

Figure 3.3 Topographic model and complete three-factor model for the ecological land units of the Northern Appalachian ecoregion.

Table 3.2 Topographic feature model for the Northern Appalachian ecoregion.

Topographic feature	Slope position	Slope degree	Example Communities	% of EOs	% of region
Cliff	Any	Very steep	Acidic/calcareous cliff	0.5	0.02
Steep slope	Any	Steep	Talus slopes, bluffs	4	0.3
Flat summit	Highest	Flat	Fir flats, alpine meadows	4	1.8
Slope crest	Highest	Moderate	Rocky summit woodlands/heaths	4	0.2
Upper slope	High	Moderate	Dry forests, Glade woodlands	9	2.8
SideslopeNE	Mid	Moderate	Matrix forest: moist	5	5
Sideslope SW	Mid	Moderate	Matrix forest: dry	4	4
Cove/toeslope NE	Low	Moderate	Hemlock-hardwoods, Cove forest	6	3
Cove/toeslope SW	Low	Moderate	Rich cove forests	3	2
Dry flat: shallow till	Mid	Flat	Matrix forest,	19	49
Dry flat: coarse soil	Mid	Flat	Pitch pine, dunes,	3	4
Dry flat: fine sed.	Mid	Flat	Floodplains	1	3
Wet flats	Mid	Flat	Swamps, Bogs, fens, marshes	22	11
Slope bottom flat	Low	Low	Hemlock ravines, small streams	2.5	2
Stream	Low	Flat	Large ravines, floodplains	7	5
River	Low	Flat	Rivershore communities	1	0.3
Lake/pond	Low	Flat	Lakeshore communities	5	4

generally very deep, there would be little or no bedrock influence on these two categories. The topographic categories included the following:

1) *Steep slopes and cliffs*. These were defined as any slopes greater than 25 degrees, with cliffs being >35 degrees, regardless of land position. Cliffs and steep slopes made up a small proportion of the ecoregion and were most closely associated with large rivers, and upper slope features.

2) *Upper slopes*: These were defined as features that have a high landscape position and moderate to flat slope degree. They included upper slopes, slope crests, hilltops, and flat summits which were differentiated by theirslope position and steepness. Generally these were associated with mountain ranges, monadnocks, low hills. These corresponded to Leak's (1982) "shallow bedrock and ledge" and "dry cemented till",

3) *Side slopes and coves*: These were defined as areas of mid to low slope positions and moderate slope degree. These were further differentiated by slope position, with coves being restricted to toeslopes or gently concave ravines. Both features are further divided by aspect. NE facing slopes were assumed to be cooler and moister than SW facing ones. These features were relatively widespread in the ecoregion. The sidelope category corresponded to Leak's(1982) "fine till" and "washed till" while the cove category corresponded to "enriched"

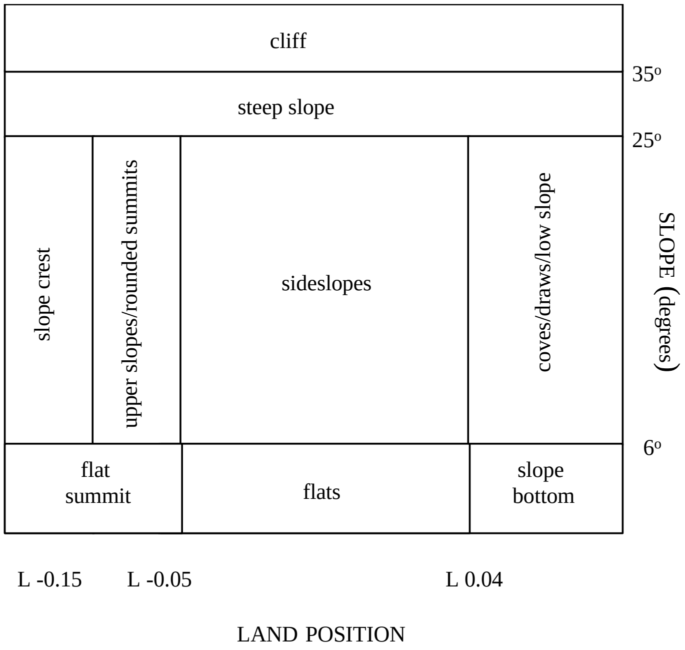
4) *Flats:* These were areas with little or no slope (<6% in the DEM), and are the most abundant features in the ecoregion. They were further differentiated into dry flats or wet flats based on a flow accumulation model. Moreover, dry flats were further divided by surficial sediment types (from USGS Digital Data Series DDS-38), into (1) dry flats on coarse soil (equivalent to Leak's (1982) sand or outwash), (2) dry flats on fine lake sediment and (3) dry flats on till or shallow till. The latter is by far the dominant feature of the ecoregion. Associated habitat types would be Leak's (1982) "dry compact till" "silty or sandy sediments". Wet flats almost always surrounded a hydrologic feature such as a stream or lake. They corresponded to Leak's (1982) "poorly drained" or "wet compact till" A particular kind of wet flat: the slope bottom flat, was a narrow flat with slopes leading into it from most sides (e.g., a large ravine). Typically these features have streams in their centers and would be associated with the Leak's (1982) "shallow loose rock".

5) *Hydrologic features*: These data were from the USGS and contains streams, rivers, lakes and ponds.

<u>Development of the topographic feature GIS data layer.</u> The topographic features were derived from a digital elevation model (DEM). The DEM used was produced and distributed by USGS for one arc second cells for the entire conterminous United States (approximate scale of 1:250k). The cell size on the ground was approximately 74 meters per side. A variety of variables may be calculated from digital elevation data and numerous methods have been developed to calculate each variable (e.g. Moore, D.M. et al.1991, Moore, I.D. et al.1988, Michaelson et al. 1994; Lynn et al. 1995; Iverson et al.1997; Fels and Zobel 1995).

Fels and Zobel (1995) developed a simple two-variable model for categorizing topographic position based on slope and landscape position (Figure 3.4). I focused on these two variables, which could easily be derived from the 1:250K DEM, grouping them into classes as described below.

Figure 3.4. Slope / Land position matrix determining topographic class modified from Fels and Zobel (1995) to reflect patterns in the NAP ecoregion.



Slope was grouped into four classes: Flat (0 – 6 degrees), Moderate (6 – 24 degrees), Steep (24 – 35 degrees), and Very steep (> 35 degrees). Using the standard slope calculation (slope angle in degrees) that is available in ARC/INFO (ESRI), the resolution of the DEM seems to underestimate slope in most areas. For example, many steep slope and cliffs were underestimated because of the long distance each cell spanned in this analysis (approximately 74 m). By examining areas that were known to contain cliffs and/or steep slopes (using USGS 7.5 minute topographic quads or Natural Heritage mapped data) these classes were further refined. Thus the categories should be interpreted as appropriate for these data given its scale and resolution not as true ecological slope classes.

I partitioned the landscape position into four classes: low (slope bottoms), middle (sideslopes), high (upper slopes), highest (summits), following Fels and Zobel (1995) and Fels and Matson (1997). I determined the appropriate cutoffs between classes in the relative index by visually examining specific areas in the ecoregion. The derived landscape position values were adjusted to match locations where ridge lines ended or slope bottoms started, etc. on USGS 7.5 minute topographic quadrangle maps.

I used a landscape position index to calculate the landscape position for each cell. This index (also referred to as topographic position or slope position) estimates where a map cell is located relative to the surrounding map cells. For instance, the cell may be either at the ridge top or at the slope bottom or somewhere in between. Landscape position calculations were based on Fels and Zobel (1995) although several other methods have been developed (e.g. Lynn et al. 1995, Skidmore 1990, Moore, D. M. et al. 1991). The selected method evaluates the elevation differences between the model cell and the surrounding cells within a specified distance. For example, if the model cell was, on average, higher than the surrounding cells then it was considered to be closer to the ridge top (a more negative Land Position value). Conversely, if the model cell was, on average, lower than the surrounding cells then it was considered closer to the slope bottom (a more positive Land Position value). The equation was as follows:

$$\text{Land Position} = \frac{\sum_{1,n} \frac{E_n - E_o}{d}}{n}$$

where E_o = elevation of the model point under evaluation
E_n = elevation of a surrounding model point
d = horizontal distance between the two model points
n = the total number of surrounding points employed in the evaluation

The land position value was the mean of the distance-weighted elevation differences between a given point and all other model points within a specified search radius. The search radius I used was the average ridge to stream distance [the average fractal dimension =6 cells (74.1879 * 6 = 445 m)] based on sample measurements of a shaded relief map and from USGS 7.5 minute topographic quad maps. Ideally, I would have used different search distances for different subsections based on their average ridge to stream distance in various subsections. My use of a single search radius for the whole ecoregion made it likely that the model was less sensitive to small-scale landscape undulations in areas of less relief. However, visual inspection of the map of low relief areas indicated that the algorithm was detecting small low hills. Perhaps because the equation was weighted by distance, a larger search radius may have yielded only subtle differences.

The slope and land position model for topography produced nine primary topographic units, most of which matched the conceptual model (Figure 3.3). Flats (excluding those which occur as summits or slope bases) remained a fairly large, undifferentiated group. To further divide them, I first used a flow accumulation model and moisture index to separate out the wet flats from the dry flats. Dry flats were then separated based on surficial soil information (Table 3.3)

Table 3.3. Differentiation of the topographic flats by moisture and surficial sediment in the Northern Appalachian ecoregion.

TOPOGRAPHIC FLATS	
DRY FLATS	**WET/MOIST FLATS (based on flow accumulation model)**
Dry flats on till or shallow till	Wet flat
Dry flats on coarse soils	Slope bottom flat
Dry flats on fine sediment	Stream or river
	Lake or pond

A simple moisture index based on surface water flow models (Grayson et al 1992, Mitasova 1996, Moore, I.D. et al.1988, Boer et al.1996, O'Loughlin 1986, Parker 1982) was used to estimate moisture accumulation in flats. The model assumed that the relative moisture in a particular area (in this case a grid cell) depends on two factors; how much water is flowing into the area and how fast the water can flow out of the area. The catchement area was determined for each cell (ARC/INFO *flowaccumulation* command). This was the amount of upslope area (or the number of cells) that contributes water to the cell. The slope at the cell then determines how fast the water can run off the cell. The index combines these two indices with the formula:

$$\text{Ln}\ [(\text{catchment area} + 1) / (\text{slope} + 1)].$$

This is a relative moisture index so the resulting numbers do not have units, yet the higher, more positive, numbers are wetter and the lower, more negative, numbers are drier.

Two moisture classes were created: dry and wet. By comparing known moist or saturated areas with the derived moisture index, I was able to determine the appropriate cutoff points. Adjustment was done using locations of Natural Heritage element occurrences of wetland natural community types and a USGS 7.5 minute quad maps. After the grid was reclassified into two levels, multiple majority filters were run which cleaned the grid of single isolated cells. It appeared that these single isolated cells were primarily due to errors in the DEM as they did not match sites of known isolated wetlands.

To enhance this classification scheme and create the full topographic layer, I added moisture index class, and rasterized hydrographic features from the USGS 1:100K DLG (Digital Line Graphics). This vector data set included permanent streams, reservoirs, lake, and banks of large rivers. I rasterized the water features including lakes, ponds, reservoirs, wide rivers, and streams to the analysis cell size (i.e., 74.19 m). Where these water features occurred I replaced the landform values with new values corresponding to lake, pond, reservoir, river, and stream. Finally, where cells were categorized as ‘flats’ in the slope-land position matrix (Fig.2.4) I replaced those values with values of dry flat or wet flat derived from the moisture index classes.

Surficial sediment information from USGS Digital Data Series DDS-38, scale 1:1 M, was used to differentiate the dry flats. I used the coarse-grained sediment and fine-grained sediment classes as they were (both are rather restricted in the northern Appalachians) but combined the till class and patchy quaternary sediment class into a single class as they are ecologically very similar.

I differentiated the Sideslopes and Coves into 2 aspect classes, Southwest facing or Northeast facing, using aspect estimates taken directly from the digital elevation model. With the addition of these categories, the model now matched the conceptual, 17-feature model (Table 3.2 and Figure 3.3)

Lithology

The bedrock geology of an area influences the chemistry of the soils and the waters with which they have contact (NAQWA 1997, Robinson 1997). Additionally, bedrock types differ in how they weather and in the characteristics of the residual soil type (Leak 1982). Certain bedrocks weather to clays with easily erodable textures, high nutrient and high water holding capacity, while others types weather to porous soils that are low in nutrients (Birkeland 1984). Many ecological community types are closely related to the chemistry and drainage of the soils or are associated with particular bedrock exposures (McVaugh 1958, Leak 1978, Sneddon et al. 1996). I grouped the 240 total bedrock classes identified on the bedrock geology maps of ME, NH, VT and NY (Osberg et al. 1985, Lyons et al. 1997, Fisher et al.1970, and Doll et al. 1961) into eight general classes (Table 3.4). I based my classes partially on broad classification schemes developed by NAQWA and Bailey (in Carpenter et al.1998) which emphasize texture and chemistry. The scheme I developed further emphasized bedrock settings that are important to many communities, particularly to herbaceous associations (Sneddon et al. 1996)

USGS Bedrock geology maps for each of the four states (Osberg et al. 1985, Lyons et al. 1997, Fisher et al.1970, and Doll et al. 1961) were compiled in both hard copy and digital form. The data were developed at a scale of 1:125,000. The 240 bedrock types occurring in the ecoregion were classified into one of eight broad groups (Table 3.4), however, for the purposes of developing the ecological land units and later analysis I decided to treat the classes a*cidic granitic* and *acidic gneiss* as a single group (*acidic granitic*). This reflected my field observations as well as discussions with several ecologists and geologists which suggested that they are ecologically interchangeable. This reduced the final list of lithological types to 7. I also used the USGS-BRD developed coverage of lithogeochemical bedrock zones for the Connecticut NAWQA, to examine the correlation with the geology map developed for a previous project in the Connecticut river watershed (Anderson et al. 1998).

Synthesis of the Biophysical Information into Ecological Land Units (ELU)

The three primary factors were combined into a single distinct unit that I refer to as the Ecological Land Unit (ELU). Each ELU represents a topographic unit occurring within a particular elevation range on a particular bedrock type (e.g., low elevation calcareous wet flat, high elevation granitic, flat summit, etc.) and thus should be related to the distribution of communities in the ecoregion (Figure 3.5). Combination of the three variables produced the possibility of 595 ELU classes (17 topographic features x 7 lithology types x 5 elevation classes = 595) although not every combination actually occurred in the ecoregion (for example alpine elevation and shale bedrock never intersect.

Table 3.4. Bedrock geology classes for the Northern Appalachian Ecoregion

Table 3.4 Bedrock geology classes for the Northern Appalachian Ecoregion

Figure 3.5. Ecological Land Units used for the biophysical assessment of the Northern Appalachians.

ECOLOGICAL LAND UNIT (ELU)

Elevation class (in feet) + **Bedrock Class** + **Topographic feature**

Elevation class (in feet)		
1000	Very low	0 - 800
2000	Low	800 - 1700
3000	Mid	1700 - 2500
4000	High	2500 - 4000
5000	Alpine	4000+

Bedrock Class	
100	acidic sed/metased
200	acidic shale
300	calcareous sed/metased
400	mod calcareous sed/metased
500	acidic granitic
600	mafic/intermediate granitic
700	ultramafic

Topographic feature	
	10's Steep Slopes
10	Cliff
11	Steep slope
12	Slope crest
13	Upper slope
14	Flat summit
	20's Side Slopes
20	Sideslope - N / E
21	Cove - N / E
22	Sideslope - S / SW
23	Cove - S / SW
	30's Flats
30	Dry Flat Till or Patchy Sediment
31	Dry Flat Fine Grained Sediment
32	Wet/Moist Flat
33	Slope bottom
34	Dry Flat Coarse Grained Sediment
	40's Aquatic
40	Stream
41	River
42	Lake

Example:
2000 Low + 500 acidic granitic + 32 Wet flat = ELU2532
Low acidic granitic wet flat

<u>Sampling the Subsections for ELU attributes</u>: In a GIS format I tabulated the area of each ecological land unit (ELU) within each subsection. Treating the subregions as samples and the ELUs as species, I used standard multi-variate analysis programs (TWINSPAN; Hill 1979a, DECORANA; Hill 1979b) available in the PC-ORD for windows software (PCORD manual 1997) to analyze the data for trends and patterns. I used the default cutoff levels applied to relativized data for all runs. Lastly I used a combination of the multivariate analysis, visual inspections of the ELU and landcover map (Figures 3.6 and 3.2), and the distribution of community occurrences across the subsections to subdivide the twenty-seven subsections into increasingly finer eco-geographic units (subregions).

Results

Ecological Land Unit Map and Data Layer:

Across all 31 million acres, the ELU analysis assigned every pixel in the Digital Elevation Model to one of 595 ELUs. This created a comprehensive and very usable estimate of the distribution of ecological features in the ecoregion. The results are best displayed in map form (Figure 3.6), but I have also organized them into a table (Appendix B).   A variety of other uses may be made of the ELU data layers such as determining what features are currently covered by existing conservation areas, how rare species are distributed across ELUs, predicting community distributions, or as the base data for reserve selection algorithms (Anderson et al. (in prep). In the next section, I use the data to develop a subregion map of the ecoregion.

Development of the Subregions

The ordination of subsections by ELUs revealed some strong patterns in the subsection characteristics (Figure 3.7 and 3.8). The primary DECORANA axis was clearly related to an elevation gradient trending from the higher Adirondack and White Mountians (M212Df and M212Ad) to the low elevations of coastal Maine (212Cb) (Figure 3.7). Axis 2 and 3 were readily interpretable (Figure 3.8). The second axis expressed a gradient from the acidic shales of the Tug Hill region (M212Fa and Fb) to the calcareous rich soils of the Vermont piedmont (M212Ba). Axis 3 was also related to lithology. This axis expressed a low-elevation bedrock gradient that polarizes the granitic and mafic regions of the Adirondacks (M212D), high White Mountains (M212Ad), and coastal Maine (M212Db) against the acidic sedimentary regions of the northern Green Mountains (M212Ca) and low White Mountains (M212Af).

The TWINSPAN analysis (Table 3.5) initially partitioned the subsections exactly along the Keys et al. (1995) “Section” lines (eigenvalue = 0.40). Diagnostic ELUs that were shared by all of the mountain subsections (province M212), but that were absent elsewhere, included sedimentary slopes, flats and summits over 1700 ft. No features were entirely unique to the non-mountainous subsections (coastal and lower Maine, Province 212, coastal, central and northern Maine), but the province consists entirely of features under 1700 ft (very low and low elevation ELUs). The predominant features were low elevation dry and wet flats under 800 ft elevation. Conversely many mid, high, and alpine elevation features were restricted to the

Figure 3.6. Ecological land unit (ELU) map of the Northern Appalachian ecoregion

mountainous regions but these were not shared equitably by all the subsections within the mountain region (Province M212). Three subsections, the lower Tug Hill (M212Fb), the western Maine foothills (M212Ag), and the international boundary plateau (M212Aa) were borderline fits for the M212 province. This pattern may be observed in the primary axis ordination diagram. In the diagram, these three subsections as well as the St. John upland (M212Ab) and Vermont piedmont (M212Ba) all reside in the central area of the axis between the two elevation extremes of high mountains to the far left end and coastal lowlands to the far right (Figure 3.7).

The second TWINSPAN division separated the two Tug Hill subsections (M212Fa and Fb) and the international boundary plateau (M212Aa) from the rest of the mountainous group (province M212) primarily by their lack of mid to high elevation granitic or mafic features. The two Tug Hill subsections shared a number of low and mid elevation shale flats but these are entirely lacking from the International boundary plateau (M212Aa). The latter region actually shared very few of the diagnostic ELUs of the Tug Hill group and was considered an outlier (it was split off by TWINSPAN in the subsequent (4th) partitioning). I later grouped the subsection with the St. John upland (M212Ab) and the Aroostook hills and lowlands (212Aa) subsections as it shared dominant vegetation types and, like the other two, it was predominantly composed of mid elevation sedimentary flats.

The third TWINSPAN division partitioned the lowland region from northernmost Maine to the coast (sections 212A,B and C) along a roughly north-south line. The northern group, consisting of the Aroostook hills and lowlands (212Aa), the Aroostook lowlands (212Ab) and the central Maine foothills (212Ba) shared a number of mid elevation acidic and calcareous sedimentary flats. The southern and coastal group shared a variety of granitic slopes and flats under 800 ft. (the rocky “downeast” region of Maine).

The fifth TWINSPAN partitioning was, overall, a weak and somewhat confounded split. One of the apparent effects of the partitioning was the separation of the high mountain subsections from the lower mountain subsections. The ordination diagram of the 2nd and 3rd axes (Figure 3.8) may be interpreted in the light of ecological variation and somewhat clears up the TWINSPAN “confusion” with this complicated

Figure 3.7 and 3.8 Decorana analysis of axis 1,2 and axis 2,3

Table 3.5. TWINSPAN table of the 100 most frequent ecological land units (ELUs) by Subsections in the Northern Appalachian Ecoregion.

```
                SUBSECTION (read down)
                MMMMMMMMMMMMMMMMMM
                22222222222222222222222222
                11111111111111111111111111
                22222222222222222222222222
                FFADDDDDCAAACADBAAAABBDCDC
                Baafdcbadefdaceagbababaacb

                00000000000000000011111111
                00011111111111111100011111
                00100000000011111101100111
                   000001111000111     001
                   001110111011011
                     011 001
                  1  111     1111112222222
                12836356578490412790124365        Ecological Land Units

  97  E3542     ---5555153421131----------  000000 moderate, acidic granitic, lake
 107  E3834     ---555524353112-----------  000001 moderate, deep sed, dry flat: coarse sed
  94  E3532     ---555515555113211--------  000001 moderate, acidic granitic, wet flat
  95  E3533     ---5555355552353-1--------  000010 moderate, acidic granitic, slope bottom flat
  96  E3540     ---5555455553452----------  000010 moderate, acidic granitic, stream
 103  E3630     ---555554553334211--------  000010 moderate, intermediate granitic, dry flat: till
  93  E3530     ---5555555555555-1--------  000010 moderate, acidic granitic, dry flat: till
  98  E3613     ---5552424413453111-------  000010 moderate, intermediate granitic, upper crest
  99  E3620     ---5552435534442111-------  000010 moderate, intermediate granitic, sideslope: NE
 100  E3621     ---5551124434331-11-------  000010 moderate, intermediate granitic, cove:NE
 101  E3622     ---5551445533452-11-------  000010 moderate, intermediate granitic, sideslope:SW
 102  E3623     ---5551133433331-11-------  000010 moderate, intermediate granitic, cove:SW
  87  E3513     --1555555555455532--------  000010 moderate, acidic granitic, upper crest
  89  E3520     --1555555555555521--------  000010 moderate, acidic granitic, sideslope: NE
  90  E3521     ---555535555455411--------  000010 moderate, acidic granitic, cove:NE
  92  E3523     ---555535555455411--------  000010 moderate, acidic granitic, cove:SW
  88  E3514     --1555555555545422--------  000010 moderate, acidic granitic, flat summit
  91  E3522     ---555555555555512--------  000010 moderate, acidic granitic, sideslope:SW
  73  E3113     -11453115555554454--------  000010 moderate, acid sed, upper crest
  77  E3122     -11454125555554354--------  000010 moderate, acid sed, sideslope:SW
 113  E4514     ---4533-55552431----------  000011 high,     acidic granitic, flat summit
 114  E4520     ---5532-55553422----------  000011 high,     acidic granitic, sideslope: NE
 115  E4521     ---4521-55551411----------  000011 high,     acidic granitic, cove:NE
 116  E4522     ---5542-55552412----------  000011 high,     acidic granitic, sideslope:SW
 117  E4523     ---5531-55551411----------  000011 high,     acidic granitic, cove:SW
  81  E3133     --1253115555533111--------  000011 moderate, acid sed, slope bottom flat
 108  E4113     ---231--5555541-2---------  000011 high,     acid sed, upper crest
 110  E4122     ---22---5555531-1---------  000011 high,     acid sed, sideslope:SW
 112  E4513     ---5553-55553533----------  000011 high,     acidic granitic, upper crest
  76  E3121     --1342115555553132--------  000011 moderate, acid sed, cove:NE
  78  E3123     --1442115555553132--------  000011 moderate, acid sed, cove:SW
  80  E3132     154555315552313122--------  000100 moderate, acid sed, wet flat
  82  E3140     153555215555543112--------  000100 moderate, acid sed, stream
  79  E3130     455555545555555335--------  000101 moderate, acid sed, dry flat: till
  74  E3114     122253115555554355--------  0010   moderate, acid sed, flat summit
  75  E3120     112554125555555355--------  0010   moderate, acid sed, sideslope: NE
  61  E2540     --2455555555455554111111--1  001100 low,      acidic granitic, stream
  55  E2521     --1555545555455553111111--1  001100 low,      acidic granitic, cove:NE
  59  E2532     --1455555555355554111111111  001100 low,      acidic granitic, wet flat
  57  E2523     --1445555555455553111111--1  001100 low,      acidic granitic, cove:SW
  60  E2533     --1455555555455553111111--1  001100 low,      acidic granitic, slope bottom flat
  62  E2542     --1355555555425554442-111--1  001100 low,      acidic granitic, lake
  64  E2621     ---55432133255551431-1----  001101 low,      intermediate granitic, cove:NE
  66  E2623     ---5442214325555-431-11---  001101 low,      intermediate granitic, cove:SW
  69  E2633     ---5552324314455153-------  001101 low,      intermediate granitic, slope bottom flat
  68  E2632     --15455515514554-551--1---  001110 low,      intermediate granitic, wet flat
  70  E2640     --25555155245551551-1----  001110 low,      intermediate granitic, stream
  71  E2642     --152525-55-1542-53-------  001111 low,      intermediate granitic, lake
  40  E2142     5352455545524553354 11-1---  010    low,      acid sed, lake
  72  E2834     5555555555555555555422-1---  010    low,      deep sed, dry flat: coarse sed
  63  E2620     ---54534144255552552-11---  0110   low,      intermediate granitic, sideslope: NE
  65  E2622     ---54534254155551552-11---  0110   low,      intermediate granitic, sideslope:SW
  49  E2420     --3-----355322-551112-1---  011100 low,      mod calcareous, sideslope: NE
  50  E2422     --2-----454312-551112-1---  011100 low,      mod calcareous, sideslope:SW
  37  E2132     5555555555555555555311-1-  011100 low,      acid sed, wet flat
  39  E2140     5555555555555555555544-111-  011100 low,      acid sed, stream
  38  E2133     13545332555555555411111--  011100 low,      acid sed, slope bottom flat
  33  E2121     11544221555555555554311111-  011100 low,      acid sed, cove:NE
  35  E2123     12543321555555555553311111-  011100 low,      acid sed, cove:SW
```

```
  48  E2340     1--14132341135553112311---  011101 low,      calcareous, stream
  54  E2520     --2555555554555555232321-1  011101 low,      acidic granitic, sideslope: NE
  67  E2630     --555555355255551553--1---  011101 low,      intermediate granitic, dry flat: till
  52  E2513     --14345454452555542233213  011101 low,      acidic granitic, upper crest
  53  E2514     --23245554452555531224221 2 011101 low,      acidic granitic, flat summit
  56  E2522     --14555555554555552223211 1 011101 low,      acidic granitic, sideslope:SW
  32  E2120     12554343555555555555541222-  011101 low,      acid sed, sideslope: NE
  58  E2530     --555555555555555543542-1  011101 low,      acidic granitic, dry flat: till
  47  E2332     1--14151241135554225411---  011110 low,      calcareous, wet flat
  44  E2320     ---13111141215555112312---  011111 low,      calcareous, sideslope: NE
  45  E2322     ----21112412254551-2312---  011111 low,      calcareous, sideslope:SW
  34  E2122     2354433355555555555531232-  100    low,      acid sed, sideslope:SW
  36  E2130     5555555555555555555554421-  100    low,      acid sed, dry flat: till
  51  E2430     --5-----555535-555555-11--  1010   low,      mod calcareous, dry flat: till
  30  E2113     1153212245455555554422233-  1011   low,      acid sed, upper crest
  31  E2114     2252212335555555555432222-  1011   low,      acid sed, flat summit
  46  E2330     1--25244554125555545534---  1100   low,      calcareous, dry flat: till
  10  E1342     -----------2-424544555512-  110100 very low, calcareous, lake
   8  E1332     -----2---1-11355545555532-  110100 very low, calcareous, wet flat
   9  E1340     -----1---1-11345523555512-  110100 very low, calcareous, stream
   7  E1330     -----3---1-41555555555554-  110101 very low, calcareous, dry flat: till
   3  E1133     2-41-1--12-454545354323341  110110 very low, acid sed, slope bottom flat
  20  E1542     ---1-12----4-5545-34555555  110110 very low, acidic granitic, lake
  17  E1530     ---1-52--2-515555145555555  110110 very low, acidic granitic, dry flat: till
  18  E1532     -----41--1-515535-25555555  110110 very low, acidic granitic, wet flat
   5  E1142     4-4--11--1-134525355555555  110110 very low, acid sed, lake
   2  E1132     5-51-51--3-455545555555555  110110 very low, acid sed, wet flat
   4  E1140     5-51-41-13-555545455555555  110110 very low, acid sed, stream
   1  E1130     5-51-51--4-555555555555555  110110 very low, acid sed, dry flat: till
  28  E1834     5-52-52-14-555555555555555  110110 very low, deep sed, dry flat: coarse sed
  15  E1520     ---1-3---1-513535-13455545  110111 very low, acidic granitic, sideslope: NE
  19  E1540     ---1-31--1-515545113455555  110111 very low, acidic granitic, stream
  27  E1831     --4--4-----15-455114555555  110111 very low, deep sed, dry flat:fine sed
  16  E1522     -----2---1-513535-12455545  110111 very low, acidic granitic, sideslope:SW
  22  E1630     ---1-5------3535-555555555  1110   very low, intermediate granitic, dry flat: till
  23  E1632     ---1-51-----4324-455555545  1110   very low, intermediate granitic, wet flat
  11  E1430     --4------2-211-5515555555-  111100 very low, mod calcareous, dry flat: till
  12  E1432     --2------1-111-4515555555-  111100 very low, mod calcareous, wet flat
  13  E1440     --1------1-111-54-4555555-  111101 very low, mod calcareous, stream
  25  E1642     -----31-----1313-25-545535  111110 very low, intermediate granitic, lake
  24  E1640     ---1-4------3314-352335535  111111 very low, intermediate granitic, stream

                00000000000000000011111111
                00011111111111111100011111
                00100000000011111101100111
                   000001111000111     001
                   001110111011011
                 011
```

region. In the ordination diagram, the high granitic mountains grouped in the center, above the low elevation granitic flat regions of the Adirondacks (M212Db,a,e,c), and below the high sedimentary slopes of the northern Green Mountains (M212Ca). The center region was flanked on the right by the calcareous flats of the Vermont piedmont (M212Ba), and to the left by the shale and sedimentary flats of Tug hill (M212F) and northern Maine (212Aa, M212Aa,b). The higher Adirondack subsections (M212Dd and Df) shared many features with the rest of the Adirondacks but generally lacked the lower elevation features.

In both analyses, the Green Mountains did not group comfortably into a single unit based on their ELUs. The Northern Green Mountains (M212Ca), although underlain at depth by resistant gneiss, are primarily composed of metasedimentary schists and phyllites which I had previously classified as acidic sedimentary. The Southern Green Mountains had a large area of exposed, strongly metamorphosed gneiss, which I had put in the acidic granitic class. The exposed Precambrian rock is closely related to the Adirondack granites/gneiss (Van Diver 1987). I could not easily determine how well this was tracked by the vegetation because when I did the alliance analysis, both the Green Mountain subsections. (M212Ca,d) and most of the White Mountains (M212Ad,e,f,g) were treated as single subsections (they were divided by the USFS just prior to the publication of the map). However, many of the distinguishing community alliances for the Green Mountains were from the southern portion and were more typical of the lower New England area to the south. The presence of these communities in the southern subsection is probably explained by the higher mean annual temperature and considerably longer growing season of the southern Green Mountains (Table 3.1). Independent examination of the three ELU factors suggests that the southern Green Mountains are more like the White Mountains in bedrock and elevation but that the northern Green Mountains are more similar in landforms and climate (Appendix B). For all these reasons, I decided to keep the White Mountains together as a subregion (although dividing them ultimately into high and low mountain regions) and the Green Mountains together as separate subregion. It should be kept in mind throughout the stratification analysis that there was a fair amount of heterogeneity between the northern and southern Green Mountains and within the White Mountains as well. Generally, the results of the quantitative multivariate analysis correlated well with visual inspections of the ELU map (Figure 3.6). The results also compared well with the vegetation structure patterns displayed in the multi-resolution land cover map (Figure 3.2).

Synthesizing the information, but giving particular weight to the ordination and classification analysis, I developed a hierarchical model which partitions the ecoregion into finer eco-geographic units. The scheme divides the ecoregion into 2, 4, 7, and 10 nested subregions (Table 3.6, 3.7 and Figure 3.7). Although differing in absolute size, the 10 finest subregions partition (relatively evenly) the biophysical variation within the region. The hierarchy, which is the primary product of this chapter, is used in chapter 4 for selecting occurrences, distributing the ecological reserves to maximize the representation of communities, and for capturing the variation within a single community type across the ecoregion.

Table 3.6. Elevation, Bedrock and Topography summary of the 10 Subregions. Numbers are all percentages of the total region.

ELEVATION	Tug hill	Low Adirondack	High Adirondack	Green Mts.	Vermont .Piedmont	High white Mts.	Low White Mts.	N Boreal	Central Maine	Coastal Maine
Very low Total	17	6	0	4	10	3	30	21	95	100
Low Total	61	72	19	44	80	47	64	77	5	0
Mid Total	22	21	60	40	10	36	5	2	0	0
High Total	0	0	20	11	0	13	1	0	0	0
Alpine Total	0	0	1	0	-	1	0	0	0	0
Grand Total	100	100	100	100	100	100	100	100	100	100
BEDROCK										
Acidic sedimentary Total	57	20	10	59	14	39	54	83	26	22
Acidic shale Total	31	0	0	0	-	0	0	0	0	0
Calcareous sedimentary	0	1	1	1	43	2	9	1	34	0
Moderately calcareous sed	0	0	0	2	21	5	3	3	18	3
Acidic granitic Total	0	55	39	33	12	46	25	1	12	39
Intermediate/mafic granitic	0	13	46	2	6	5	6	10	3	19
Ultramafic Total	0	0	0	0	0	1	0	0	0	0
Deep sediment Total	13	10	3	3	5	3	3	3	7	16
Water Total	0	1	0	0	-	0	0	0	0	0
Grand Total	100	100	100	100	100	100	100	100	100	100
TOPOGRAPHIC FEATURES										
Steep cliff Total	0	0	0	0	0	0	0	0	0	0
Steep slope Total	0	0	2	1	0	1	0	0	0	0
Upper crest Total	0	0	1	0	0	1	0	0	0	0
Upper slope Total	0	3	8	7	4	7	3	1	0	0
Upper summit Total	0	2	3	4	4	3	2	1	1	0
Sideslope: NE Total	0	5	10	11	9	11	7	2	1	1
Cove: NE Total	0	2	7	8	3	7	3	1	0	0
Sideslope: SW Total	0	4	10	11	8	11	6	2	1	1
Cove: SW Total	0	2	6	8	3	7	3	0	0	0
flat: dry, till Total	61	48	31	33	47	32	52	70	59	36
flat: dry,fine sed. Total	0	0	0	0	1	0	0	0	5	12
flat: wet/moist Total	15	12	6	4	5	6	9	12	20	10
flat: slope bottom Total	0	2	5	4	5	4	2	1	0	0
flat: dry, coarse sed Total	13	9	3	3	3	3	3	2	3	4
Stream Total	10	6	5	5	6	5	4	5	6	4
River Total	0	0	0	0	0	0	0	0	0	1
Lake Total	0	4	2	1	1	2	4	3	4	3
Ocean Total	0	0	0	0	-	0	0	0	0	28
Grand Total	100	100	100	100	100	100	100	100	100	100

Table 3.7. Hierarchical subregions of the Northern Appalachian ecorgion: Divisions into two, four, seven and ten ecological subregions based on the TWINSPAN and DECORANA analysis of ELUs and vegetation patterns.

Northern Appalachian / Boreal Ecoregion									
Northern Appalachian Mountains (16.8M)							Boreal Hills and Lowlands (15.4M)		
Adirondacks / Tug Hill (6.7M)			White and Green Mountains (10.2M)				Northern Boreal Hills (5.3M)	Southern Boreal Hills (10.1M)	
Tug Hill Plateau M212F (700K)	Adirondack Mountains M212D (5.9M)		White Mountains M212A (6.8M)		Green Mountains/ Vermont Piedmont M212C M212B (3.4M)		Northern Boreal Hills M212Aa,b 212Aa (5.3M)	Central Maine Lowland 212A,B 212C,D (6.9M)	Southern Maine Coastal 212C 212D (3.1M)
Tug Hill Plateau Fa,b (700K) (2%)	Adirondack High Peaks Dd,f (1.6M) (5%)	Adirondack Low Mts. Da,b, c,e (4.3M) (13%)	High White Mts. Ad,e,f (4.3M) (13%)	Low White Mts. Ac,g (2.5M) (7%)	VT. Piedmont Ba (1.8M) (6%)	Green Mts. Ca, Cd (1.6M) (5%)	Northern Boreal Hills (5.3M) (16%)	Central Lowland Ba,b Da, Ab (6.9M) (22%)	Maine Coastal Ca,b Dc (3.1M) (10%)

Figure 3.9. Map of the ecological subregions of the Northern Appalachian ecoregion

Table 3.4 Bedrock geology classes for the Northern Appalachian Ecoregion

Bedrock Geology Classes for the Northern Appalachian Ecoregion									M. Anderson 1999	
Geogroup	Lithotypes	meta-equivelents	Acidity	Nutrients	Texture	Resist.	NAWQA	Baily equivalent	Comments	Communities
ULTRAMAFIC: magnesium rich alkaline rock	Serpentine, Soapstone, Pyroxenites, dunites, peridotites, talc schists		Basic	Low to high	Fine to medium	Mod	50, 50c	Ultra-mafic	Thin rocky iron rich soils may be toxic to many species, high mag to calcium ratios often contain endemic flora favoring high magnesium, low potassium, alkaline soils. Upland hills knobs or ridges	Serpentine barrens
MAFIC or INTERMEDIATE GRANITIC: quartz poor alkaline to slighly acidic rock, weathers to clays	(Ultrabasic:) Anorthosite, (Basic:) Gabbro, Diabase, Basalt. (Intermediate, quartz-poor:) Diorite/Andesite, Syenite/Trachyte	Greenstone, Amphibolites, Epidiorite, Granulite, Bostonite, Essexite	Neutral to sl. Acidic	mod to high	Medium to coarse	Mod	41,42,43,44,61	mafic, inter-mediate	Moderately resistant, thin rocky, clay soils, sl acidic to sl. Basic, mafic soils are high in mag, low in potassium, moderate or rolling hills., uplands and lowlands, depending on adjacent lithologies. quartz poor plutonic rocks weather to thin clay soils with topographic expressions more like granite	Traprock ridges, greenstone glades, alpine areas in adirondacks
ACIDIC GRANITIC: Quartz rich, resitant acidic igneous rock weathers to thin coarse soils	Granite, granodiorite, rhyolite, felsite, pegmatite	Granitic gneiss, Charnocktites, Migmatites	Acidic	low	Coarse	High	61, 61v	felsic	Resistant, quartz rich rock, underlies mountains and poorly drained depressions, uplands & highlands may have little internal relief and steep slopes along borders. Generally sandy nutrient poor soils	Many: matrix forest, high elevation types, bogs and peatlands
ACIDIC GNEISS / QUARTZITE: quartz rich, resitant acid meta-sedimentary rock, weathers to coarse soils		Gniess, quartzite, quartzoze gneiss or metasandstone, quartz granofels.	Acidic	Low	Coarse	High	34,35	Felsic	Resistant, quartz rich rock, underlies uplands, highlands, low to moderate rolling hills, Forms sandy to rocky soils (occ. Clays)	Many: sandstone pavement barrens,
ACIDIC SEDIMENTARY or META-SEDIMENTARY: fine to coarse grained, acidic sedimentary rock	Mudstone, Claystone, Siltstone, non-fissile shale, sandstone, conglomerate,Breccia, Greywake, Arenites	(low grade:) slates, phyllites, pelites (Mod grade:) Schists, pelitic schists, granofels	Acidic	low	fine to coarse	mod (low-high)	21, 22, 23, 31, 32, 33	low & med grade pelitic sed, sulfide	low to moderate resistant rocks typical of valleys and lowlands with subdued topography. Pure sandstone and meta sediments are more resistant and may form low to moderate hills or ridges	low and mid elevation matrix forests, floodplains, Oak pine forest, deciduous swamps and marshes
ACIDIC SHALE: Fine grained acidic sedimentary rock with fissile texture	Fissile shales		Acidic	low	fine	low	22 (in	na	Low resistant, produces unstable slopes of fine talus	Shale cliff and talus, Shale barrens

CALCAREOUS SEDIMENTARY: basic/alkaline, soft (meta)sedimentary rock with high calcium content	Limestone, dolomite, dolostone, other carbonate-rich clastic rocks	Marble	Neutral to basic	mod to high	Fine to medium	low	11, 12, 13	carbonate	Lowlands and depressions, stream/river channels, ponds/lakes, groundwater discharge areas, Soils are thin alkaline clays, high calcium, low potassium. Rock is very susceptible to chemical weathering, Often underlies prime agricultural areas	rich fens, wetlands, woodlands & cove forests, cedar swamps, alk. cliffs
MODERATELY CALCAREOUS, SEDIMENTARY Neutral to basic, moderately soft (meta)sedimentary rock with some calcium	cal shales, calc pelities, calc sandstones, calc schists or phyllites, calc-silicate granofels	?none	Neutral to sl. Acidic	mod	Fine to medium	low	21c, 32c, 33c, 34c	calc-silicate	Variable group depending on lithology but generally susceptible to chemical weathering, soft shales often underlie agricultural areas	rich coves, intermediate fens.