ECOLOGICAL COMPOSITION AND CONDITION OF THE BOREAS PONDS TRACT

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Michale J. Glennon
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Finally, I am very grateful for the support and insight of the Wildlife Conservation Society's Adirondack and North America Program staff and the extensive help from Adirondack Program director Zoë Smith in preparing this document.

Foreword

New York State is poised to augment its Forest Preserve holdings with the transition of the Boreas Ponds tract to state ownership. The Boreas tract is a 20,578 acre parcel recently purchased in the town of North Hudson on the edge of the High Peaks wilderness. It is the last of a multi-year process of transition to New York State ownership of 69,000 acres of the former Finch Pruyn lands. The Wildlife Conservation Society (WCS) Adirondack Program conducted a scientific analysis of the ecological characteristics of the Boreas Pond tract to inform the upcoming state land classification decision to be undertaken by the Adirondack Park Agency and NYS Department of Environmental Conservation upon its transfer to the state. We offer this report to highlight a number of publicly available regional datasets, which provide unprecedented opportunities for amassing ecological information to provide objective, science-based information, demonstrate patterns, and guide important decisions in the region. The report demonstrates how this process could be applied to other land use decisions in the Adirondacks and across the North Atlantic region.

We examined the extent and condition of the natural resources on the Boreas tract, the tract in the context of the adjacent High Peaks Management Unit, and its relative ecological value in comparison to existing state land units in the Adirondack Park. Our analysis made no consideration of intangible characteristics (social or psychological) that may influence the character of the land and the potential recreational opportunities that may be desired upon it. We considered only the ecological characteristics of the tract and their relative quality, as measured via the use of emerging datasets of terrestrial and aquatic ecosystems in the Northeast.

This analysis examined fine-scale ecological resources within the boundaries of the Boreas tract, and considered the parcel in the larger context of existing Forest Preserve lands in the Adirondacks. Our findings, based on the best available regional science, indicate that the Boreas tract contains significant and important ecological characteristics worthy of consideration in future decisions on its classification and management. Among them, the report illustrates that this tract scores high in terms of its resilience to climate change impacts, and its importance to local and regional scale ecological connectivity. We hope that this analysis can serve as a demonstration of the ways in which newly available, high quality, regional-scale public datasets can inform important management decisions in the Adirondacks and beyond.

About The Author

As the Science Director for WCS's Adirondack Program, Dr. Michale Glennon serves a leading role in the ecological research conducted in the Adirondacks. Her research interests lie primarily at the intersection between land use management and ecological integrity, with a number of projects ranging from the impacts of low density, exurban development on wildlife to the potential changes to Adirondack lowland boreal communities resulting from climate change. Michale joined WCS in 2003 after completing a Ph.D. at the State University of New York, College of Environmental Science and Forestry where she explored the effects of land use management on bird and small mammal communities in the Adirondacks. She has also worked on the potential impacts of ski area development on Bicknell's thrush, a Neotropical migrant of high conservation priority in the east, and on a project to understand the rapidly expanding moose population in the Adirondacks and its relatedness to nearby populations in neighboring states and provinces. In addition to her exurban development work, Michale is currently working to understand the potential impacts of recreation on wildlife communities. She serves on advisory committees for a number of organizations including for the Shingle Shanty Preserve and Research Station, the Adirondack Park Agency, the New York State Department of Environmental Conservation, the Adirondack All-Taxa Biodiversity Inventory, the North Atlantic Landscape Conservation Cooperative, and the Paul Smiths College Fisheries and Wildlife Science Program. Dr. Glennon is widely published and holds an adjunct faculty position at SUNY-ESF. She grew up in Lake Placid, NY, in the Adirondack Park, graduated from Lake Placid High School and lives in Ray Brook with her husband, Scott van Laer – a New York State Forest Ranger, children Phoebe and Clancy, one cat, two rabbits, 16 chickens, and three horses.

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Introduction

Purpose of this paper

The Wildlife Conservation Society Adirondack Program was asked by the Adirondack Council to provide a scientific analysis of the characteristics of the Boreas Pond tract to inform the upcoming state land classification decision to be undertaken by the Adirondack Park Agency and NYS Department of Environmental Conservation upon its transfer to the state of NY. The largest of the tracts acquired by the state as part of the Finch-Pruyn acquisition, the Boreas Ponds tract is often described as one of the the crown jewels of the Park. Adjacent to the High Peaks Wilderness, addition of the Boreas to the Forest Preserve offers an opportunity to enhance protection for critical resources and to provide new recreational opportunities in this region of the Park. In an effort to inform important considerations about the classification of Boreas Ponds within the framework of the NY State Land Master Plan, I made use of a number of recently available datasets to provide information on the current composition, condition, and quality of resources on the Boreas tract. These resources are described briefly in individual sections of this report, but also listed with links for their full documentation in the Literature Cited. It should be noted that all of the analysis presented here was conducted via use of publicly available datasets and by use of GIS tools and mapping capabilities. No information contained here comes from on-the-ground research. We have visited the site, but not for the purpose of this report nor for data collection of any kind. As such, it must be recognized that these datasets are large scale and varying in resolution; field verification is always recommended in any context related to questions about natural features depicted in the attached maps.

Sources of data

Though the mapped information consulted to produce this report consists of several very large scale maps of varying degrees of resolution, these data are nonetheless extremely powerful for their ability to bring to life information on the composition and condition of natural communities that has not previously been mapped at this scale. Furthermore, the extent of these data allow for comparisons to be made among and between any individual tracts within the Adirondacks and beyond.

The Northeast US has taken the unprecedented step of collaborating on a number of efforts to produce landscape scale data for the 13 states encompassed within the North Atlantic Landscape Conservation Cooperative (NALCC) which stretches from Virginia to Maine. One of the 22 Landscape Conservation Cooperatives created by the Department of the Interior in 2010, the NALCC is a partnership in which the private, state, tribal and federal conservation community works together to address increasing land use pressures and widespread resource threats and uncertainties amplified by a rapidly changing climate. As a part of these efforts, hundreds of datasets have been developed that span the 13 state region, among them several consulted for this report and including the following:

Northeast Terrestrial Habitat Classification and Northeast Terrestrial Habitat Map

The Northeast Habitat Classification and Mapping project (Gawler 2008) grew out of a 2006 workshop of the Northeast Association of Fish and Wildlife Agencies, at which the importance of development of consistent regional habitat maps was highlighted as a top priority for the northeast region. A major component of the project was the development of a terrestrial habitat classification that could be used to provide a standardized and consistent habitat and ecosystem classification at multiple scales across states and to offer managers a tool for understanding regional biodiversity patterns. The resulting Northeast Terrestrial Habitat Classification System (NETHCS) was created by a team of staff from NatureServe, with a steering committee consisting of representatives from each of the 13 states that make up the USFWS eastern region (ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, MD, DC, WV, VA) and mapped by The Nature Conservancy's Eastern Conservation Science office. The Northeast Terrestrial Habitat Map (Ferree and Anderson 2014) is a continuous, 30 meter raster coverage that maps upland and wetland wildlife habitats/ecological systems for the Northeast. The ecological systems represented in the map are mosaics of plant community types that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients, in a pattern that repeats itself across landscapes (Glennon and Curran 2013). Ferree and Anderson (2013) provide a complete description of the methods used to map these terrestrial communities on the landscape. The map, often referred to as ESM (Ecological Systems Map) has been improved upon for the developed and wetland classes by the University of Massachusetts (McGarigal 2012) and I have used the improved version referred to as ESM+ for the purpose of mapping and analyzing habitats for this report.

The finest level of delineation included in the classification and map is that of the terrestrial habitats or ecological systems. These habitats are ecological cover types based on vegetation and occasionally include finer-scale characteristics to define types that can be used to represent habitat for one or more wildlife species; there are 140 mapped habitats in the Northeast region. They consist of all upland habitats, and wetland habitats exclusive of the aquatic habitats of rivers and lakes (Gawler 2008). Macrogroups are a second level grouping variable and are defined by combinations of moderate sets of diagnostic plant species and growth forms that reflect biogeographic differences in composition and sub-continental to regional differences in mesoclimate, geology, substrate, hydrology, and disturbance regimes (Gawler 2008). In other words, macrogroups represent broader categories of habitat types but still capture important differences among them. In general, I refer to these habitat groups at the macrogroup level, for several reasons. I believe it to be easier in general to conceptualize the smaller number of macrogroup types and their straightforward names, in contrast to the finer distinctions and complex names of the habitat types. I also believe that linking individual species to habitat types is more accurate at the macrogroup level.

Northeast Aquatic Classification System and Northeast Aquatic Habitat Map

The Northeast Aquatic Classification System (NAHCS) arose from the same initial classification project as the terrestrial classification and is described in Olivero and Anderson (2008). The goal of this project was to develop a standard classification system and GIS dataset to describe and map stream systems across the NALCC region as a means to unify individual state classifications and promote an understanding of aquatic biodiversity patterns across the region.

Northeast Lake and Pond Classification and Northeast Lake and Pond Map

Although the NAHCS described above included attributes of waterbodies, no classification of waterbodies into ecologically meaningful types was included and hence, the purpose of the subsequent lake and pond classification was to create a mapped classification of lakes and ponds in the Northeast US. This classification is based on variables that structure lacustrine ecosystems and that could be mapped consistently across all lakes and ponds in the region. The full description of the classification system is provided in Olivero-Sheldon and Anderson (2016). Each of these datasets (terrestrial habitats, aquatic habitats, and lakes/ponds) is extensively documented and accompanied by individual habitat guides for all types mapped, available at conservationgateway.org.

Resilient Sites for Terrestrial Conservation

Climate change is creating an increasingly dynamic world in which species distributions and habitats are rearranging themselves rapidly on the landscape. As a result of these shifting patterns, conservationists need a means by which to identify important areas for protection that does not rely on the assumption that the locations of existing plants and animals will remain the same. There is increasing recognition that "conserving the stage," rather than the actors themselves, is the means by which we might safeguard biodiversity into the future. The Nature Conservancy's efforts to map resilient sites for terrestrial conservation (Anderson et al. 2012) represent a major contribution to the thought and planning required to approach biodiversity conservation in a climate change era. Resilience refers to the capacity of a site to adapt to climate change while still maintaining diversity, but does not assume that the species currently located there will remain the same. Growing evidence suggests that sites that have both complex topography and connected land cover are those in which conservation action is most likely to succeed in the long term (Anderson et al. 2012). The theoretical and analytical foundations of the resilience science are described in Anderson and Ferree (2010) and Anderson et al. (2014). The full description of the mapping methodology is provided in Anderson et al. (2012). Though resilience as a term has varied meanings, the TNC resilience science specifically has garnered much attention in the conservation community and is the subject of the Open Space Institute's $12 million Resilient Landscapes Initiative.

Any reference to resilience in this report can be considered a reference to the TNC work and associated definition.

Ecological Integrity and associated datasets

This dataset depicts the ecological integrity of locations throughout the northeastern United States based on environmental conditions existing in approximately 2010. Ecological integrity is defined as the ability of an area (e.g., local site or landscape) to sustain important ecological functions over the long term. In particular, the functions include the long-term ability to support biodiversity and the ecosystem processes necessary to sustain biodiversity. The Index of Ecological Integrity (IEI) is expressed on a relative scale (0 to 1) for ecosystems mapped on a modified version of the ESM map developed by the Nature Conservancy and the northeastern states. The IEI has been mapped as a component of the Designing Sustainable Landscapes (DSL) project led by Kevin McGarigal at the University of Massachusetts Amherst. The DSL project is the source of numerous other datasets in addition to integrity and has an overall purpose of assessing the capability of current and potential future landscapes within the extent of the Northeast United States (13 states) to provide integral ecosystems and suitable habitat for a suite of focal (e.g., representative) species, and provide guidance for strategic habitat conservation. McGarigal (2012) describes the DSL project and McGarigal (2011) the ecological integrity component specifically. Information, documentation, and spatial data for this project are available at http://www.umass.edu/landeco/research/dsl/dsl.html.

Forest Aboveground Biomass and Forest Loss/Gain

This dataset measures the total amount of above-ground live biomass in forested systems, which is an important attribute of forested communities and an indicator of successional development, an important habitat attribute for many forest-associated wildlife species. The dataset is derived from a combination of remote sensing products arising from multi-temporal Landsat TM data and Forest Inventory and Analysis (FIA) plot data and forest succession models derived from FIA plot data.

To create this dataset, the Woods Hole North American Carbon Program (NACP) Aboveground National Biomass and Carbon Baseline Data (NBCD 200) Version 2 (Kellndorfer et al. 2013) was updated with the High-Resolution Global Maps of 21st-Century Forest Cover Change (Hansen et al. 2013) to generate a current biomass grid. This dataset was also developed as part of the DSL project led by Kevin McGarigal of UMass Amherst and sponsored by the North Atlantic Landscape Conservation Cooperative (www.northatlanticlcc.org). Hansen et al. (2013) provide a full description of the underlying science and data that provide the foundation for the biomass map.

The datasets mentioned are available at one or more of the following locations:

1. NALCC online Conservation Planning Atlas on Databasin: nalcc.databasin.org
2. NALCC spatial data page: http://northatlanticlcc.org/spatial-data
3. TNC Eastern Division Science and Data page on conservation gateway: http://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/Pages/default.aspx
4. Designing Sustainable Landscapes project page at U Mass Landscape Ecology Lab: http://www.umass.edu/landeco/research/dsl/dsl.html

Methods

I used the data described above to examine the Boreas tract in light of the extent and condition of the resources on the tract itself, the tract in the context of the High Peaks management unit to which it is adjacent, and its relative value in comparison to existing state land units. Five primary components make up this analysis and report: (1) a description of the composition of the Boreas tract, (2) a description of the current condition of the resources on the tract, (3) a description of potential future threats to the tract, (4) a consideration of the Boreas tract in the context of the High Peaks management unit, and (5) a comparison of the tract to NY state land units classified as Wilderness, Wild Forest, and Primitive. Composition is described in terms of terrestrial and aquatic habitats present, their characteristics, distributions, patch sizes, and characteristic species. Condition of the tract is described in terms of aboveground forest biomass, recent forest loss and gain, resilience, connectivity, ecological integrity, and wildlife habitat value. Potential future threats to the tract are discussed in terms of habitat loss and climate change. The context of the Boreas tract is considered in terms of how the tract compares to the adjacent High Peaks management unit, the state land unit to which it could potentially be added. I compare the composition of the Boreas to both the Adirondacks as a whole and specifically to the High Peaks unit and describe what it would add to the latter if it became a part of the High Peaks unit. I also examine the Boreas tract in comparison to existing state land units in wilderness, wild forest, and primitive designations. I describe similarities and differences in habitat composition, geology, patch size, and forest biomass between the Boreas tract and existing state lands. Last, I use several condition indices to compare the Boreas to existing state land tracts in terms of resilience, integrity, and connectedness.

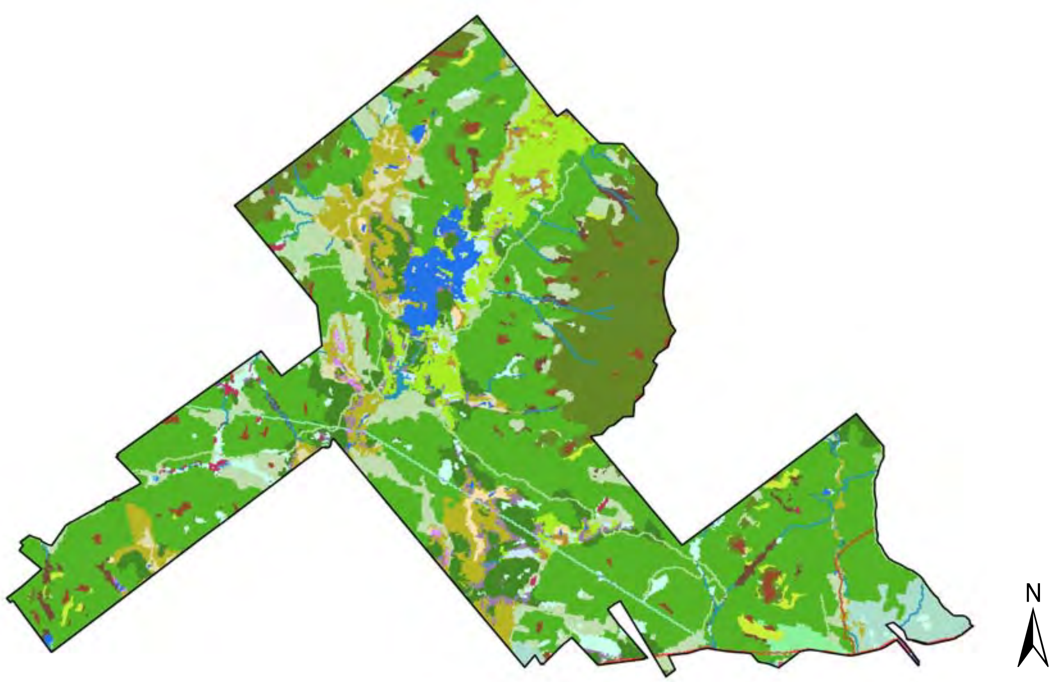
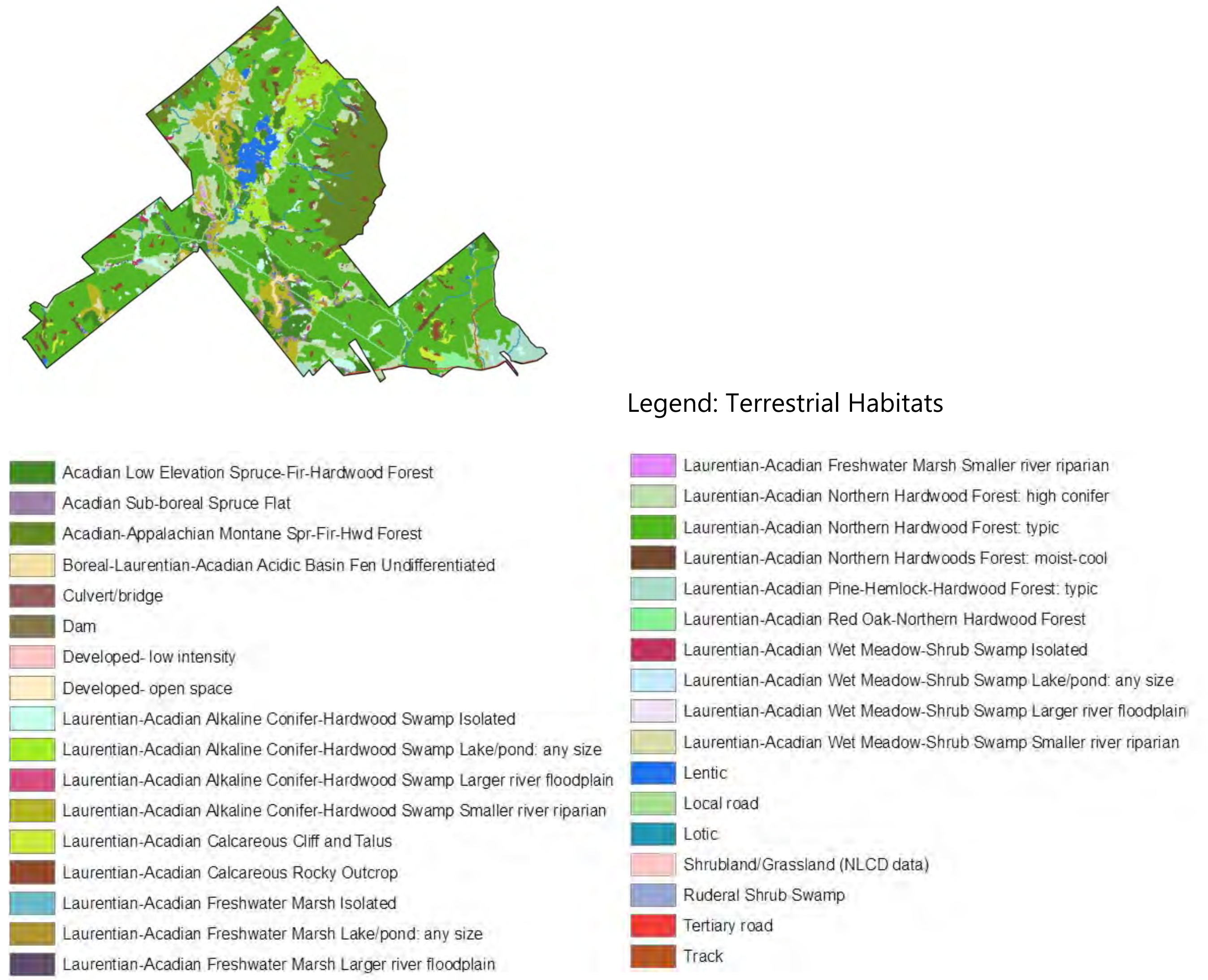


Figure 1. Terrestrial habitats on the Boreas Tract



Results

Composition of the Boreas Tract

Terrestrial Habitats

Terrestrial habitats present on the Boreas tract were summarized from recent habitat maps created by TNC (Ferree and Anderson 2014) and improved by UMass-Amherst (ESM+). I used ArcGIS to import the habitat data and overlay them with a Boreas tract boundary shapefile obtained from the Adirondack Council. I used the Tabulate Areas function to summarize terrestrial habitats at 2 layers of organization. There are 30 terrestrial habitats within 13 macrogroups represented on the Boreas tract (Tables 1, 2 and 5, Figures 1 and 2).

The terrestrial composition of the Boreas tract is representative of the Adirondack Park in general in terms of dominance by the Northern Hardwood and Conifer group. The majority of the Adirondack landscape (68%) consists of forest types which are contained within the Northern Hardwood and Conifer macrogroup, 3 of which are found on Boreas including Laurentian-Acadian Northern Hardwood Forest, Laurentian-Acadian Pine-Hemlock-Hardwood Forest, and Laurentian-Acadian Red Oak-Northern Hardwood Forest. The Northern Hardwood and Conifer group is the dominant matrix forming forest in the Adirondacks and the type in which smaller patch forming systems are embedded. The average patch size in the Park is large (84 acres) and these forests are very well represented on both public and private lands in the Adirondacks (Glennon and Curran 2013). Because most of the Adirondacks are of this type, most Adirondack vertebrates make use of this habitat, including ~60% of New York's Species of Greatest Conservation Need (SGCN, NYSDEC 2015). The average patch size for Northern Hardwood and Conifer on the Boreas is slightly smaller at 55 acres and this type represents 58% of the tract.

The second dominant forest type on the Boreas and in the greater Adirondack landscape is Boreal Upland Forest. This is both a matrix and a patch forming community type but, due to the location of the Adirondacks in the transition between temperate and boreal forest zones, tends to be patchily distributed in our region. Boreal Upland Forest habitats represented on the Boreas tract include Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest, Acadian Low Elevation Spruce-Fir-Hardwood Forest, and Acadian Sub-Boreal Spruce Flat. Together with the Northern Peatland and Fen macrogroup, these habitats constitute what we think of as the Adirondack boreal and are critical because they provide habitat for 40 – 60% of the species of conservation concern and habitat for most of the *responsibility* species in the Adirondacks. Responsibility species are those species found nowhere else in the state and hence, species for which their future in NY depends on what occurs in the Adirondack Park. These habitats make up a larger proportion of the Boreas tract by area (~18%) than they do of the greater Adirondack landscape (~11%) in patch sizes similar to those across the Adirondacks. These habitats are fairly well represented on state and easement lands, but are likely to be highly threatened by climate change because they are decidedly northern, adapted to cool, wet summers and cold winters, nutrient poor, and maintained in some places by northern processes like ice buildup on river shores (Jenkins 2010).

The remaining habitat types on the Boreas tract are those that are generally patch forming communities, or wetland and aquatic types. Wetland types include small components of meadow and marsh communities which are generally associated with the flowing (streams, creeks) and still water habitats (lakes, ponds) on the tract, as well as a larger component within the macrogroup of Northern Swamp communities. The Northern Swamp type deserves special attention and consists of one habitat – Laurentian-Acadian Alkaline Conifer Hardwood Swamp – on the Boreas. This habitat comprises a significant proportion of the tract (12%, or 2,569 acres) and, similar to the boreal types described above, is also likely to harbor some of New York's rarest avifauna including species such as gray jay and black-backed woodpecker. Northern Swamp is distinguished in part from Northern Peatland and Fens by its richer substrate. A forested swamp of alkaline wetlands associated with limestone or other calcareous substrate, these forested wetlands are uncommon in the glaciated northeast except in areas with extensive limestone or similar substrate (Anderson et al. 2013). Across the Adirondacks, the Northern Swamp type makes up only 10% of the landscape, is less protected than the Boreal Upland Forest and Northern Peatland types, and is distributed primarily on Resource Management (27.1%) and Wild Forest (28.2%) lands, with a smaller proportion in Wilderness (16.1%; Glennon and Curran 2013).

Cliff and Talus and Outcrop and Summit Scrub communities make up the remainder of the terrestrial patch forming systems on the Boreas tract. These rocky zones and mountaintop areas are the homes of icons such as the Bicknell's thrush, peregrine falcon, raven, and several other bird and mammal species. They are a small component of the Boreas tract and of the Adirondacks on the whole, and are generally well-protected on Forest Preserve and easement lands but recreation in these zones has the potential to impact these fragile communities (Glennon and Curran 2013).

The remaining terrestrial land area on the Boreas is comprised of anthropogenic habitats, the largest proportion of which is roads. Table 5 provides a description of all of the terrestrial and aquatic habitats on the Boreas, as well as information on ecological settings in which they are found, associated species, and the amount of protection that exists for these habitat types in the northeast region.

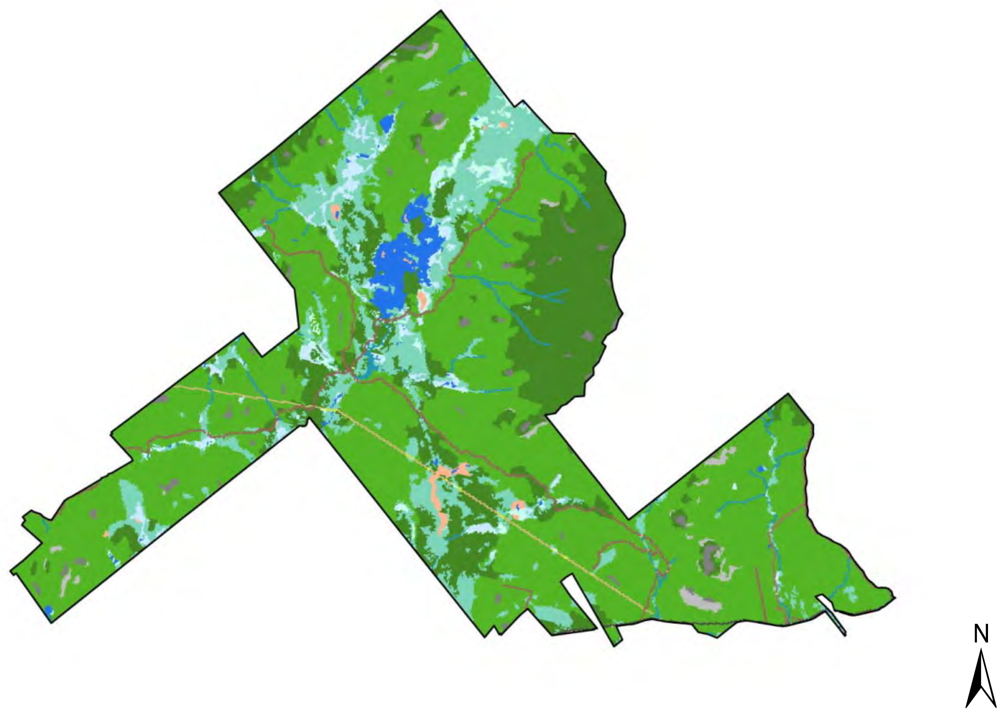


Figure 2. Terrestrial Habitats on the Boreas Tract: macrogroup level

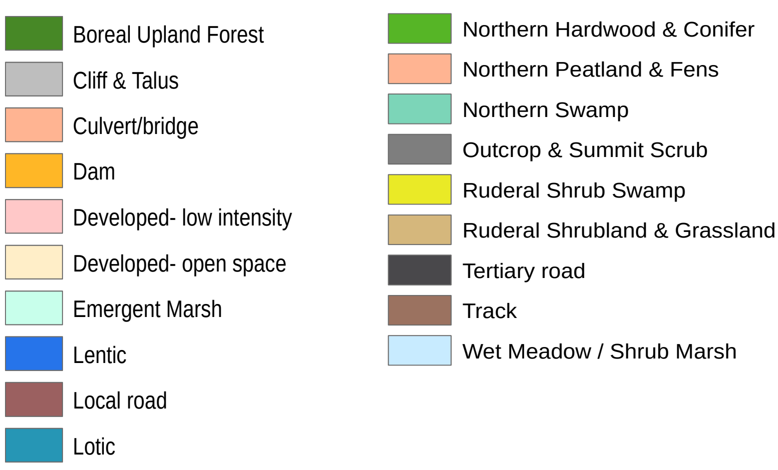


Table 1. Northeast Terrestrial Habitat Classification system types on the Boreas tract: habitat level

Habitat	Macrogroup	Acres	%	Ave. Patch Size
Laurentian-Acadian (L-A) Northern Hardwood Forest: typic	Northern Hardwood & Conifer	9,447	4	50.1
Acadian-Appalachian Montane Spr-Fir-Hwd Forest	Boreal Upland Forest	2,036	1	41
L-A Northern Hardwood Forest: high conifer	Northern Hardwood & Conifer	1,942	9	6.4
Acadian Low Elevation Spruce-Fir-Hardwood Forest	Boreal Upland Forest	1,324	6	7
L-A Alkaline Conifer-Hwd Swamp Smaller river riparian	Northern Swamp	1,196	6	5.4
L-A Alkaline Conifer-Hwd Swamp Lake/pond: any size	Northern Swamp	979	5	7.3
Lentic	Lentic	418	2	6.3
L-A Alkaline Conifer-Hwd Swamp Isolated	Northern Swamp	393	2	2.5
L-A Pine-Hemlock-Hardwood Forest: typic	Northern Hardwood & Conifer	315	2	41.8
Lotic	Lotic	313	2	1.9
Local road	Local road	301	1	8.4
Acadian Sub-boreal Spruce Flat	Boreal Upland Forest	300	1	1.1
L-A Northern Hardwoods Forest: moist-cool	Northern Hardwood & Conifer	253	1	1.3
L-A Calcareous Rocky Outcrop	Outcrop & Summit Scrub	246	1	3.4
L-A Wet Meadow-Shrub Swamp Smaller river riparian	Wet Meadow/Shrub Marsh	241	1	3.8
L-A Freshwater Marsh Lake/pond: any size	Emergent Marsh	180	1	1.9
L-A Calcareous Cliff and Talus	Cliff & Talus	172	1	3.8
L-A Wet Meadow-Shrub Swamp Lake/pond: any size	Wet Meadow/Shrub Marsh	144	1	2.2
Boreal- L-A Acidic Basin Fen Undifferentiated	Northern Peatland & Fens	101	<	5.3
NLCD 52/71: shrublands/grasslands	Ruderal Shrub & Grassland	77	<	4.4
L-A Red Oak-Northern Hardwood Forest	Northern Hardwood & Conifer	60	<	8.1
L-A Wet Meadow-Shrub Swamp Isolated	Wet Meadow/Shrub Marsh	51	<	2.3
L-A Freshwater Marsh Smaller river riparian	Emergent Marsh	41	<	1
Track	Track	25	<	9.1
L-A Freshwater Marsh Isolated	Emergent Marsh	17	<	0.7
Ruderal Shrub Swamp	Ruderal Shrub Swamp	9	<	0.8
Culvert/bridge	Culvert/bridge	4	<	0.2
Developed- low intensity	Developed- low intensity	1	<	0.3
Developed- open space	Developed- open space	<1	<	0.4
Dam	Dam	<1	<	0.2

Table 2. Northeast Terrestrial Habitat Classification System types on the Boreas Tract: Macrogroup level

Macrogroup	System Type	Acres	%	Ave. Patch Size
Northern Hardwood & Conifer	Matrix	12,017	58	54.5
Boreal Upland Forest	Matrix/Patch	3,660	18	15.3
Northern Swamp	Wetland	2,569	12	4.9
Wet Meadow / Shrub Marsh	Wetland	435	2	2.9
Lentic (still waters)	Water	418	2	6.3
Developed/Anthropogenic*	Developed	332	2	5.1
Lotic (flowing waters)	Water	313	2	1.9
Outcrop & Summit Scrub	Patch	246	1	3.4
Emergent Marsh	Wetland	238	1	1.5
Cliff & Talus	Patch	172	1	3.7
Northern Peatland & Fens	Wetland	101	<1	5.3
Ruderal Shrubland & Grassland	Other	77	<1	4.3
Ruderal Shrub Swamp	Wetland	9	<1	0.8

* Consists of: culvert/bridge, dam, developed low intensity, developed open space, local road, and track; 301 acres of this total (91%) is local roads.

Aquatic Habitats

Aquatic habitats present on the Boreas tract were also summarized from recent mapping and classification created by The Nature Conservancy Eastern Science Division (NEAHCS; Olivero and Anderson 2008, Olivero-Sheldon and Anderson 2016). I used ArcGIS to import the habitat data and overlay them with a Boreas tract boundary shapefile obtained from the Adirondack Council. Standard GIS zonal summary methods are challenging with respect to the aquatic habitat data because flowlines cross the Boreas boundary and classifications and statistics were compiled for stream segments that do not reflect this boundary. As such, the information provided for the aquatic habitats was compiled by visually inspecting these layers and individually selecting features to examine their attribute information.

Aquatic habitats have been classified and described in 2 separate efforts, one of which focuses on flowing water habitats (Olivero and Anderson 2008) and a second classification of still water (lake and pond; Olivero-Sheldon and Anderson 2016) habitats. All of the lotic habitats on Boreas are headwater and creek habitats classified as moderate or high gradient, neutral pH, moderate buffering capacity, and cold temperatures (Table 3, Figure 3). Lentic habitats consist of 8 waterbodies all of which are classified as ponds except, ironically, Boreas Ponds which is classified as a lake. All are classified as mesotrophic lakes with low alkalinity and cool to cold temperature except for Boreas Ponds which is classified as very cold (Table 4). In other words, these are cold, acidic lakes characterized by low to moderate levels of productivity. They often stratify in the summer into a warmer upper layer and a colder lower layer which provides a refuge for native coldwater fish species. Table 5 provides a comprehensive description of these habitats, as well as information on ecological settings in which they are found, associated species, and the amount of protection that exists for these habitat types in the northeast region.

Table 3. Northeast Aquatic Habitats and Classification on the Boreas Tract: Flowing Waters

Name/Description	Macrogroup	Gradient	Buffer	pH	Temp
White Lily Brook	Headwater/Creek	Moderate/High	Moderate	Neutral	Cold
Brant Brook	Headwater/Creek	Moderate/High	Moderate	Neutral	Cold
Snyder Brook	Headwater/Creek	Moderate/High	Moderate	Neutral	Cold
Boreas River	Headwater/Creek	Moderate/High	Moderate	Neutral	Cold
LeClair Brook	Headwater/Creek	Moderate/High	Moderate	Neutral	Cold
Andrew Brook	Headwater/Creek	Moderate/High	Moderate	Neutral	Cold
The Branch (from Elk Lake)	Headwater/Creek	Moderate/High	Moderate	Neutral	Cold

Table 4. Northeast Aquatic Habitats and Classification on the Boreas Tract: Lakes/Ponds

Name/Description	Acres	Max Depth	Trophic	Alkalinity	Temp
No Name	22.4	6.3	Mesotrophic	Low	Cool to Cold
No Name	11.6	2.3	Mesotrophic	Low	Cool to Cold
White Lily Pond	16.0	9.3	Mesotrophic	Low	Cool to Cold
Boreas Ponds	343.7	25.7	Mesotrophic	Low	Very Cold
No Name	5.0	4.1	Mesotrophic	Low	Cool to Cold
No Name	3.7	1.3	Mesotrophic	Low	Cool to Cold
No Name	3.2	1.9	Mesotrophic	Low	Cool to Cold
Fly Pond	12.5	3.6	Mesotrophic	Low	Cool to Cold

Table 5. Descriptions of natural habitats on the Boreas tract (information from Anderson et al. 2013)

Macrogroup	Habitat	Description	Ecological settings and major disturbance factors	Associated species	% conserved in NE region
Northern Hardwood & Conifer	Laurentian-Acadian Northern Hardwood Forest	Hardwood forest dominated by sugar maple, American beech, and yellow birch; white ash common on some sites, hemlock and red spruce are frequent but minor canopy associates. This is the "matrix" forest in the northern part of our region, within which upland and wetland systems that occur at smaller scale are embedded.	A broadly defined ecological generalist, found on slopes, hills, and flats, on a wide variety of bedrocks and tills. It occurs at low to moderate elevations that vary with latitude, but generally from 800 to 2200 feet. Blowdowns of small and large scale, snow and ice loading are primary disturbances.	Black-and-white warbler, blackburnian warbler, black-throated blue warbler, black-throated green warbler, Eastern wood pewee, hermit thrush, Northern saw-whet owl, ovenbird, pine warbler, ruffed grouse, scarlet tanager, veery, wood thrush, black bear, fisher, grey fox, Northern flying squirrel, porcupine, smoky shrew, white-footed mouse, woodland jumping mouse, spring salamander	37.8

Northern Hardwood & Conifer	Laurentian-Acadian Pine-Hemlock-Hardwood Forest	Coniferous or mixed forest widespread in the glaciated northeast. White pine, hemlock, and red oak are typical canopy dominants. Red maple common, other hardwoods also occur. Red spruce and balsam fir uncommon associates, other oaks essentially absent. Transitional between northern hardwood forests at higher elevations/north, and warmer Appalachian hemlock- hardwoods and oak-pine forests at lower elevations/south.	Dry to mesic forests usually occuring on low-nutrient loamy-to-sandy soils on a wide range of landforms at lower elevations, mostly below about 2000'. Single tree blowdowns and gap replacement most common disturbance/regeneration event; fire infrequent.	Black-and-white warbler, blackburnian warbler, Eastern wood pewee, hermit thrush, Northern saw-whet owl, Northern waterthrush, ovenbird, pine warbler, ruffed grouse, scarlet tanager, veery, wood thrush, yellow-bellied sapsucker, deer mouse, red squirrel, southern red-backed vole, Northern redbelly snake	15
Northern Hardwood & Conifer	Laurentian-Acadian Red Oak-Northern Hardwood Forest	Closed canopy forest of low to moderate moisture in which a significant component of red oak is present along with the normal suite of northern hardwoods, primarily sugar maple, beech, and yellow birch. Red maple, hemlock, and white pine are common associates. Most common across the southern part of the northern hardwood forest's range, where it is transitional to oak or oak-pine forests.	Found at low to mid elevations, on convex landforms and slopes with strong insolation. Highest elevations are about 1500' in the north, 2500' in the south. Generally favors sites with acidic bedrock and well drained soils derived from glacial till. Fire promotes regeneration of the oak, and is probably more common in these stands than in northern hardwoods without oaks. Wildlife browsing (deer in particular) can severely inhibit it.	Black-and-white warbler, blackburnian warbler, black-throated blue warbler, black-throated green warbler, Eastern wood pewee, hermit thrush, Northern saw-whet owl, Northern waterthrush, ovenbird, pine warbler, ruffed grouse, scarlet tanager, veery, wood thrush, black bear, fisher, grey fox, Northern flying squirrel, porcupine, smoky shrew, white-footed mouse, woodland jumping mouse	19.2
Boreal Upland Forest	Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest	High elevation conifer forest dominated by red spruce and balsam fir, and forming small to very large patches on the highest peaks of the northern Appalachian Mountains. Heart- leaved birch characteristic along with yellow birch, white birch, mountain maple, striped maple, mountain ash, and occasionally black spruce at upper patch edges.	Occurring on acidic, low nutrient soils, subject to disturbance from windthrow and mass downslope slippage. Gaps formed by wind, snow, and ice are the major replacement agents; fires may be important over a longer return interval. Acid rain deposition and climate change pose the primary threats to this mountain system.	Blackburnian warbler, blackpoll warbler, boreal chickadee, golden-crowned kinglet, gray jay, purple finch, Swainson's thrush, white-throated sparrow, yellow-bellied flycatcher, yellow-rumped warbler, American marten, deer mouse, northern flying squirrel, porcupine, red squirrel	67.4
Boreal Upland Forest	Acadian Low Elevation Spruce-Fir-Hardwood Forest	Low elevation conifer forest dominated by red spruce and balsam fir, often forming the matrix forest in colder parts of the Acadian and northern Appalachian region. Black and white spruce sometimes present, along with yellow birch, paper birch, beech, and red or sugar maple, and northern white cedar in moister, richer locations.	Found at elevations up to 2000' in the northern part of its range. Occurs on acidic, rocky, well- to moderately well-drained soils, with pockets of poor drainage in depressions and slope bottoms. Blowdowns and gap regeneration most common disturbances; large-scale fires at longer return intervals important in drier regions.	American three-toed woodpecker, bay-breasted warbler, black-backed woodpecker, boreal chickadee, Cape May warbler, gray jay, olive-sided flycatcher, red crossbill	27.2

Boreal Upland Forest	Acadian Sub-boreal Spruce Flat	Conifer or mixed forest forming extensive flats on areas of imperfectly drained soils. Black spruce, red spruce, and balsam fir dominate; yellow birch, hemlock, black cherry, and red maple sometimes present. Characteristic of colder regions of the northern Appalachians-Acadian region, where it often forms long narrow patches along riverside flats in valley bottoms.	Often in low flats along streams and lakes, transitional between wetland and upland. Loamy to sandy, nutrient-poor mineral soils typically saturated at snowmelt but moderately well-drained for much of the growing season and may be reasonably dry at the soil surface.	Black-backed woodpecker, blackburnian warbler, golden-crowned kinglet, Northern waterthrush, palm warbler, ruby-crowned kinglet, spruce grouse, Swainson's thrush, white-throated sparrow, yellow-bellied flycatcher, American marten, Canada lynx	30.1
Northern Swamp	Laurentian-Acadian Alkaline Conifer-Hardwood Swamp	A forested swamp of alkaline wetlands associated with limestone or other calcareous substrate in the northern part of the glaciated northeast. Northern white cedar is often present and may dominate the canopy or be mixed with other conifers or with deciduous trees, most commonly red maple or black ash.	These forested wetlands are uncommon in the glaciated northeast except in areas with extensive limestone or similar substrate. The substrate is typically mineral soil, but there may be some peat, and there is often direct contact with alkaline groundwater.	Black-backed woodpecker, Canada warbler, golden-crowned kinglet, gray jay, Northern waterthrush, palm warbler, red-shouldered hawk, American three-toed woodpecker, veery, white-throated sparrow, wood duck, yellow-bellied flycatcher, masked shrew, mink, red-backed vole, short-tailed shrew	19.5
Wet Meadow / Shrub Marsh	Laurentian-Acadian Wet Meadow-Shrub Swamp	A shrub-dominated swamp or wet meadow on mineral soils characteristic of the glaciated Northeast and scattered areas southward. Examples often occur in association with lakes and ponds or streams in small and solitary pockets or, more often, part of a larger wetland complex. Typical species include willow, red-osier dogwood, alder, buttonbush, meadowsweet, bluejoint grass, tall sedges, and rushes. Trees generally absent or thinly scattered.	Shrub swamps and wet meadows associated with lakes and ponds and along headwater and larger streams where the water level does not fluctuate greatly. Commonly flooded for part of the growing season but generally do not have standing water throughout the season. A dynamic system that may return to marsh in beaver impounded areas or succeed to wooded swamp with sediment accumulation or water subsidence.	Alder flycatcher, American woodcock, common yellowthroat, least bittern, Nashville warbler, Northern waterthrush, ruddy duck, sedge wren, swamp sparrow, Tennessee warbler, veery, Wilson's snipe, yellow warbler, eastern cottontail, meadow jumping mouse, short-tailed shrew, raccoon, smoky shrew, snowshoe hare, southern bog lemming, star-nosed mole, Virginia opossum, water shrew	25.5
Emergent Marsh	Laurentian-Acadian Freshwater Marsh	Freshwater emergent or submergent marsh dominated by herbaceous vegetation and associated with isolated basins, edges of streamways, and seepage slopes. Typical plants include cattails, marsh fern, pondweeds, water lilies, pickerelweed, and tall rushes. Trees generally absent and, if present, are scattered. A very broadly defined system, with many variants distributed widely in the Northeast.	Freshwater marshes associated with lakes, ponds, headwater basins and slow-moving streams, impoundments, ditches, or any low lying basin that collects water. Such basins are often flat-bottomed and shallow, or marsh vegetation forms a ring around the edge of deeper basins. Typically occur on muck over mineral soil, and as part of a larger wetland complex that may include forested or shrubby swamps, peatlands, and/or open water.	American bittern, American black duck, blue-winged teal, great blue heron, least bittern, marsh wren, pied-billed grebe, swamp sparrow, wood duck, Eastern cottontail, meadow jumping mouse, mink, moose, muskrat, raccoon, Southern bog lemming, Virginia opossum, water shrew, blue-spotted salamander, Northern leopard frog, Northern spring peeper, red-spotted newt, spotted turtle	21.6

Outcrop & Summit Scrub	Laurentian-Acadian Calcareous Rocky Outcrop	A sparsely vegetated ridge, summit, dome, or flat plain, composed of circumneutral or calcareous bedrock such as limestone or dolomite. Vegetation is a mosaic of woodlands and open glades reflecting the proportion of rock surface to thin soil. Northern white cedar is a characteristic tree although it rarely forms extensive cover. Sites are often exposed and dry; however, there may be local areas of more moist conditions.	Occurs on ridges or summits of circumneutral to calcareous bedrock such as limestone or dolomite. Occurs in scattered locations from New England west to the Great Lakes. Exposure, thin soils, and occasional fire are the major factors in keeping the vegetation open.	Gray jay, Bicknell's thrush, peregrine falcon, raven	51.5
Cliff & Talus	Laurentian-Acadian Calcareous Cliff and Talus	Sparsely vegetated cliff or talus slope formed on limestone, dolomite, or other calcareous bedrock. Lack of soil, constant erosion, and harsh edaphic conditions limits vegetation to herbs, ferns, and sparse trees. Northern white cedar characteristic and may dominate on some cliffs. Ash and basswood are other woody indicators of enriched setting. Zone of vegetation at the horizontal clifftop often gladelike or grassy.	Near-vertical cliffs and talus slopes occurring on limestone or other calcareous rock, associated with steep hill slopes, bluffs, and river gorges. Wind and water erosion, mass movement, and fire are primary system dynamics. Harsh edaphic conditions limit vegetation cover. Occurs widely with distinct variants in the Appalachians, Ridge and Valley Province and adjacent Cumberland Plateau, and the northcentral interior west of the Appalachians.	Eastern phoebe, golden eagle, raven, turkey vulture, peregrine falcon	48.2
Headwater & Creek	Moderate Gradient, Cold Headwaters and Creeks	Cold, moderately fast-moving, headwaters and creeks of hills and gentle slopes. Instream habitats dominated by riffle-pool development with low sinuosity, moderate entrenchment, moderately narrow valleys. Substrates dominated by cobble, gravel, and sand with occasional boulders. Permanent cold water temperatures means coldwater fish species, such as brook trout, likely represent over half of the fish community.	Small streams of northern regions or high elevations, occur on hills and slopes at moderate to high elevations in watersheds less than 39 sq.mi in size. These moderate gradient streams are transitional types and often exhibit some characteristics of both the higher and lower gradient streams. Cold moderate gradient streams typically flow into moderate or low gradient cold and cool rivers in areas of less topography.	Brook trout, slimy sculpin, longnose dace, creek chub, white sucker, common shiner, central stoneroller, mottled sculpin, fathead minnow, fallfish, bluntnose minnow, brook stickleback, tessellated darter, fantail darter, blue ridge sculpin, Atlantic salmon, mountain redbelly dace, trout-perch, river chub, spottail shiner, northern hog sucker, finescale dace, rainbow darter, burbot, longnose sucker	17.8
Headwater & Creek	High Gradient, Cold Headwaters and Creeks	Cold, moderately fast-moving, headwaters and creeks of steeper slopes at moderate to high elevations. High clarity and well oxygenated. Instream habitats dominated by riffles and cascade and step/pool systems. Channels usually narrowly confined, surrounded by upland forests. Bed materials often bedrock, boulders, cobbles, and coarse gravel. Coldwater fish species likely represent over half of the fish community.	Small streams of northern regions or high elevations, occur on steep slopes in watersheds less than 39 sq.mi in size.	Brook trout, slimy sculpin, longnose dace, longnose sucker, Eastern blacknose dace, creek chub, mottled sculpin, white sucker, fantail darter, common shiner, lake chub, fallfish, Atlantic salmon	26.3

Lakes & Ponds	Very Cold, Oligo-Mesotrophic, Acidic Lake or Pond	Very cold, deep, acidic clear lake characterized by high dissolved oxygen content and low to moderate levels of biological productivity. Water alkalinity is low, supporting acid tolerant biota. May stratify in summer into warm upper layer supporting warmwater fish (e.g., largemouth bass) and a cold lower layer providing refuge for coldwater fish (e.g., lake and brook trout).	Typical of acidic substrates, northern latitudes, or deep kettleholes on the coastal plain. Average lake in this category has a surface area of 962 acres and depth of 68 feet.	Lake trout, rainbow smelt, brook trout, brown trout, Atlantic salmon (landlocked), whitefish, burbot, slimy sculpin, Northern pike, walleye, smallmouth bass, white sucker, yellow perch, creek chub, fallfish, common shiner, sunfish, chain pickerel, brown bullhead, golden shiner	32.6 (shoreline)
Lakes & Ponds	Cold, Oligo-Mesotrophic, Acidic Lake or Pond	Cold, acidic, clear lake or pond characterized by low to moderate levels of biological productivity. Cold, oxygenated water is present year round, usually in the deepest zone. Water alkalinity is low, supporting acid tolerant biota. May stratify in summer into warm upper layer supporting warmwater fish (e.g., largemouth bass) and a cold lower layer providing refuge for coldwater fish (e.g., lake and brook trout).	Typical of acidic substrates at high elevations or northern latitudes, such as the mountainous areas of the northeastern US. Average lake in this category has a surface area of 155 acres and depth of 34 feet.	Rainbow smelt, brook trout, brown trout, Atlantic salmon (landlocked), burbot, slimy sculpin, Northern pike, walleye, smallmouth bass, white sucker, yellow perch, creek chub, fallfish, common shiner, sunfish, chain pickerel, brown bullhead, golden shiner	40 (shoreline)

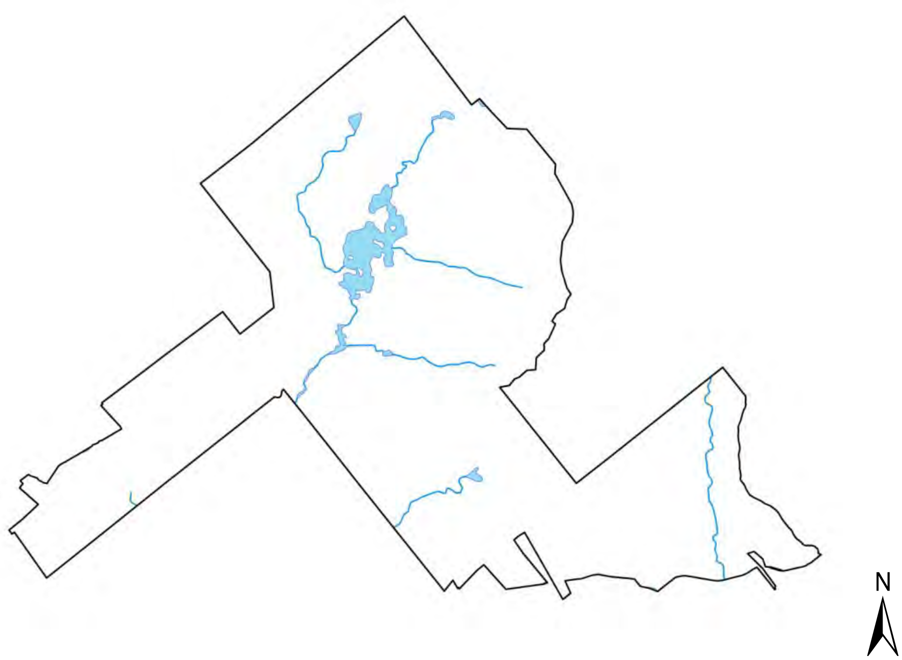


Figure 3. Aquatic habitats on the Boreas Tract

Condition of the Boreas Tract

In addition to the current habitat composition of the Boreas, we can also assess the condition of the tract via a number of available datasets including aboveground forest biomass and forest loss/gain, ecological integrity, resilience, and connectivity.

Forest Aboveground Biomass

Biomass refers to the amount of living matter within a given area. Forest Aboveground Biomass measures the total amount of above-ground living material in forested systems, which is an important attribute of forested communities and an indicator of successional development. Though forest biomass is often discussed in the context of renewable energy sources, it can also be useful in describing forest structure and revealing patterns that may result from forest management. As described above, forest aboveground biomass has been mapped as part of the DSL project led by Kevin McGarigal at the Landscape Ecology lab of UMass Amherst. The dataset is derived from a combination of remote sensing products, Forest Inventory and Analysis (FIA) plot data and models; units are in kilograms/meters squared times 10. Biomass can be helpful in distinguishing younger from older forests in a given area and therefore identifying habitat important for early successional (e.g., American woodcock) or mature forest (e.g., brown creeper) species.

Total forest aboveground biomass on the Boreas tract is 12,576,665 kg/m2 x 10 and highest biomass is within the Northern and Hardwood and Conifer forest type, followed by Boreal Upland Forest and Northern Swamp. The general pattern is one of a highly variable mix of high and low biomass areas on the tract (Figure 4). These patterns are interesting in the context of the following dataset, in which the same underlying data were used to map forest loss/gain patterns.

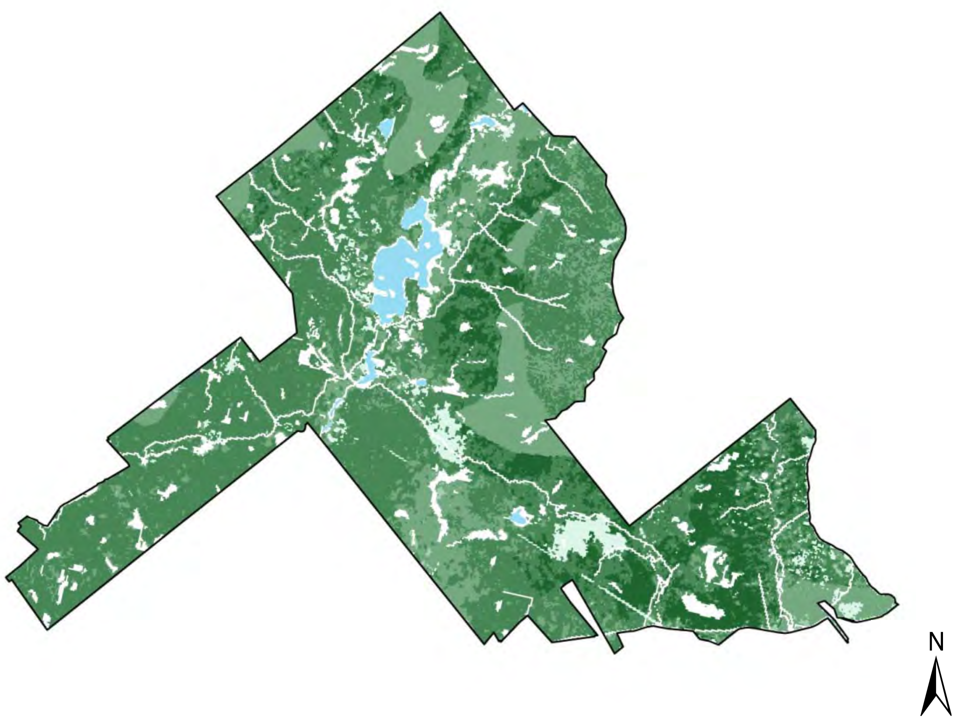


Figure 4. Forest aboveground biomass on the Boreas Tract (km/m^2 x 10)

Forest Loss and Gain

Forest cover loss and gain have been mapped for the Northeast Region for the period 2000 – 2012. Forest loss is defined as a stand-replacement disturbance, or a change from a forest to non-forest state, entirely within the study period, and was mapped as either 1 (loss) or 0 (no loss) for the Northeast region including Canada as a component of the Global Forest Cover Change Project. The Global Forest Cover Change (GFCC) project is a multi-year activity designed to generate forest cover and forest cover change products at multiple resolutions and multiple dates for every land surface in the world. The GFCC team is located at the University of Maryland, NASA Goddard Space Flight Center, and the South Dakota State University. This activity is sponsored primarily through the NASA MEaSUREs program. The Global Forest Watch website (globalforestwatch.org) provides an interactive mapper where these data can be readily explored and used for a variety of analyses.

Forest loss on the Boreas Tract (Figure 5) is more apparent than forest gain (Figure 6). Forest loss on the Boreas represents 1.6% of the tract or approximately 325 acres, while forest gain represents 0.1% of the tract or 16 acres. It is important to note that this dataset captures only those patterns of change occurring between 2000 and 2012, and that it measures only areas that have transitioned between a forested and non-forested state. Some areas of low forest biomass align closely with forest loss and probably represent recent logging activities. Others may represent older harvests, or natural differences in biomass among habitat types.

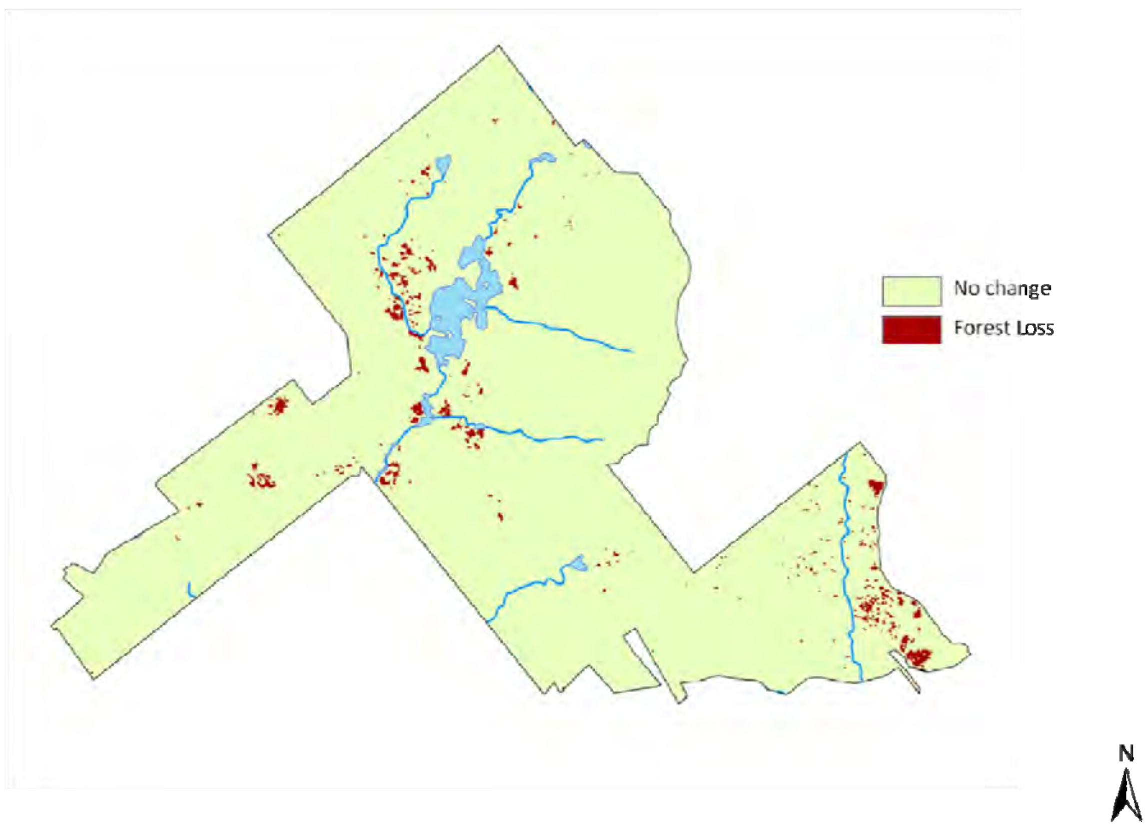


Figure 5. Forest loss on the Boreas Tract 2000 – 2012

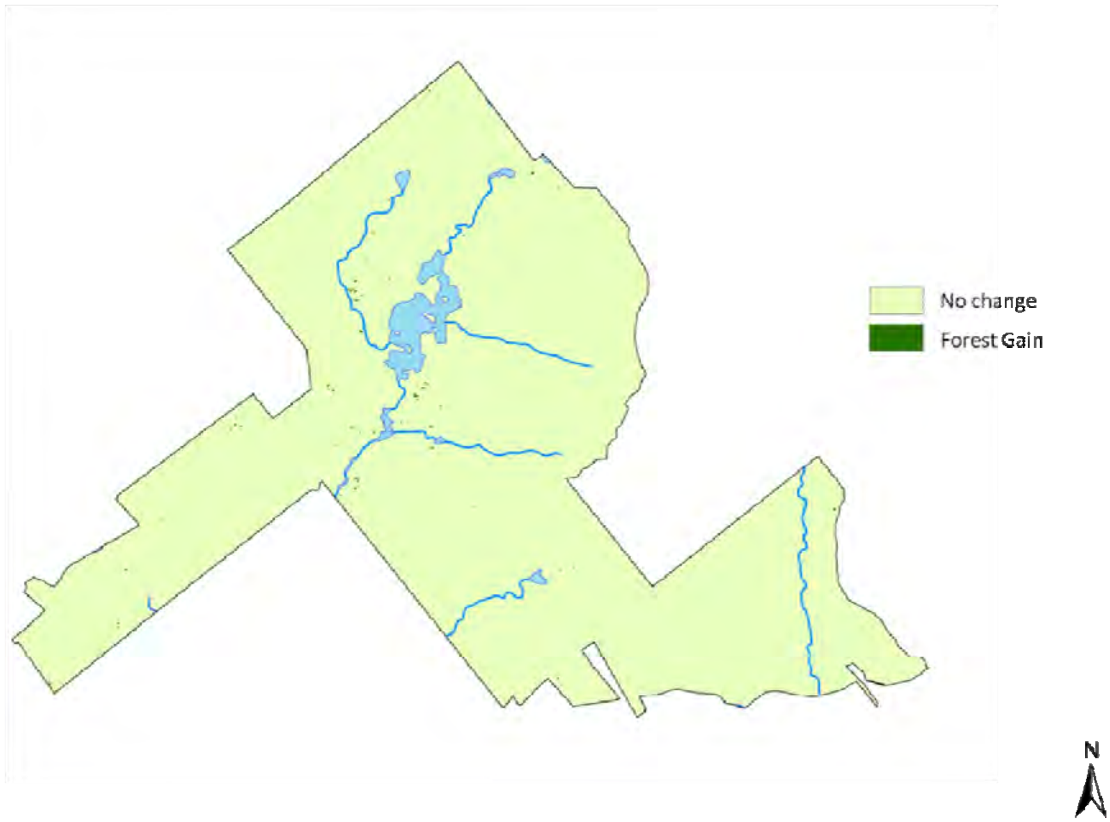


Figure 6. Forest gain on the Boreas Tract 2000 – 2012

Resilience

As described above, resilience denotes capacity for renewal in the face of a dynamic environment and refers to the capacity of a site to adapt to climate change while still maintaining diversity. Resilience describes both the current condition of the Boreas tract, as well as its likely capacity to support biological diversity in the future. Mapped by The Nature Conservancy, resilient sites are considered to be natural strongholds – places where the direct effects of climate change are moderated by *complex* topography and *connected* natural landcover, and where the current landscape contains high quality biodiversity features. These two components – landscape complexity and landscape permeability – determine the resilience characteristics of any given location and are the components that were examined and combined to map resilient sites throughout the northeast. Landscape complexity contributes toward resilience by providing a variety of microclimates that can be exploited by organisms moving about the landscape. Complexity comes from landform variety, elevation gradients, and moisture accumulation. Landscape permeability contributes toward resilience by enhancing the degree to which organisms can move freely within the landscape to obtain needed resources, especially as those resources change or redistribute in the context of climate change. Landscape permeability comes from local connectedness – similarity of cover types and the degree to which barriers exist on the landscape – and larger scale patterns of regional flow. In order to map resilience, TNC combined information on landscape complexity and permeability and scaled resulting resilience scores by underlying geophysical settings (some geophysical settings have naturally higher levels of complexity than others, e.g., mid-elevation granites vs. coastal sand plains) allowing for comparison across all areas. The resulting resilient sites offer the greatest potential for species to adapt to a changing climate (Anderson et al. 2012).

The Boreas tract has very high resilience (Figure 7). Nearly all of the site (97%) is mapped as having a resilience that is above average or far above average for its geophysical setting in comparison to the

Northeast region. Small areas of average or below average resilience correspond primarily to the locations of roads on the landscape. Resilience of the Boreas tract comes primarily from its degree of connectedness rather than its underlying complexity. All of the tract is mapped has having an average level of landscape complexity for its geophysical setting. With respect to connectedness, in contrast, nearly all of the tract is above average, as described below.

Most conservation literature refers to "connectivity" as the capacity of an individual species to move between areas of habitat via corridors and linkage zones (Lindenmayer and Fischer 2006). Consideration of climate change and its impacts on the landscape, however, requires consideration of broad groups of species and large-scale ecological reorganization. As such, permeability is the chosen term to represent the structure of the landscape itself in terms of hardness of barriers, connectedness of natural cover, and arrangement of land uses. As used by TNC, permeability is defined as the degree to which regional landscapes, encompassing a variety of natural, semi-natural and developed land cover types, will sustain ecological processes and are conducive to the movement of many types of organisms (Anderson et al. 2012). Two aspects of permeability have been mapped by TNC to assess different aspects of its local and regional nature, local connectedness and regional flow.

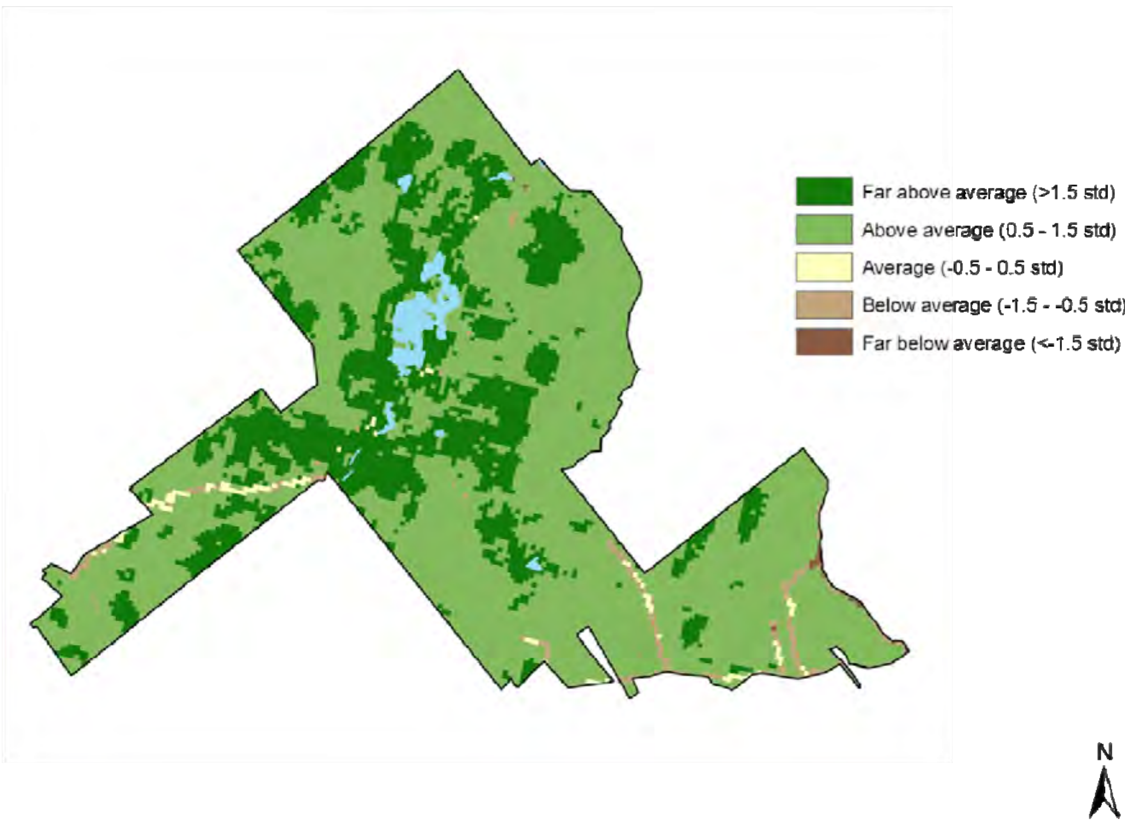


Figure 7. Terrestrial resilience on the Boreas Tract (90m resolution)

Local Connectedness

Local connectedness measures the degree to which structural connections between natural ecosystems within a landscape are impaired. Roads, development, noise, dams, and other structures can all serve to impair ecological connections by altering processes and creating resistance to species movement by increasing the risk (real or perceived) of harm. Local connectedness is a component of the resilience metric and indicates whether a process is likely to be disrupted or how much access a species may have to the microclimates within its given neighborhood (Anderson et al. 2012). Ninety-seven percent of the land area in the Boreas tract meets the criteria for above average local connectedness (Figure 8). This is not surprising given that the landcover features that serve to disrupt ecological flows to the greatest degree (development and roads, agriculture) are largely absent from the Boreas tract, but the pattern reinforces the importance of the connectedness of this tract in determining its level of resilience.

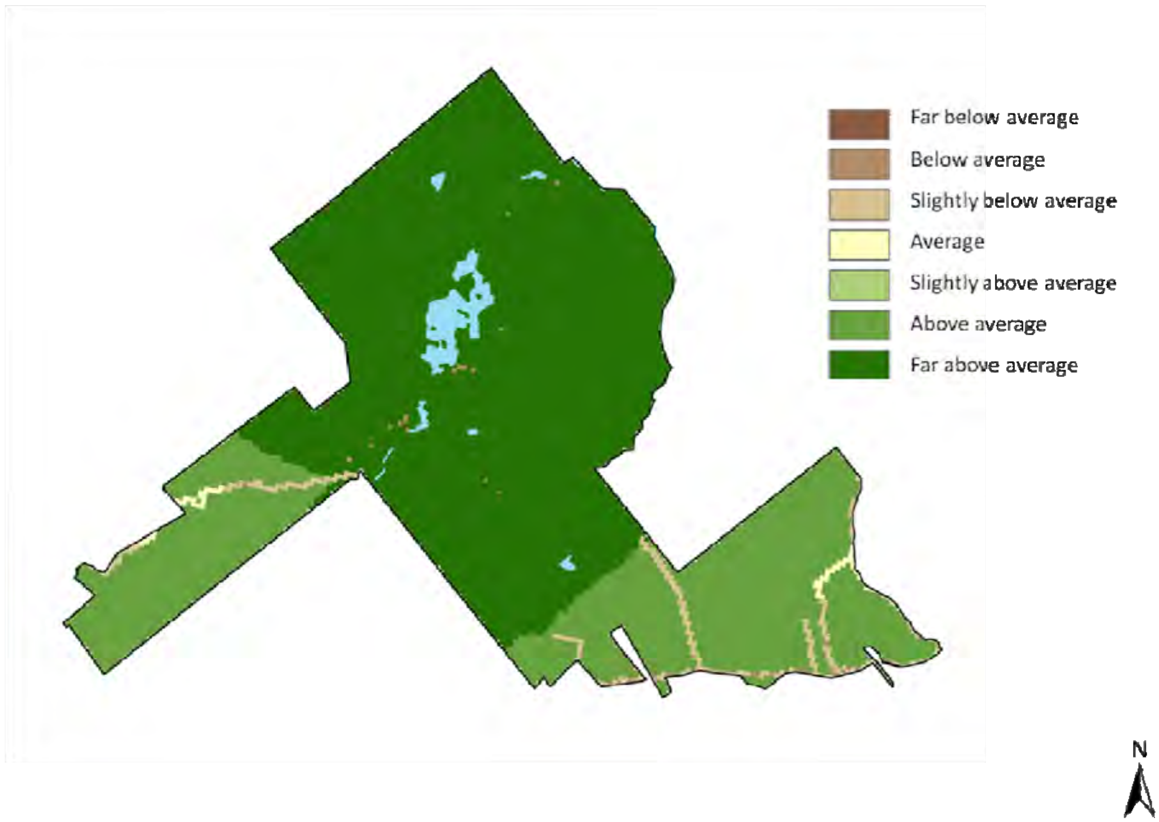


Figure 8. Local connectivity on the Boreas Tract (90m resolution)

Regional Flow

A second component of landscape permeability is that which reflects patterns at larger regional scales. The regional flow metric considers broad east-west and north-south flow patterns across the northeast region and measures how flow patterns become slowed, redirected, or channeled into concentration areas due to the spatial arrangement of cities, towns, farms, roads, and natural lands (Anderson et al. 2012). As defined by the creators of the dataset, these patterns reveal the implications of the physical landscape structure with respect to the continuous flow of natural processes, including not only the dispersal and recruitment of plants and animals, but the rearrangement of existing communities; flows therefore refers to both species movements and ecological processes (Anderson and Clark 2012). Regional flow was not incorporated into resilience scores, but used instead as a means of identifying broader scale flow patterns and linking individual sites into resilient networks. As such, the regional flow patterns are less useful when considered within an individual tract, but can provide information about the degree to which a specific location contributes to larger scale connectivity of the landscape. Nonetheless, the Boreas tract contributes toward regional flow in that 83% of the site scores above the average (Figure 9).

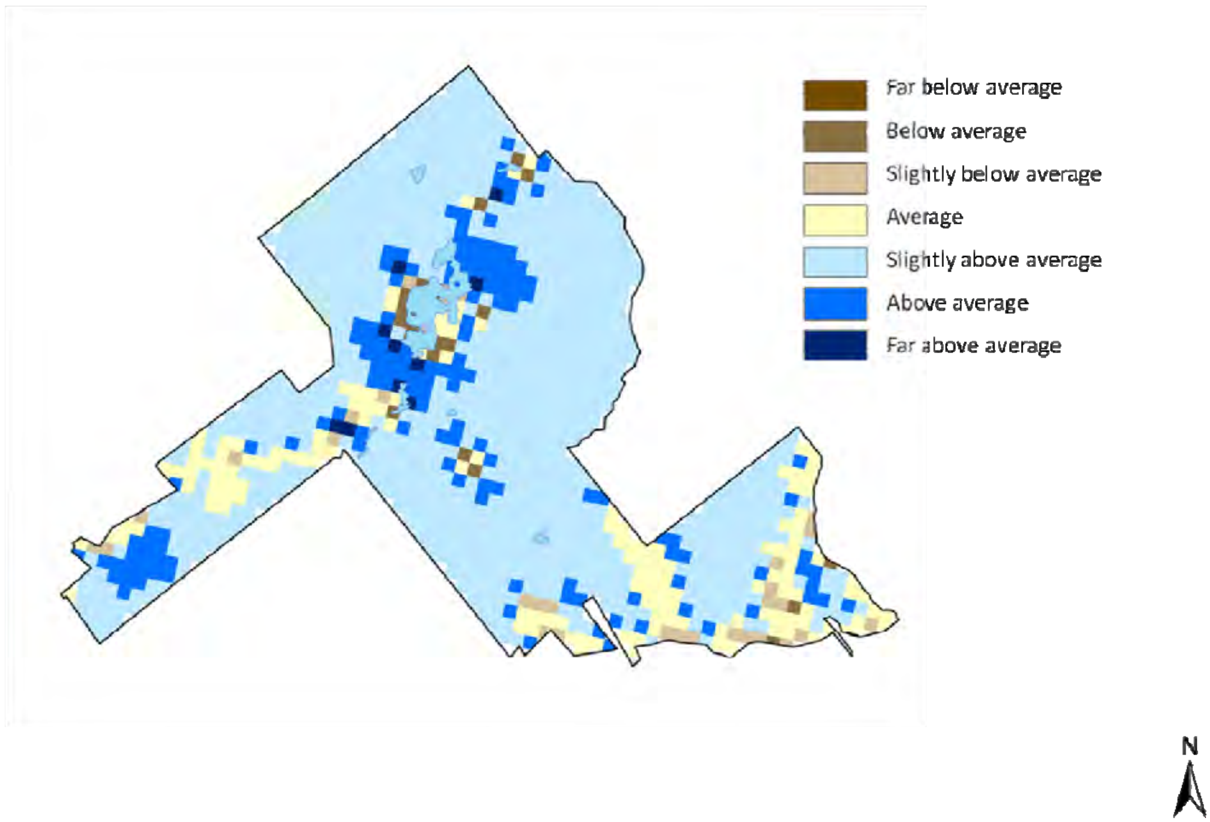


Figure 9. Regional flow on the Boreas Tract (270m resolution)

Ecological Integrity

The ecosystem-based assessment of ecological integrity developed by the DSL project represents an effort to identify the capacity of the landscape to sustain ecological functions over the long term and, in particular, the ability to support biodiversity and ecosystem processes necessary to sustain biodiversity over time (McGarigal 2014). Species-based approaches to conservation are challenged by the complexity of the earth's biodiversity and often considered insufficient, and conclusive evidence remains elusive as to the degree to which umbrella species can adequately represent larger groups. The more recent philosophy of focusing on the conservation of geophysical settings ("conserving the stage") underlying the resilience approach described above represents a recognition of these challenges and the best means we currently have at our disposal for conservation planning in the context of climate change. The University of Massachusetts, as a component of the Designing Sustainable Landscapes Project (DSL), has mapped ecological integrity in the northeast as a coarse filter approach for identifying core conservation areas. This concept of ecological integrity encompasses 3 major components of the landscape: (1) freedom from human impairment (intactness), (2) capacity to recover from or adapt to disturbance and stress (resiliency), and (3) propensity to facilitate or impede ecological flows (connectivity). It is mapped at a fine scale (30m) and scored on a continuous range from 0 – 100.

Ecological integrity values on the Boreas tract range from 2 to 100, indicating a wide range of variation on the tract (Figure 10). Low integrity areas are primarily associated with areas surrounding existing roads and development, as well as some areas of more recent forest harvest. By habitat type, highest integrity is associated with several wetland habitats as well as the northern hardwood and conifer forest. The majority of the tract (77%) has above average ecological integrity.

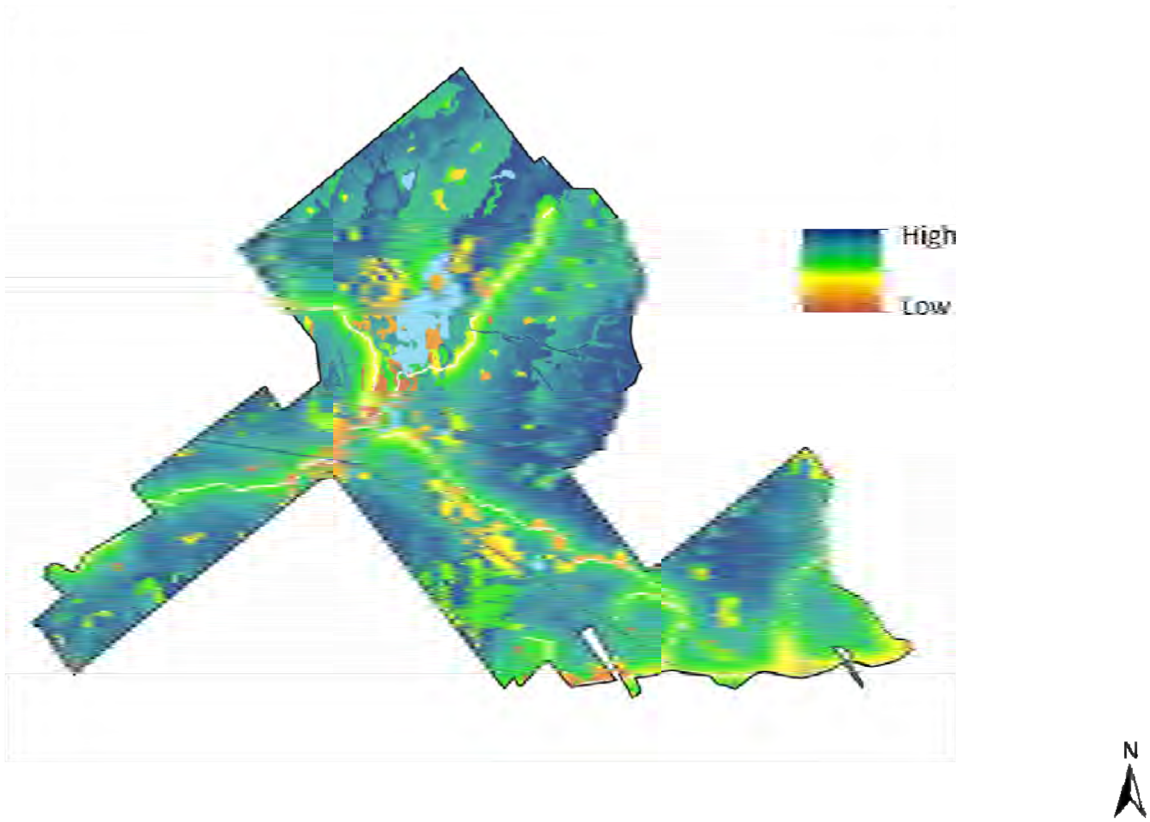


Figure 10. Ecological integrity on the Boreas Tract (30m resolution)

A Note on Resilience vs. Integrity

There are many similarities between the resilience and integrity datasets I have presented here. Both are multimetric indices that incorporate several landscape characteristics into a single measure aimed at identifying areas on the landscape that have the greatest capacity for the *maintenance of ecological processes and biological diversity* over time. I have included both because I find them both to be of use but understand, given the similarity of their definitions, that it may be challenging to understand the differences between the two.

The primary differences in my interpretation are these. First – in a general sense – ecological integrity is closer to a representation of the current condition of the landscape while resilience, contrastingly, takes a longer view. Resilience is aimed distinctly toward planning for the future, with climate change as a primary lens of consideration.

Second, on a more technical level, integrity is finer in scale (30m resolution vs 90m) and incorporates a far greater number of underlying metrics in its calculation (19 vs 3) than does the more coarsely scaled (90m) resilience. Because it is a dataset that considers long-term processes like climate change and relies in part on relatively static characteristics like underlying geology, resilience is mapped for a single, current timescale. Integrity, on the other hand, was designed to incorporate finer scale information and to respond to more rapidly changing features of the landscape. It is mapped for current conditions but also mapped for the future (2080) in order to incorporate considerations about changing land use and climate conditions that may impact integrity.

Third, with respect to connectivity, resilience emphasizes connectivity across diverse geophysical settings, operating on the assumption that areas that are well connected and highly complex in their underlying geography will have the best chance at slowing down the pace of climate change in its impacts on biological communities. Integrity, on the other hand, emphasizes connectedness with similar ecological settings and emphasizes the current habitat composition on the landscape rather than underlying geophysical settings. Both are scaled to underlying ecological settings to allow for comparison across diverse areas, but in the case of resilience those underlying settings are geophysical, where for integrity they are terrestrial habitats. This results in a much greater variability and finer scale look of the integrity data.

Figure 11 shows a comparison of these two datasets for the Boreas tract, in which integrity is mapped using the same color scheme and number of classes as the resilience layer. There is overlap in terms of areas that have both high resilience and high integrity, but there are also some striking differences and we should not necessarily expect the two to look the same. High integrity may not necessarily be associated with high resilience if underlying geophysical characteristics are relatively homogeneous. Areas with both high integrity and high resilience would certainly be worthy of conservation attention. A final point to make is that, with respect to using these data, the resilience science is described in two published papers (Anderson and Ferree 2010, Anderson et al. 2014) as well as several technical documents, fact sheets, and other resources that provide information on its development and utility (Anderson et al. 2012, Anderson and Clark 2012, Borrell 2014), and has now been expanded into the southeastern to cover the entirety of the eastern US. At the current time, though extremely comprehensive, the ecological integrity work is described only in the documentation and resources available from the DSL website (http://www.umass.edu/landeco/research/dsl/dsl.html).

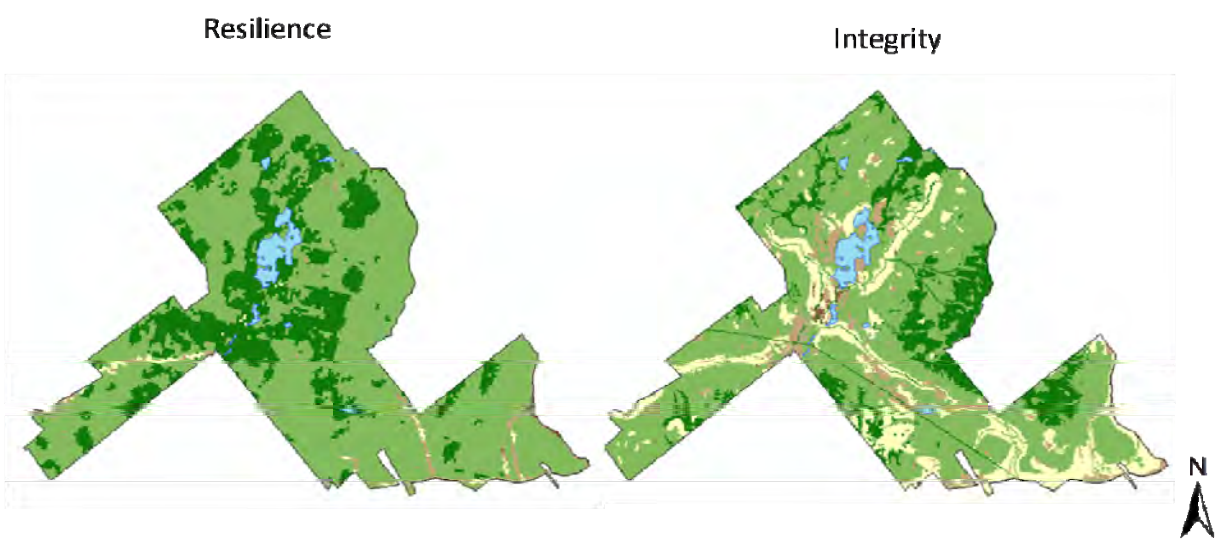


Figure 11. Terrestrial resilience vs ecological integrity on the Boreas Tract

Wildlife Habitat

Empirical data for wildlife on the Boreas tract are not readily available. There are, however, several sources of modeled habitat quality that are informative in considering which parts of the tract may be critical for individual species. As a component of the Designing Sustainable Landscapes project, landscape capability models have been created for a suite of representative species to assess the capability of the Northeast Region to sustain a suite of identified conservation priority species under future landscape change scenarios. Of the 18 species modeled for the northeast by the DSL project, 13 have potential habitat on the Boreas tract (American woodcock, Bicknell's thrush, blackpoll warbler, blackburnian warbler, Louisiana waterthrush, marsh wren, Northern waterthrush, red-shouldered hawk, ruffed grouse, wood duck, wood thrush, moose, black bear; Figure 12). The diversity of areas on the site modeled as important to these species demonstrates their complementarity as representative species. Among the bird species, wood duck appears to have the greatest amount of habitat considered of high capability for this species; wood thrush and ruffed grouse also appear to have significant potential habitat on the tract (Figure 12). Both of the representative mammals occurring on the Boreas tract are highly generalist; this is evident in the landscape capability maps for these species which depict all of the tract as mid-to-high quality for these species (Figure 12).

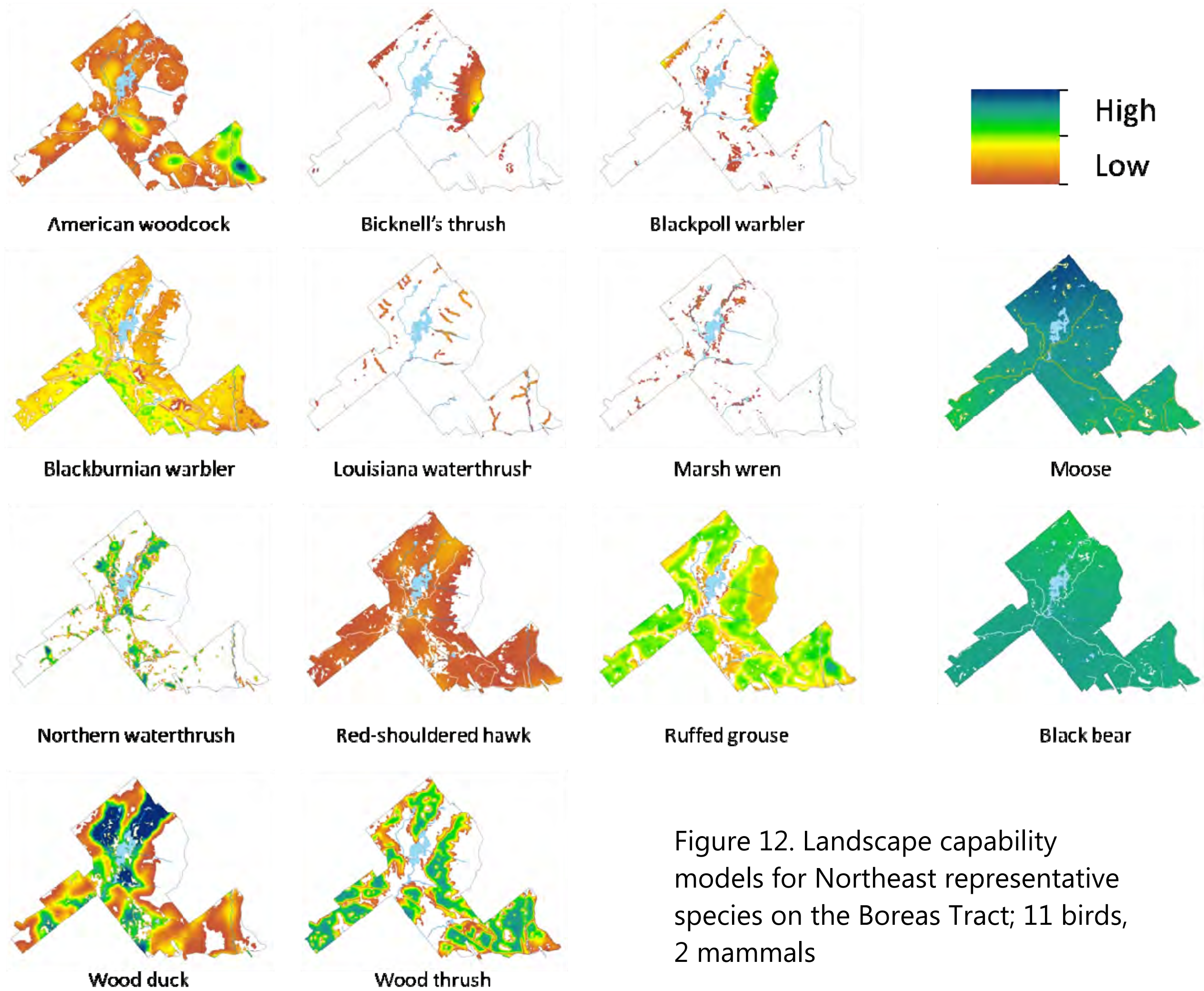


Figure 12. Landscape capability models for Northeast representative species on the Boreas Tract; 11 birds, 2 mammals

Landscape capability as mapped for these species integrates factors influencing climate suitability, habitat capability, and other biogeographic features affecting the species' prevalence in the area and these maps can be considered a representation of the potential capability of the landscape to support each species during its breeding season (migratory species) or year round (resident species). The individual targets represent a selection of species chosen by the US Fish and Wildlife Service as part of their Strategic Habitat Conservation program (US Fish and Wildlife Service 2008). The goal of this effort was to identify a suite of species for designing conservation and management strategies that will most effectively sustain fish and wildlife populations at desired levels in the face of land use change, climate change, and other stressors and representative species are defined as species whose habitat needs, ecosystem function, or management responses are similar to a group of other species such that conservation planning and actions oriented toward representative species are expected to also address the needs of other species. Predictive species habitat models have also been produced by the New York Natural Heritage Program including rare species (Figure 13). Individual species identities are not available for these data but the maps represent the results of 379 individual species distribution models, combined into one layer. For each rare species, known locations were used to predict suitable habitat throughout the state. Locations then identified as suitable were then added across all species. A higher number indicates more species were predicted to have suitable habitat at that location. The maximum number of overlapping models at any location is 32 (http://nynhp.org/data#stackedEDMs). The cumulative rare species map for the Boreas indicates a maximum of only 2 rare species at any given location, but does predict that a significant component of the tract provides habitat for at least one rare species (Figure 13).

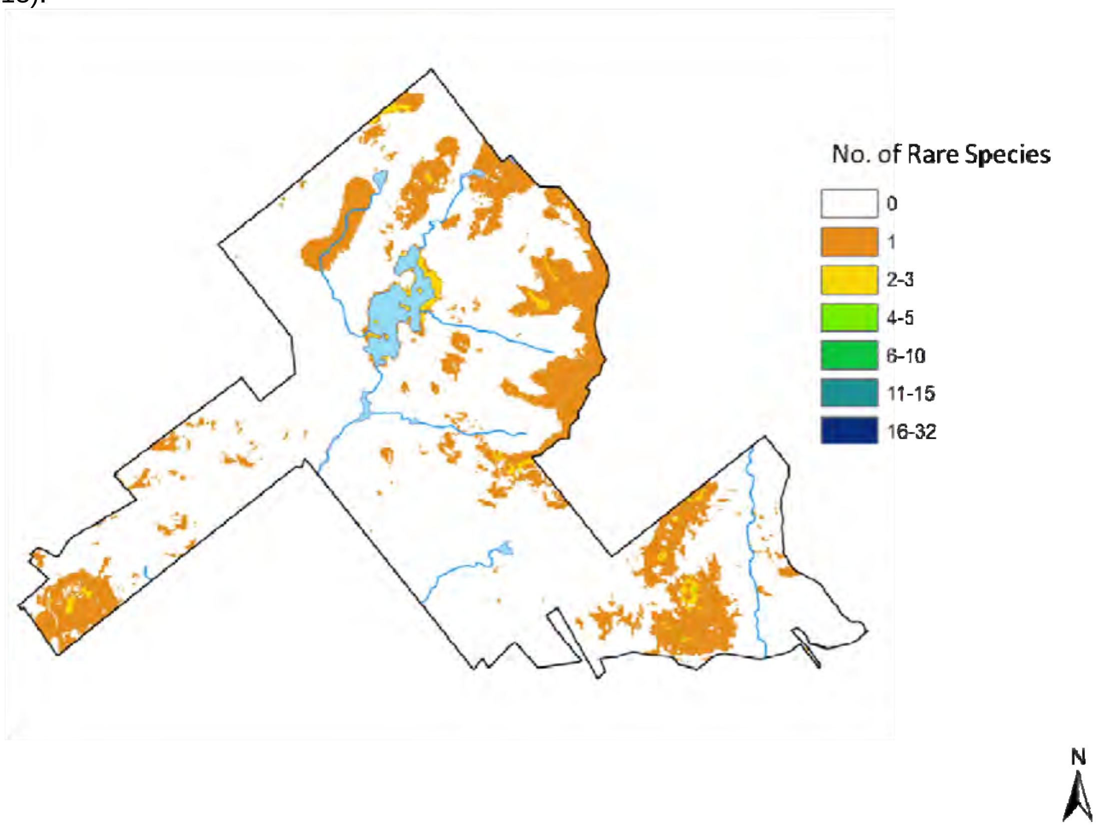


Figure 13. Modeled rare species habitat on the Boreas Tract

Potential Future Threats on the Boreas Tract

Habitat Loss

Two sources of information exist that allow for consideration of future habitat loss on the Boreas tract. The DSL project has modeled habitat loss as a component of current and future ecological integrity and as input to future habitat capability maps for representative species. Maps for future habitat loss are not yet available as the urban growth model that was used as a component of the loss models is currently being revised. The map of current conditions depicts the intensity of habitat loss caused by all forms of development and demonstrates that the roads and associated impacts of roads are the primary source of habitat loss on the Boreas (Figure 14).

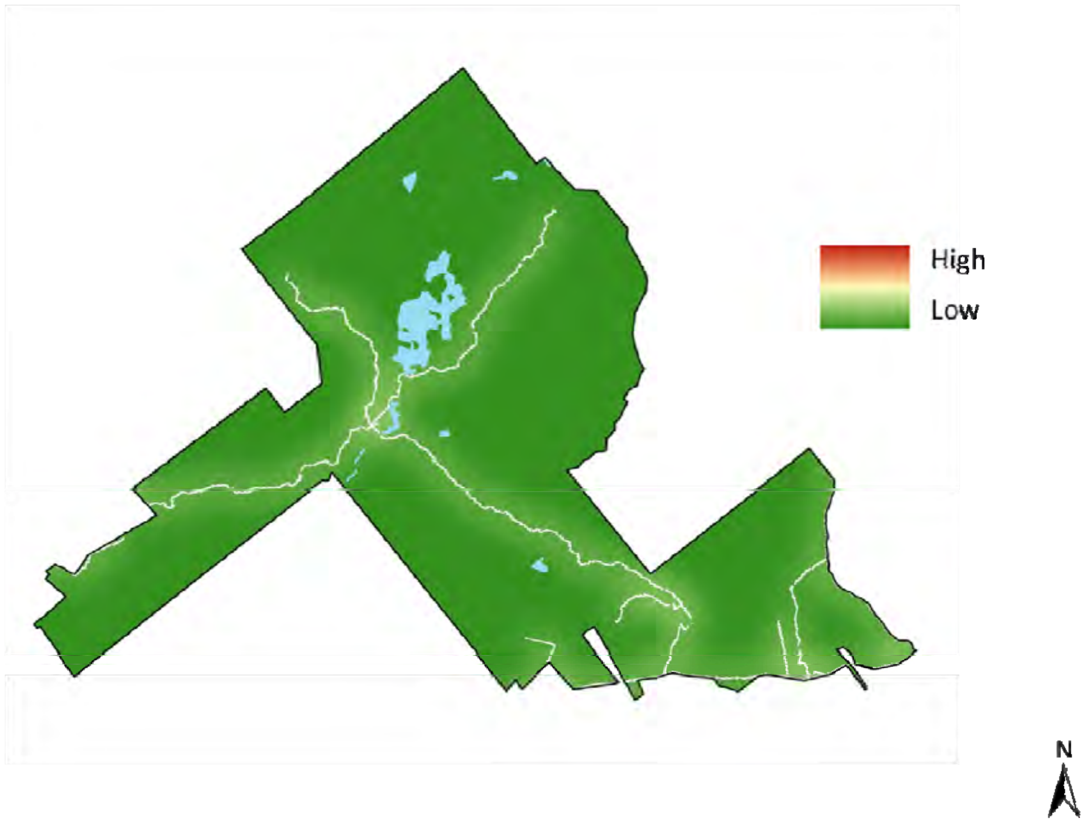


Figure 14. Future threats on the Boreas Tract: Habitat Loss

Habitat loss can also be assessed through the Human Footprint (Sanderson et al. 2002, Woolmer et al. 2008, Trombulak et al. 2010). The human footprint is a representation of the magnitude of human transformation of the landscape and was originated at a global scale by Sanderson et al. (2002). Woolmer et al. (2008) used an adaptation of Sanderson's methodology to map the human footprint at the Northern Appalachian ecoregional scale. Scores range from 0 to 100 and represent the relative impact associated with human settlement, access, land-use change, and electrical power infrastructure. This dataset provides a relative measurement of human transformation of the natural landscape and has been projected into the future under several land use change scenarios in order to allow for evaluation of future human footprint. Similar to the UMass data, the human footprint map shows low human footprint throughout much of the tract with the exception of areas influenced by roads. There is no difference in the human footprint for the current and future scenarios on the Boreas tract, indicating a low expectation for high development pressure on the tract or in the immediate vicinity (Figure 15).

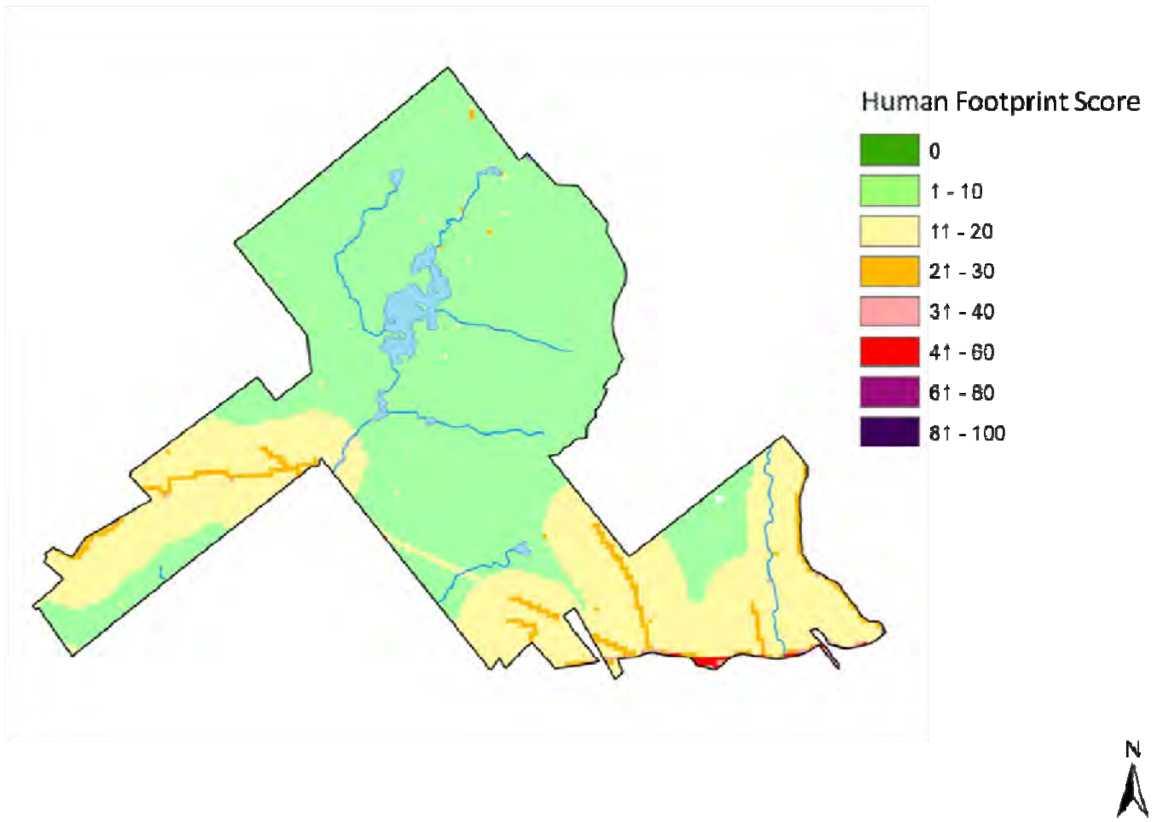


Figure 15. Future threats on the Boreas Tract: Human Footprint

Climate Stress

Perhaps a more significant threat to the future of the Boreas tract is climate change. Climate stress has been mapped for the DSL project as a component of future ecological integrity and future landscape capability models for representative species (McGarigal 2014). The climate stress metric measures the magnitude of climate change stress at the focal cell based on the climate niche of the corresponding ecological system and the predicted change in climate (i.e., how much is the climate of the focal cell moving away from the climate niche envelope of the corresponding ecological system). When mapped on the Boreas, these data demonstrate that the boreal upland forest habitats show the greatest degree of potential future threat from climate change, with lowest threats in the emergent marsh and wet meadow/shrub marsh habitats (Figure 16). Much of the tract, however, appears to be at risk from climate stress. Adirondack boreal habitats, in particular, are expected to be particularly at risk from warming global temperatures (Glennon 2014).

Risks to Individual Species

A number of species may be at risk from future threats on the Boreas tract. If we consider threats posed by habitat loss, they are primarily associated with existing or future areas of development on the tract. Currently, the majority of anthropogenic habitat on the Boreas consists of local roads (approximately 327 acres or 1.6% of the tract). It is almost impossible to overstate the degree to which roads influence wildlife populations (Trombulak and Frissell 2000), even small forest roads like the ones on the Boreas (Robinson et al. 2010). Impacts of forest roads on species and ecosystems begin during the construction phase, but persist and accumulate well after a road is no longer in use (Robinson et al. 2010), with effects including mortality from construction, mortality from vehicle collision, modification of animal behavior, alteration of the physical environment, alteration of the chemical environment, spread of exotics, and increased use of areas by humans (Trombulak and Frissell 2000). Species most at risk from roads tend to be specialists requiring interior forest conditions, especially those that are K-selected species (i.e., typically having a large body size, long life span, and few offspring), including species such as forest songbirds, salamanders, flying squirrels, pileated woodpecker, northern goshawk, and American marten (Robinson et al. 2010). Turtles are extremely vulnerable to mortality on roads because they are slow moving, long-lived and do not reach reproductive age for many years (Gibbs and Shriver 2002). Though future road construction on the Boreas tract is probably unlikely, any improvement or expansion of existing roads, as well as increased vehicular traffic on current roads (Charry and Jones 2010), is likely to have negative impacts on a number of species. Examples of species likely found on the Boreas tract which may be at risk from the effects associated with the road network include: hermit thrush, ovenbird, scarlet tanager, red-backed salamander, painted turtle, snapping turtle, American marten.

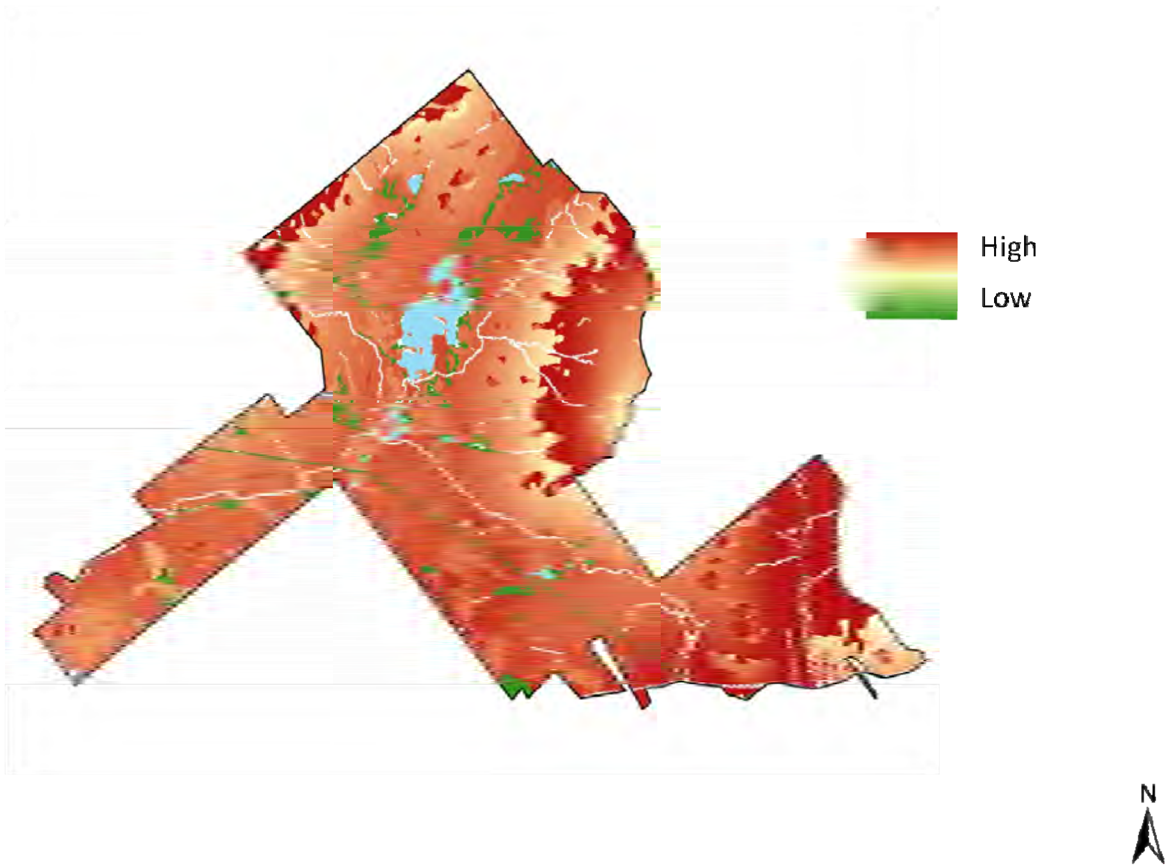


Figure 16. Future threats on the Boreas Tract: Climate Stress

Habitat loss associated with roads may also result from indirect effects including predation pressure on interior nesting bird species, spread of invasive species from road edges, and noise disturbance created by road use. There exists the potential for these same indirect effects in association with trails on the Boreas tract. Although nature-based tourism provides a variety of benefits to humans, there is also evidence that human recreation activity can negatively impact plant and animal communities. The common assumption is that these activities have little or no impact on wildlife communities. However, this assumption is called into question by a growing scientific literature that links recreation activity to declines in wildlife abundance or density, changes in habitat use, increased physiological stress, reduced reproductive success, and altered behavior (Hammit et al. 2015). The potential effects of increased recreation on wildlife on the Boreas tract are likely to be highly variable depending on the type, intensity, and spatial and temporal patterns of activities occurring. Species that have demonstrated sensitivity to recreational activities (Gutzwiller and Anderson 1999, Titus and Van Druff 1981, Skagen et al. 2001, Garber and Burger 1995) and which may occur on the Boreas tract include: hermit thrush, common loon, great blue heron, and wood turtle.

Climate change is potentially the greatest long-term threat to the future of wildlife on the Boreas tract. Several of the same characteristics that tend to make species vulnerable to impacts from habitat loss and alteration may also make them vulnerable to climate change including specialization on restricted habitat types or food sources. Because the Adirondack Park is located at the transition zone between the boreal forest biome to the north and the temperate forest biome to the south, species inhabiting our boreal habitats are already experiencing the challenges of life at the range margin. There are several species of boreal forest birds that are found in the Adirondack Park and almost nowhere to the south of us; these species are highly specialized on the restricted and naturally fragmented boreal habitats found throughout the park. A number of mammal species make use of boreal habitats as well. Because they are cold, wet, northern habitat types adapted to northern processes and temperature regimes, boreal habitats are expected to be at great risk from climate change in the Adirondacks (Jenkins 2010, Glennon 2014) and across the globe (Moore 2002). Boreal bog and Acadian-Appalachian montane spruce-fir have been identified as habitats highly vulnerable to climate change in New York (Hilke and Galbraith 2013). As such, species that may occur in these habitats on the Boreas and are therefore potentially threatened by future climate change include: black-backed woodpecker, boreal chickadee, golden-crowned kinglet, gray jay, olive-sided flycatcher, palm warbler, rusty blackbird, yellow-bellied flycatcher, American marten, northern flying squirrel, mink frog. Among the representative species modeled on the tract by UMass, Bicknell's thrush and blackpoll warbler habitats appear to overlap most closely with predicted areas of climate stress.

The Boreas Tract in Context: What it Adds

The Boreas tract is adjacent and ecologically similar to the High Peaks Complex which includes the High Peaks Wilderness, Ampersand Primitive Area, and Johns Brook Primitive Corridor. I considered the Boreas in the context of the High Peaks to determine what it would bring to an expanded High Peaks Wilderness if such a classification were made.

Primary Habitats

In terms of the primary habitats that make up the majority of both the Adirondack Park and the Boreas tract, the Boreas differs from the park as a whole in having a greater proportion of Boreal Upland Forest (18% vs 10%) and lesser amount of Northern Hardwood and Conifer (58% vs 62; Figure 17). In comparison to the High Peaks unit, however, it has more Northern Hardwood and Conifer (58% vs 37%) and a much smaller proportion of Boreal Upland Forest (18% vs 48%). It has more Northern Swamp as a proportion of its area than does the High Peaks or the Adirondacks as a whole. It is otherwise fairly similar to the Park and to the High Peaks unit in terms of other dominant habitat types. The amount of Northern Swamp habitat present on the Boreas tract is notable. As mentioned previously, these forested wetlands are uncommon in the glaciated northeast except in areas with extensive limestone or similar substrate and across the Adirondacks, the Northern Swamp type makes up only 10% of the landscape, distributed primarily on Resource Management and Wild Forest lands, with a smaller proportion in Wilderness (Glennon and Curran 2013).

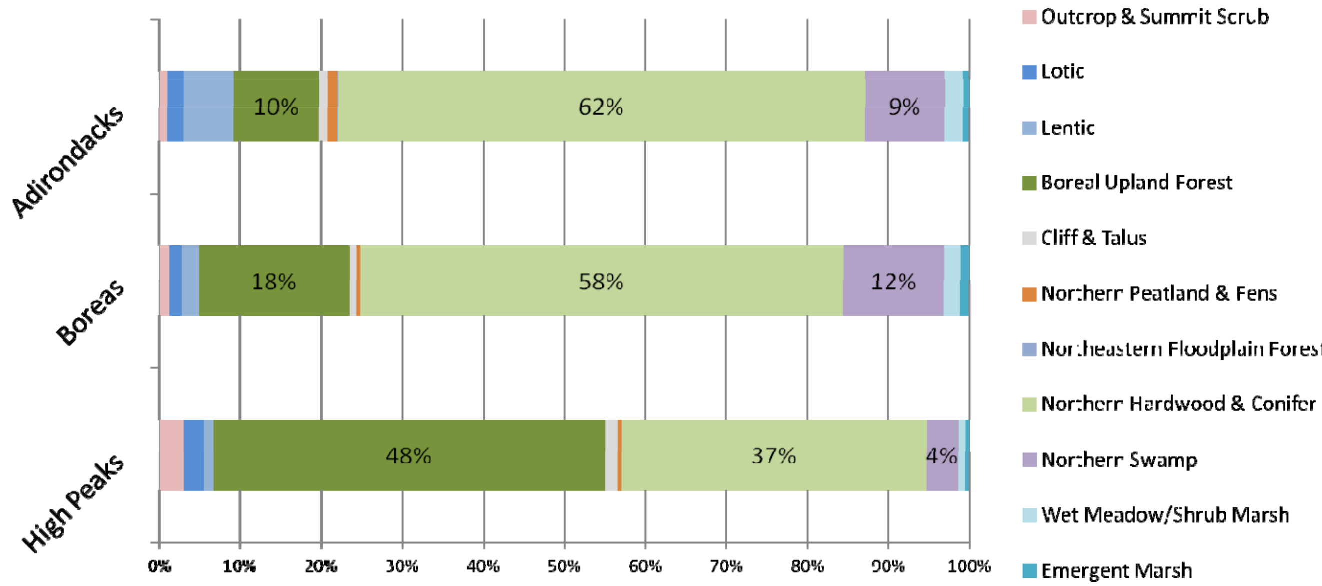


Figure 17. The Boreas Tract in context: proportional representation of primary habitats

High Quality Lands

I examined the Boreas in comparison to the High Peaks unit with respect to 4 metrics that indicate the relative condition of the tract including terrestrial resilience, ecological integrity, local connectivity, and regional flow (Table 6, Figure 18).

Table 6. Proportions (%) of the High Peaks and Boreas tracts classified by degree of terrestrial resilience, ecological integrity, local connectedness, and regional flow.

	Resilience	Integrity	Connectivity	Regional Flow
High Peaks Wilderness				
Far above average	15	28	91	0
Above average	82	59	7	87
Average	1	10	1	10
Below average	2	3	1	3
Far below average	1	0	0	0
Boreas Tract				
Far above average	26	12	97	1
Above average	71	64	0	82
Average	1	17	1	12
Below average	2	5	2	5
Far below average	0	0	0	0

The Boreas adds significantly to all of these qualities. In terms of resilience, if added to the High Peaks, the Boreas tract would increase the amount of high resilience lands (above or far above average) in the complex by 20,236 acres or 10% (Figure 19). It would also add 15,589 acres of lands of above average ecological integrity (8% increase, Figure 20), 20,261 acres of above average connectivity (9% increase, Figure 21), and 17,437 acres of above average regional flow (8% increase, Figure 22) to the High Peaks.

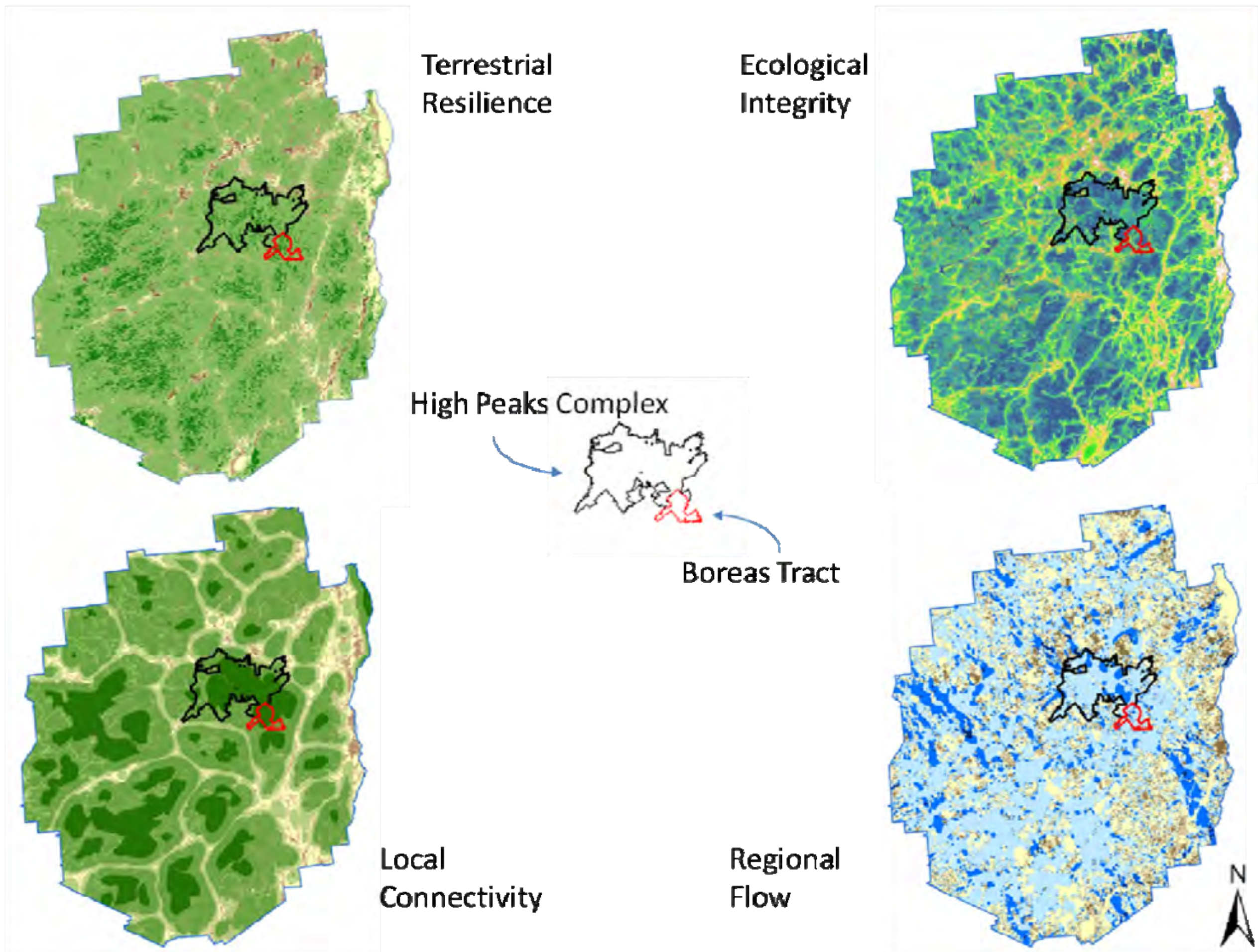


Figure 18. The Boreas Tract in context: condition metrics

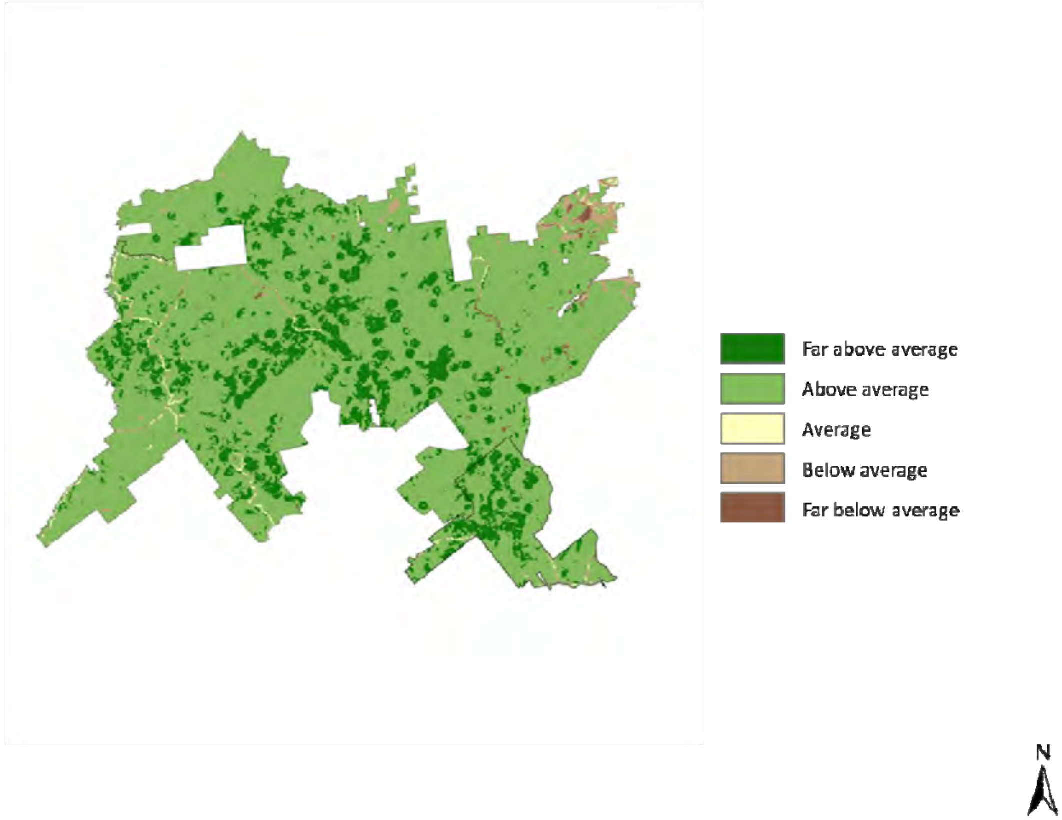


Figure 19. The Boreas Tract in context: terrestrial resilience

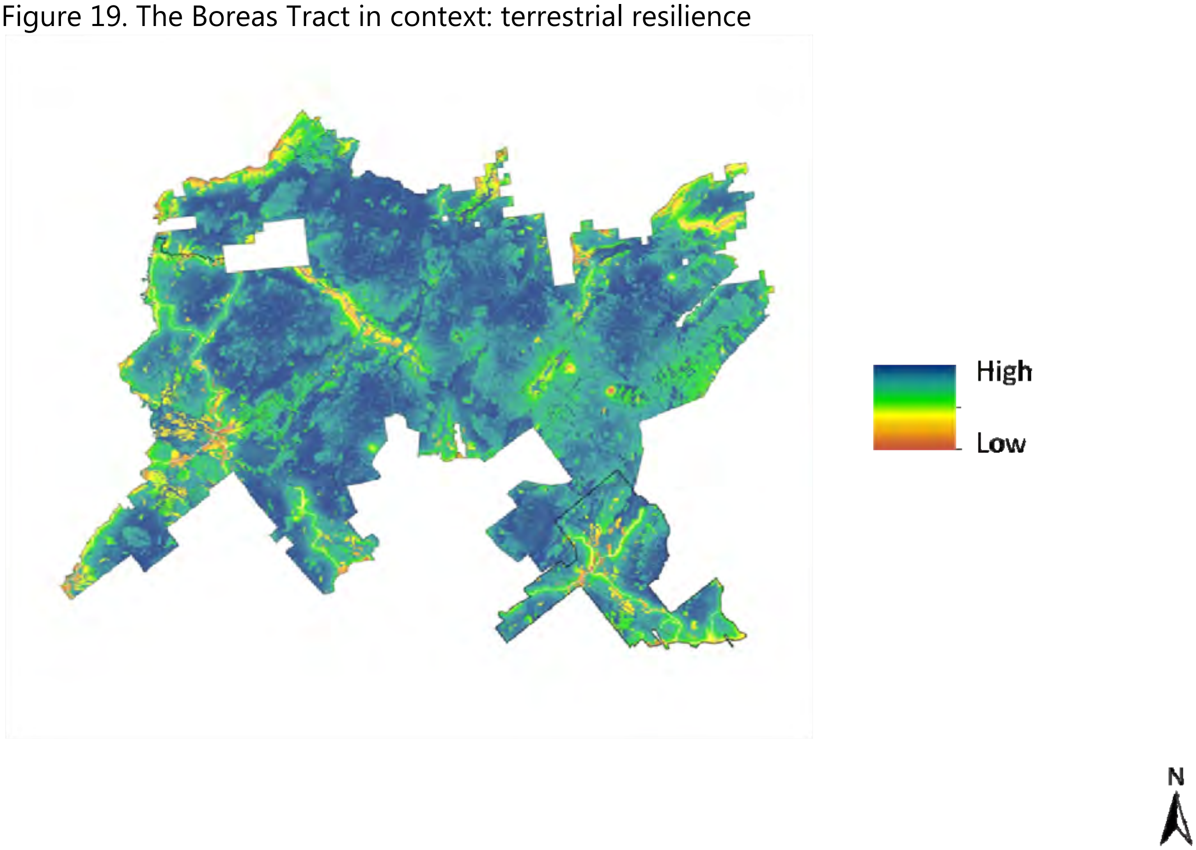


Figure 20. The Boreas Tract in context: ecological integrity

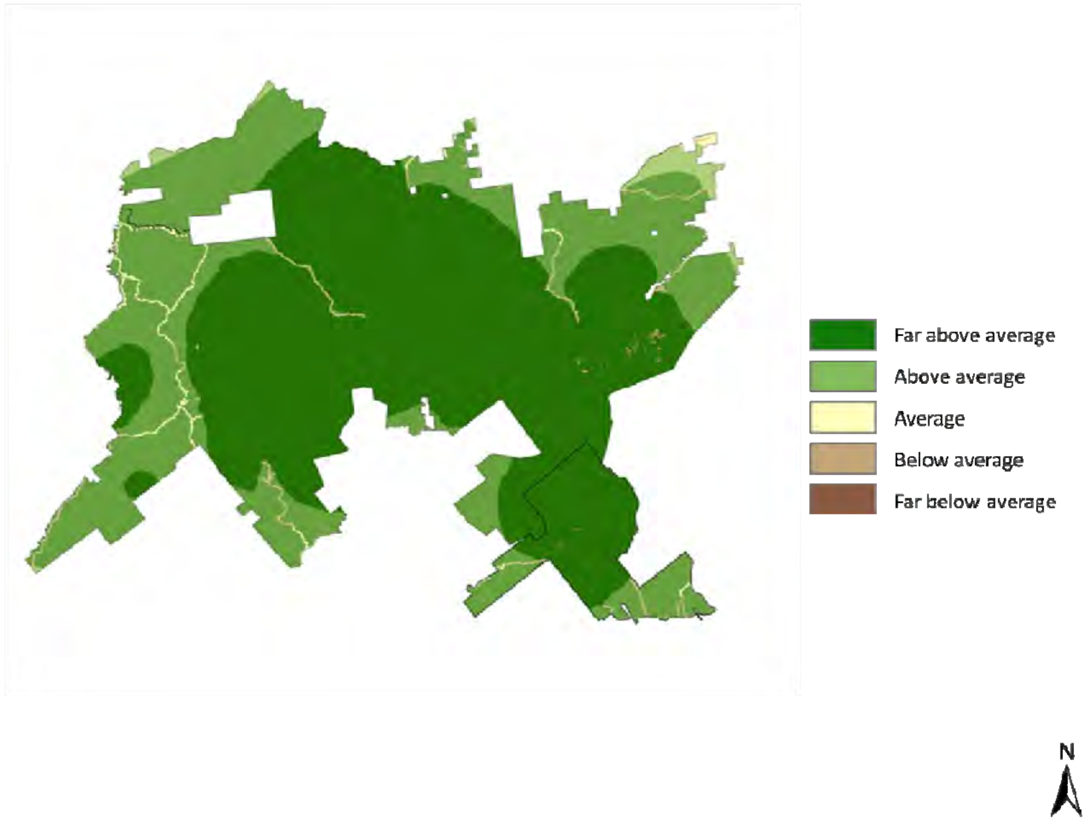


Figure 21. The Boreas Tract in context: local connectivity

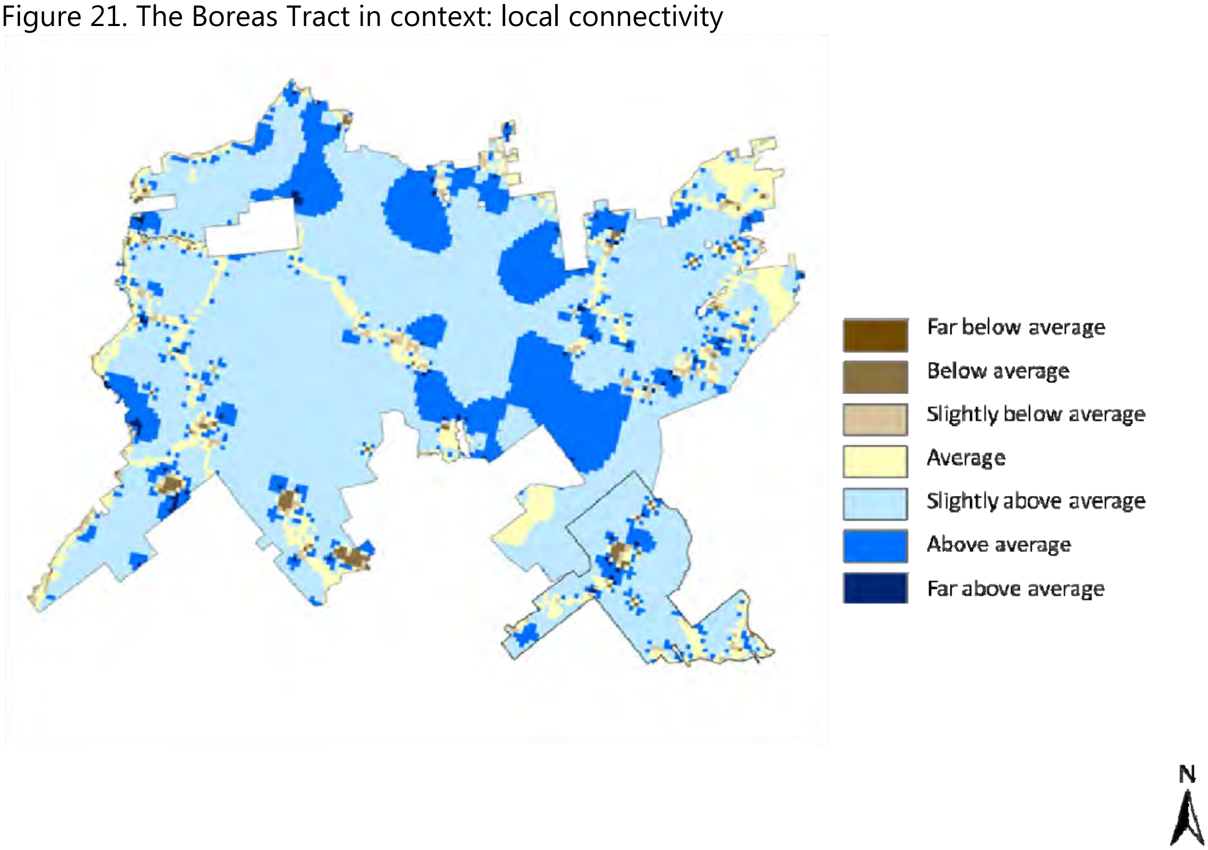


Figure 22. The Boreas Tract in context: regional flow

The Boreas Tract in Context: How it Compares

It is potentially of interest to consider not only what the Boreas tract may add to an expanded High Peaks complex, but how it compares to existing state land units. It is difficult to choose a set of units against which to compare the Boreas because those that are similar in area tend to differ in habitat composition and underlying geology and those that are more similar by composition differ strongly by size. To avoid any bias in selection, I instead compared the tract to nearly all units using the following process. I obtained a shapefile from the Council delineating all areas of New York state land and then filtered out all campgrounds, ski areas, state forests, boat launches, access points, islands and other small parcels and selected tracts that were (1) entirely within the blue line, and (2) at least 1000 acres in size. What remained is 44 state land units that are classified as primitive, canoe, wilderness, or wild forest (Table 7). It is important to note that these are units consisting fully of state-owned lands and not the "management units" that are utilized by NYSDEC for planning purposes. The full management units are larger and encompass areas of both state and private land. I then compared the Boreas tract to these areas in terms of habitats, patch sizes, aboveground forest biomass, underlying geology, resilience, integrity, connectedness, and regional flow. I considered wilderness, wild forest, and primitive areas in these comparisons (omitting canoe area) as the most likely potential designations for the Boreas.

Table 7. State land units used for comparative purposes, by classification and acreage.

Name	Classification	Size (Acres)
Blue Mountain	Wild Forest	42,554
Blue Ridge	Wilderness	47,327
Cranberry Lake	Wild Forest	25,883
Dead Creek	Primitive	1,135
Deer River	Primitive	1,871
Dix Mountain	Wilderness	44,773
Eastern Five Ponds	Primitive	1,909
Essex Chain Lakes	Primitive	6,959
Five Ponds	Wilderness	131,303
Fulton Chain	Wild Forest	16,023
Giant Mountain	Wilderness	23,667
Hah-De-Ron-Dah	Wilderness	25,850
Hammond Pond	Wild Forest	45,575
High Peaks	Wilderness	205,959
Hoffman Notch	Wilderness	38,493
Horseshoe Lake	Wild Forest	17,130
Hudson Gorge	Wilderness	23,470
Hurricane Mountain	Wilderness	13,976
Jay Mountain	Wilderness	7,871
Jessup River	Wild Forest	48,454
Little Moose	Wilderness	12,283
Madawaska-Quebec Brook	Primitive	6,038
McKenzie Mountain	Wilderness	37,416
Moose River Plains	Wild Forest	66,658
Pepperbox	Wilderness	24,324
Pharoah Lake	Wilderness	46,209
Pigeon Lake	Wilderness	50,481
Pine Lake	Primitive	2,789
Raquette-Jordan	Primitive	12,370
Raquette River	Wild Forest	3,546
Round Lake	Wilderness	11,405
Saint Regis	Canoe	18,964
Saranac Lakes	Wild Forest	80,682
Sargent Ponds	Wild Forest	43,491
Sentinel Range	Wilderness	23,864

Siamese Ponds	Wilderness	114,983
Silver Lake	Wilderness	109,511
Split Rock	Wild Forest	3,542
Vanderwhacker Mountain	Wild Forest	85,091
Watson's East Triangle	Wild Forest	13,472
West Canada Lake	Wilderness	174,366
West Canada Mountain	Primitive	3,139
William C. Whitney	Wilderness	20,362
Wilmington	Wild Forest	16,945
Boreas Tract	N/A	20,845

Composition: Terrestrial Habitats, Geology, Patch Size, Forest Biomass

By proportion, the Boreas tract is most similar to wilderness areas in terms of representation of the dominant terrestrial matrix habitats of Northern Hardwood and Conifer and Boreal Upland Forest (macrogroup level, Figure 23). Among the smaller patch-forming habitats, it is fairly similar in its composition to most wilderness, wild forest, and primitive tracts.

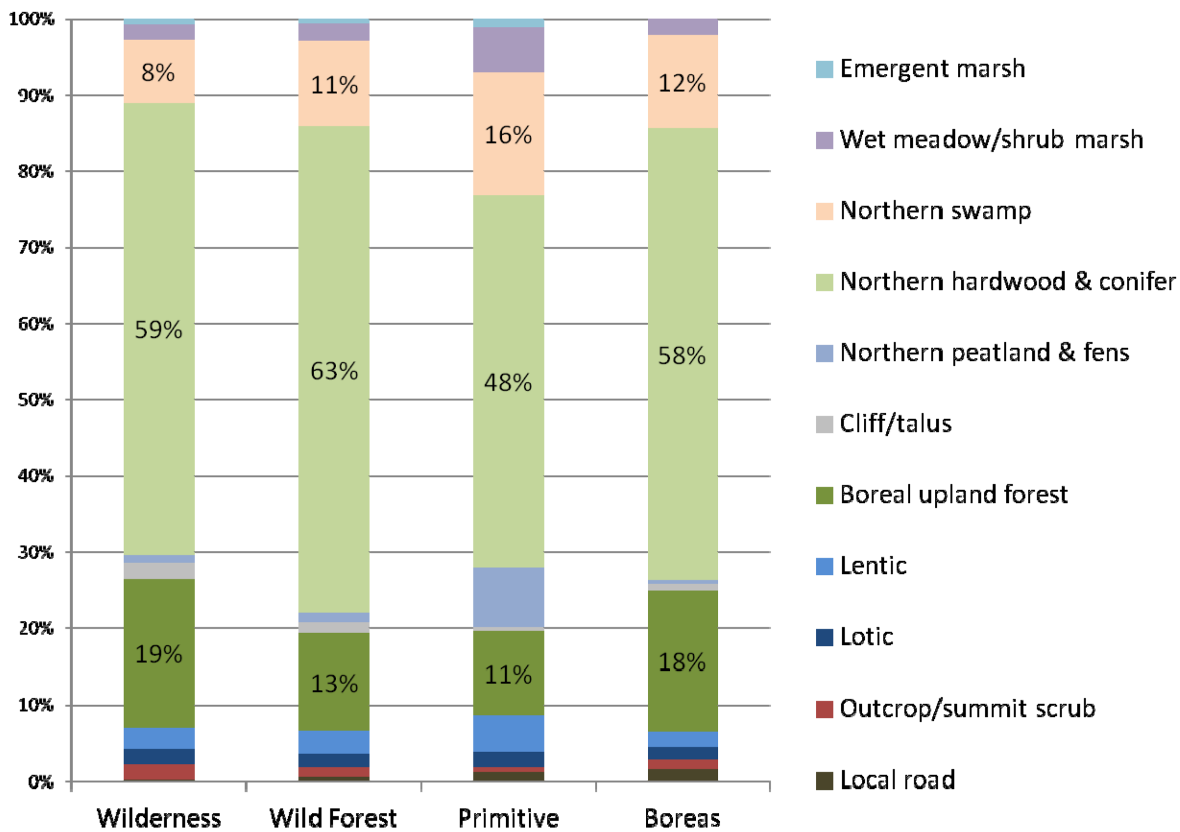


Figure 23. The Boreas Tract in context: comparison to state lands by dominant habitats

Among the full set of terrestrial habitat types, it stands out against all of the units by having a greater proportion of its area made up of 2 specific types: Laurentian-Acadian Calcareous Rocky Outcrop and Laurentian-Acadian Alkaline Conifer Hardwood Swamp. These represent very small components of the tract (1-5%) but a larger proportion by area in comparison to all wilderness, wild forest, and primitive units.

The underlying geologic settings on which the Boreas is found may explain why it stands out in the context of these few habitats (Table 8). As a component of TNC's terrestrial resilience mapping, information on geology, elevation, and landform were used to describe a set of geophysical settings on the northeast landscape, which serve as the foundation for the species habitats and natural communities found on them. The combination of geology, elevation, and landform resulted in 30 distinct geophysical settings, 12 of which occur in the state land units evaluated here (Table 8). Complete definitions of these geophysical settings are provided in Anderson et al. (2012). It is noteworthy that wilderness, wild forest, and primitive areas are generally dominated by the mid elevation granite setting (51 – 62% on average), whereas the primary geophysical setting underlying the Boreas tract is mid elevation mafic. These mid elevation mafic settings are mountainous and often intermixed with granite, but are derived from volcanic basalts or intrusive igneous rocks and generally supporting a richer flora and fauna than the natural communities typical of the acid, nutrient-poor shallow soil environments characterizing mid elevation granite more dominant in wilderness, wild forest, and primitive areas.

Table 8. Proportional representation (mean %) of 12 geophysical settings on wilderness, wild forest, primitive areas, and the Boreas tract.

	Wilderness	Wild Forest	Primitive	Boreas
Mid Elevation Granite	51	55	62	21
Mid Elevation Mafic	21	18	11	67
Low Elevation Fine Silt	0	3	0	0
Low Elevation Sedimentary and Coarse Sand	0	1	0	0
Mid Elevation Acidic Sedimentary	4	8	3	0
Steep Slopes on Sedimentation	6	9	11	0
Low Elevation Mafic	0	4	0	0
Mid Elevation Surficial Sediments	0	0	1	0
Mid Elevation Calcareous	2	1	11	0
High Elevation Granite or Mafic	6	2	0	0
Alpine and Subalpine	9	0	0	12
High Elevation Sedimentary	0	0	0	0

The Boreas tract stands out in having generally larger average patch size of Northern Hardwood and Conifer and Northern Peatland types than the state land units and is similar to wilderness for those two types, while it is more similar to wild forest in patch size for Boreal Upland Forest and Wet Meadow/Shrub Marsh, and like primitive areas in its relatively high mean patch size of lake/pond habitat (Table 9). I evaluated patch sizes of the primary habitat types found on state lands and on the Boreas tract by converting the raster data for macrogroup level habitats into a polygon coverage and selecting polygons of individual habitat types within the wilderness, wild forest, and primitive areas. I then used the calculate geometry function within the ArcMap table to determine mean patch sizes. Because the conversion of a raster to a polygon coverage is not perfect, the resulting patch sizes are also not perfect, but I believe them to be reasonably accurate measurements of the patch sizes of individual habitat types. It is important to note that these are patch sizes of *individual habitat types* and not more general patch sizes of forest/nonforest, a characteristic often considered in the context of habitat fragmentation.

Table 9. Mean patch size of dominant terrestrial habitat types within wilderness, wild forest, primitive units and the Boreas tract (acres).

	Wilderness	Wild Forest	Primitive	Boreas
Northern Hardwood and Conifer	15.0	6.8	6.7	17.0
Boreal Upland Forest	12.8	6.4	4.4	6.1
Cliff and Talus	5.5	4.9	8.1	3.7
Outcrop and Summit Scrub	6.0	5.4	5.7	4.1
Northern Peatland	4.7	4.2	4.2	5.3
Northern Swamp	2.7	2.4	2.0	3.6
Wet Meadow/Shrub Marsh	3.8	3.1	2.3	2.8
Emergent Marsh	1.7	1.6	1.5	1.5
Lentic	4.0	3.8	9.3	6.9

In terms of aboveground forest biomass, the Boreas tract is very similar to wilderness and wild forest when biomass is averaged across units (all 3 have a per pixel mean of 151 kg/m^2 x 10), whereas primitive areas have lower mean aboveground forest biomass (mean 142 kg/m^2 x 10).

Condition: Resilience, Integrity, Connectedness, Regional Flow

I used the resilience, ecological integrity, local connectivity, and regional flow metrics described above to calculate mean values for each of the state land units in comparison to the Boreas tract. The Boreas tract stands out for resilience (Table 10, Figure 24) and local connectivity (Figure 25), scoring higher than wilderness, wild forest, and primitive units when averaged across classifications. In terms of integrity (Figure 26), the Boreas scores lower than wilderness but higher than wild forest or primitive areas while on regional flow (Figure 27), it scores slightly lower than wilderness and wild forest and higher than primitive. Regional flow is less applicable here in judging the similarity of the Boreas to various state land units because it is a metric inherently aimed at considering large landscape patterns. It is more appropriately an indicator of the degree to which larger scale ecological flows incorporate the Boreas tract, rather than an indicator of the relative quality of the tract itself. When considered together, a scatterplot of values for resilience, integrity, and local connectivity reveals that Boreas has strongest similarities with existing wilderness areas (Figure 28).

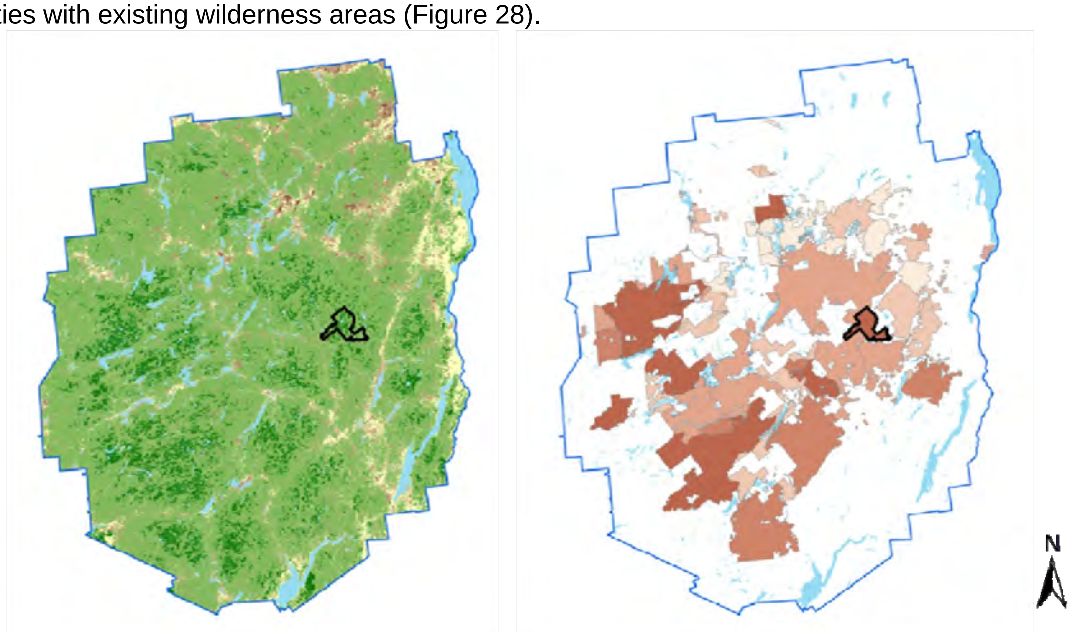


Figure 24. Resilience overall and by unit, Boreas outlined in black

Table 10. Mean values for the above condition metrics calculated across wilderness, wild forest, and primitive units as well as the Boreas tract.

	Resilience	Integrity	Connectedness	Regional Flow
Wilderness	1085	81	1756	743
Wild Forest	877	71	1331	712
Primitive	969	67	1506	559
Boreas	1296	76	1975	673

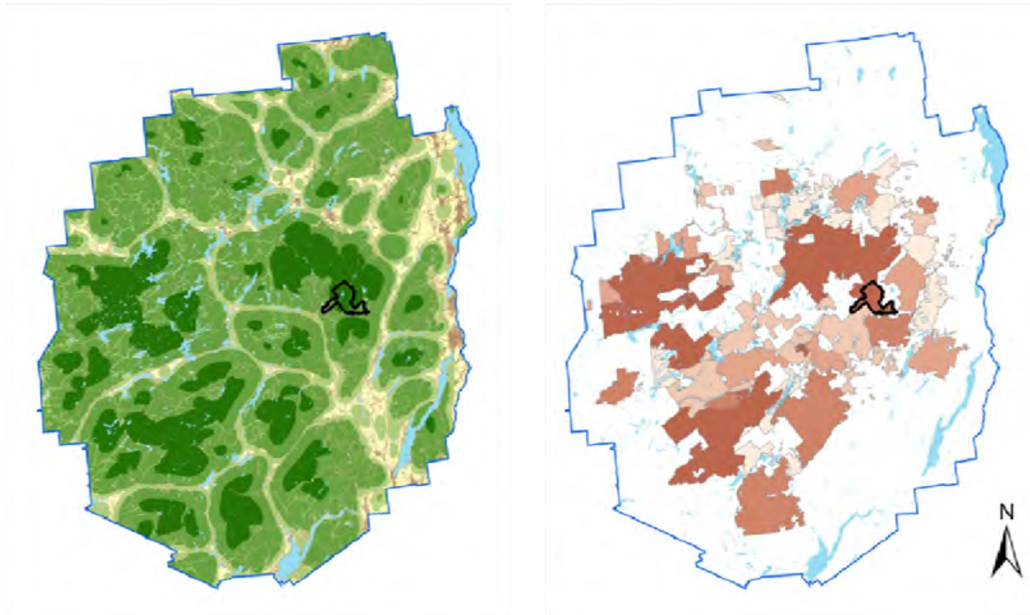


Figure 25. Local connectedness overall and by unit, Boreas outlined in black

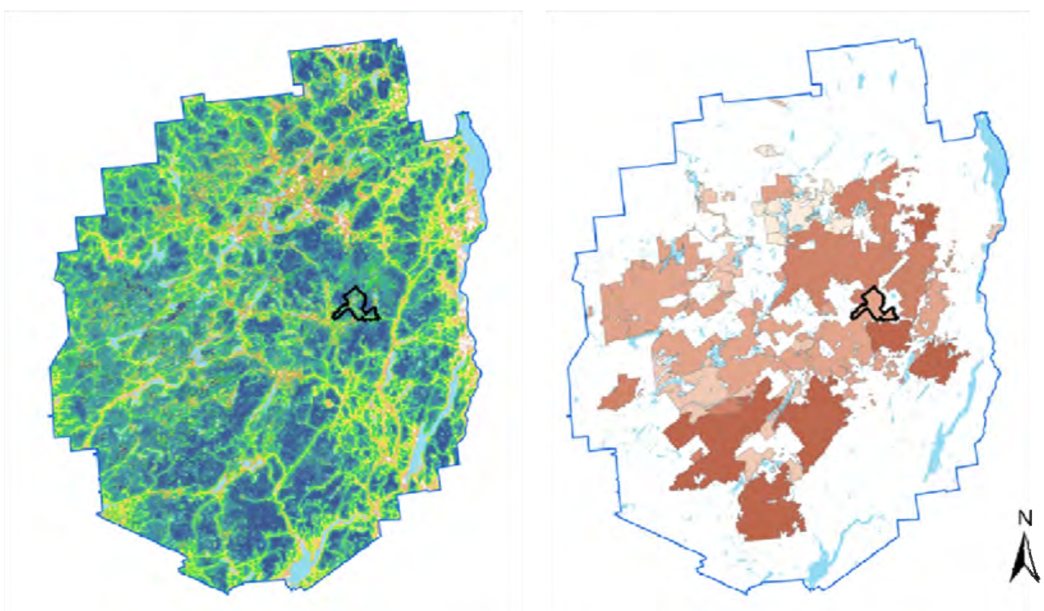


Figure 26. Ecological integrity overall and by unit, Boreas outlined in black

I calculated the correlation between area and each of these metrics to assess the degree to which area of an individual unit may influence its mean score for these condition metrics. Area was mildly correlated with resilience (R = 0.261), integrity (0.373), connectivity (0.342), and regional flow (0.086). These are generally low correlations and especially low for regional flow; they are significant correlations only in the case of integrity and local connectivity. This information helps to provide context in consideration of the relative quality of the Boreas tract versus the state land units. Values for all units are provided in table 11.

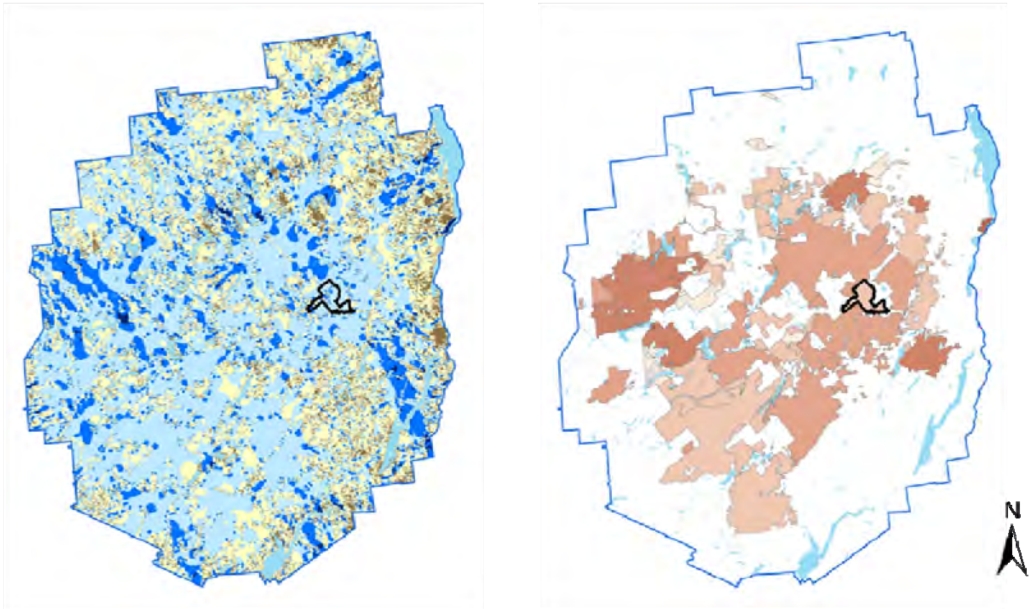


Figure 27. Regional flow overall and by unit, Boreas outlined in black

Table 11. Means per unit for condition metrics calculated for wilderness, wild forest, and primitive units and the Boreas tract.

Name	Class	Resilience	Integrity	Connectedness	Regional Flow
Blue Mountain	Wild Forest	975	76	1473	681
Blue Ridge	Wilderness	1075	78	1687	741
Cranberry Lake	Wild Forest	1076	78	1600	810
Dead Creek	Primitive	597	69	1227	648
Deer River	Primitive	362	69	801	357
Dix Mountain	Wilderness	984	81	1717	738
Eastern Five Ponds	Primitive	1018	49	1526	842
Essex Chain Lakes	Primitive	1173	65	1577	368
Five Ponds	Wilderness	1342	78	2039	869
Fulton Chain	Wild Forest	969	63	1318	497
Giant Mountain	Wilderness	560	81	1283	582
Hah-De-Ron-Dah	Wilderness	1301	81	1851	820
Hammond Pond	Wild Forest	933	75	1176	569
High Peaks	Wilderness	1131	83	1934	804
Hoffman Notch	Wilderness	1112	88	1810	784
Horseshoe Lake	Wild Forest	627	68	1145	471
Hudson Gorge	Wilderness	1293	76	1701	778
Hurricane Mountain	Wilderness	743	85	1506	678
Jay Mountain	Wilderness	1053	89	1848	969
Jessup River	Wild Forest	877	70	1267	575
Little Moose	Wilderness	1245	79	1837	582
Madawaska-Quebec Brook	Primitive	893	60	1526	223
McKenzie Mountain	Wilderness	909	82	1630	840
Moose River Plains	Wild Forest	1017	70	1469	634
Pepperbox	Wilderness	1272	75	1901	956
Pharoah Lake	Wilderness	1199	85	1702	956
Pigeon Lake	Wilderness	1311	75	1923	863
Pine Lake	Primitive	1469	72	1922	671

Raquette-Jordan	Primitive	915	67	1494	610
Raquette River	Wild Forest	904	62	1257	482
Round Lake	Wilderness	969	68	1628	531
Saranac Lakes	Wild Forest	639	59	1135	658
Sargent Ponds	Wild Forest	1022	74	1570	750
Sentinel Range	Wilderness	561	82	1264	654
Siamese Ponds	Wilderness	1226	85	1804	718
Silver Lake	Wilderness	1237	88	1840	645
Split Rock	Wild Forest	1030	65	838	1888
Vanderwhacker Mountain	Wild Forest	1056	78	1496	708
Watson's East Triangle	Wild Forest	1056	75	1709	771
West Canada Lake	Wilderness	1298	86	1999	664
West Canada Mountain	Primitive	1328	83	1972	754
William C. Whitney	Wilderness	980	75	1967	436
Wilmington	Wild Forest	92	79	1183	473
Boreas Tract	N/A	1296	76	1975	673

Conclusions

The transition of the Boreas tract to the New York State Forest Preserve presents a tremendous opportunity to enhance protection for critical resources and to provide new recreational opportunities in this region of the Park. I have attempted to provide a variety of information to describe the biological resources of the tract in terms of their composition and condition, and to examine those resources in the context of existing state lands. Implemented jointly by the APA and the DEC, the New York State Land Master Plan (SLMP) serves as a framework for the stewardship of the Forest Preserve. Among the fundamental determinants of land classification, the SLMP acknowledges both the physical characteristics of a tract which have direct bearing on the capacity of the land to accept use, as well as intangible considerations (including social or psychological) that have an inevitable impact on the character of the land (Adirondack Park Agency 1987). This analysis has not made any consideration of intangible characteristics that may influence the character of the land and the potential recreational opportunities that may be desired upon it. I have considered only the ecological characteristics of the tract and their relative quality, as measured via the use of emerging datasets that describe the extent and condition of terrestrial and aquatic ecosystems in the Northeast. Among the physical characteristics of the site that may be considered as a component of a classification decision, I would highlight the following:

- The Boreas tract contains a number of significant habitats including Boreal Upland Forest, Northern Swamp, and Wet Meadow/Shrub Marsh; these are among a set of habitats thatmake up <15% of the Adirondack landscape but may provide suitable habitat for more than 50% of our terrestrial vertebrates and a significant number of our rare species (Glennon and Curran 2013). At the system level, Laurentian-Acadian Alkaline Conifer Hardwood Swamp, Laurentian-Acadian Pine Hemlock Hardwood Forest, Laurentian-Acadian Wet Meadow/Shrub Swamp, Laurentian Acadian Freshwater Marsh, and Boreal Laurentian Acadian Acidic Basin Fen are found on the tract. Across the Adirondacks, more than 50% of these habitat types are currently located on private lands.
- Although empirical species data from the site are unavailable, available information suggests that the tract very likely provides habitat for a number of representative and rare species.
- Climate change is probably the most significant future threat and will impact boreal habitats on the tract more than wetland and northern hardwood forest habitats. Species associated with those habitats are probably most at risk on the tract.
- If added to the High Peaks management unit, the Boreas tract would enhance overall resilience, integrity, and local and regional connectedness of that unit.

- In terms of terrestrial habitats, the profile of the Boreas tract for major forest types is most similar to existing wilderness tracts. With respect to smaller patch forming habitats (e.g., rocky outcrops, wetlands), it characteristic of most wilderness, wild forest, and primitive tracts.
- The Boreas tract is distinctive from existing state land areas in terms of its underlying geology, much of which is derived from volcanic basalts or intrusive igneous rocks and generally supporting a richer flora and fauna than the natural communities typical of the acid, nutrient-poor shallow soil environments characterizing mid elevation granite more dominant in wilderness, wild forest, and primitive areas.
- Its geologic characteristics may be the reason why the Boreas tract supports a higher proportion by area of a number of distinct habitat types in comparison to existing state land units – these types are Laurentian-Acadian Calcareous Rocky Outcrop and Laurentian-Acadian Alkaline Conifer Hardwood Swamp. The latter is uncommon in the glaciated northeast.

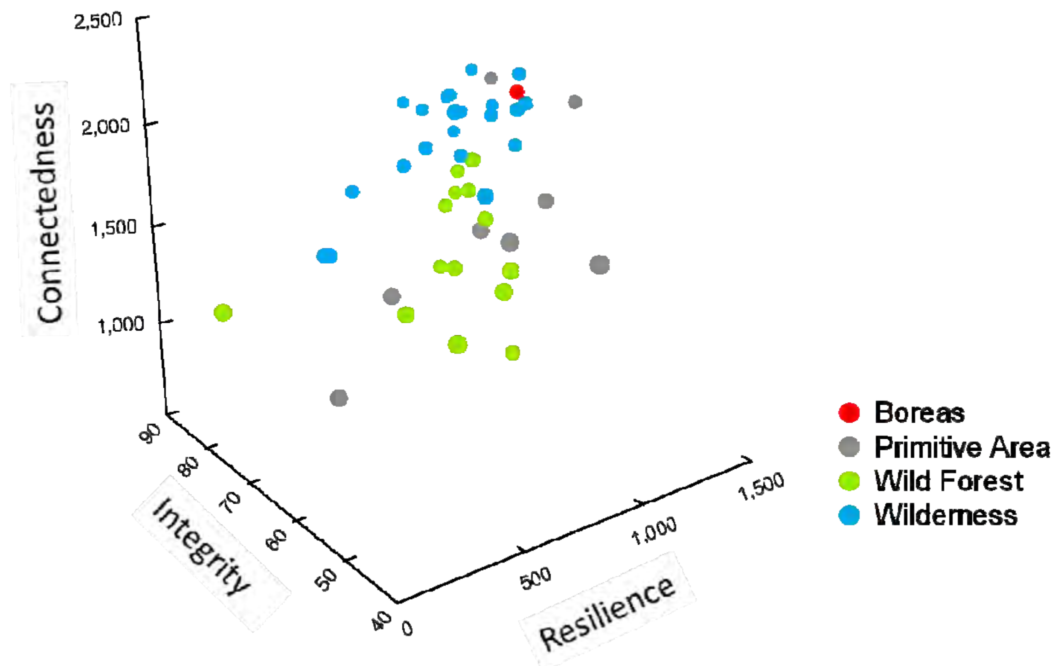


Figure 28. Resilience, integrity, and connectivity values for existing units and the Boreas Tract

- By patch size distribution of major habitat types, the Boreas tract is similar to most state land units with the exception of Northern Hardwood and Conifer, Northern Peatland, and Northern Swamp, patches of which are larger, on average, on the Boreas tract than those on existing state land units.
- In terms of characteristics that are most closely aligned with the ability of the tract to maintain ecological processes and biodiversity over time, the Boreas tract is most similar to existing areas of wilderness. These characteristics include resilience, ecological integrity, and local and regional connectivity, all of which are above average on the Boreas tract. With respect to resilience and local connectivity, in particular, the tract is exceptional – among the top 15% and 10%, respectively, when compared against existing state land units for these measures.

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