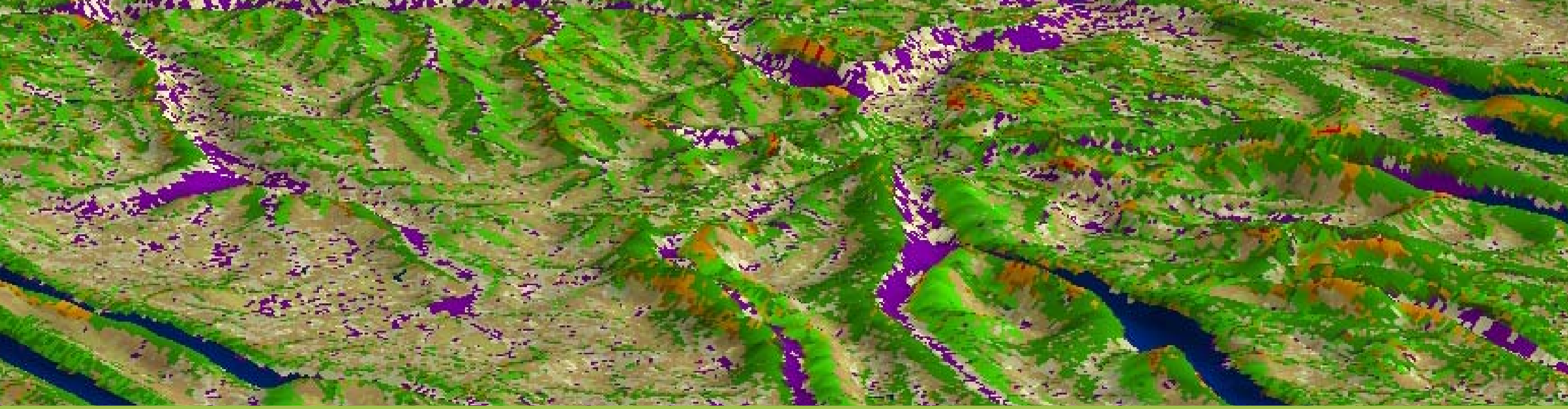

Resilient Sites for Species Conservation

in the Northeast and Mid-Atlantic Region

The Nature Conservancy · Eastern Conservation Science
Mark G. Anderson, Melissa Clark, and Arlene Olivero Sheldon

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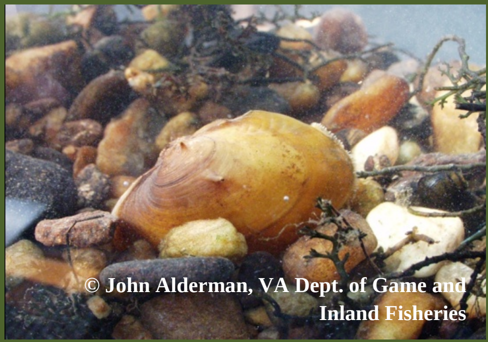

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Northeast Association of Fish and Wildlife Agencies

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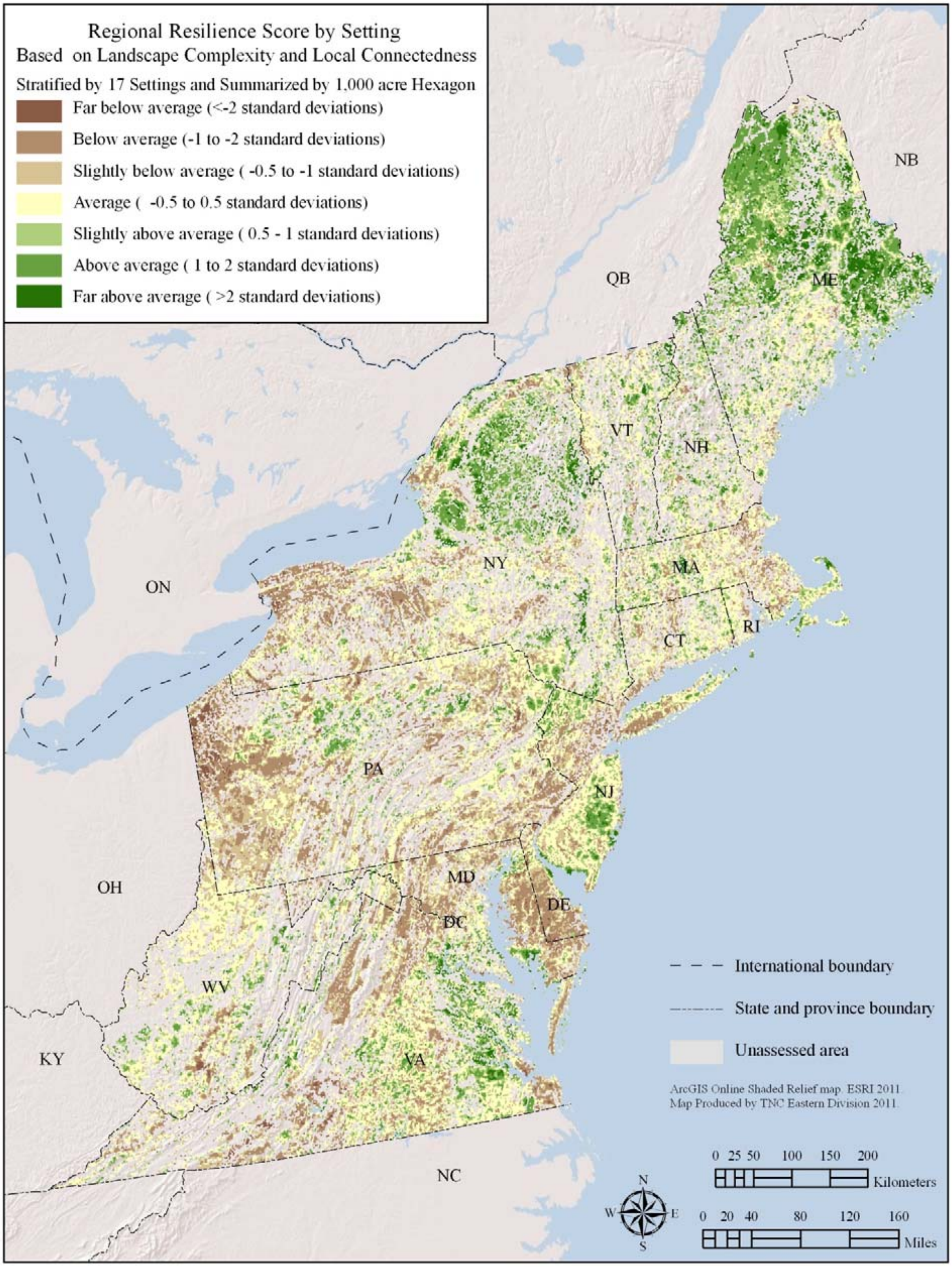
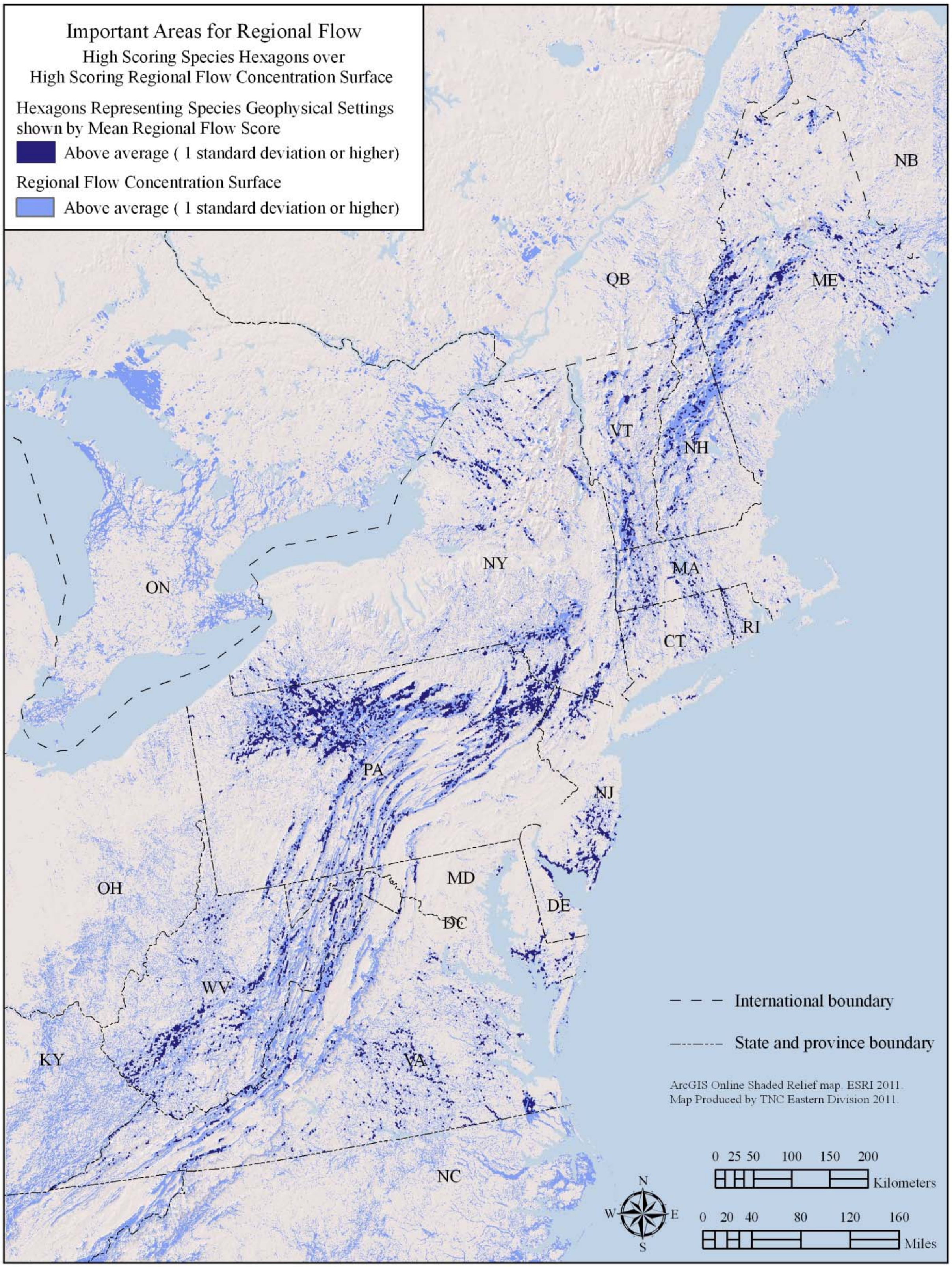
This project was supported by a grant to the Northeast Association of Fish and Wildlife Agencies (#2008-03 Regional Focal Areas for Species of Greatest Conservation Need based on Site Adaptive Capacity, Network Resilience and Connectivity) and through funding from the Doris Duke Charitable Foundation and The Nature Conservancy. The work was made possible by data and contributions from the network of Natural Heritage Programs and NatureServe.

Project Summary: Resilience concerns the ability of a living system to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with consequences, in short: its capacity to adapt (IPCC 2007). In this project, we aimed to identify the most resilient examples of key geophysical settings (sand plains, granitic mountains, limestone valleys, etc.), in relation to species of greatest conservation need, to provide conservationists with a nuanced picture of the places where conservation is most likely to succeed under climate change. The central idea was that by mapping key geophysical settings and evaluating them for landscape characteristics that buffer against climate effects, we could identify the most resilient examples of each setting. Our approach was based on observations that 1) species diversity is highly correlated with geophysical diversity (Anderson and Ferree 2010), and 2) that species take advantage of the micro-climates available in complex landscapes and 3) if the area is permeable, species can move to adjust to climatic changes. Developing a quantitative estimate of site resilience was the essence of the project, and we accomplished this by measuring the landscape complexity and permeability of every 30 by 30 square meter of the region, creating comprehensive wall-to-wall data on the physical components of resilience. We applied the information to known species sites and compared the scores between sites with a similar geophysical composition to identify the most resilient sites for each setting (Facing page –front map). Further, we analyzed broad east-west and north-south permeability gradients to identify areas where ecological flows and species movements potentially become concentrated. These areas may need conservation attention to allow the biota to adjust to a changing climate (Facing page – back map).

The Most Resilient Sites for Species of Greatest Conservation Need. The map encompasses 17 separate geophysical settings and shows the sites that score the highest for landscape complexity and local connectedness within in each setting. Only settings that contain SGCN species are shown (about half of the region). See also Map 5.18.



Key Areas for Ecological Flows. The map shows areas where processes and species movements potentially become concentrated due to the regional pattern of land uses and natural cover. Sites important to Species of Greatest Conservation Need are overlaid as darker hexagons. See also Map 5.22.



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Finally, state and federal agencies provided many of the underlying datasets used in this project, and we would like to particularly thank the Multi-Resolution Land Characteristics (MRLC) Consortium for their work on the national land cover datasets and the U.S.G.S for their work on the National Elevation Dataset (NED). We would also like to thank John Kantor for help with the selection of Species of Greatest Conservation Need.

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Introduction

Climate change is expected to alter species distributions. As species move to adjust to changing conditions, conservationists urgently require a way to prioritize strategic land conservation that will conserve the maximum amount of biological diversity in spite of shifting distribution patterns. Current conservation approaches based on species locations or on predicted species' responses to climate, are necessary, but hampered by uncertainty. Here we offer a complementary approach, one that aims to identify key focal areas for species conservation based on land characteristics that increase resilience.

The central idea of this project is that by mapping key geophysical settings and evaluating them for landscape characteristics that buffer against climate effects, we can identify the most resilient places in the landscape. Ideally, these places will conserve the full spectrum of physical "stages" and each place will offer many microclimates and options for species movement, thus maintaining landscape functionality and improving the chances of species' survival in a changing climate. Our approach is based on observations that in the Northeast and Mid-Atlantic, species diversity is highly correlated with geophysical diversity (Anderson and Ferree 2010). Species take advantage of the micro-climates available in complex landscapes and, if the area is permeable, species can move to adjust to climatic changes. Thus, the characteristics of geophysical representation, landscape complexity and landscape permeability, are central concepts in this research.

This project is presented in three parts: 1) the identification of the species of greatest conservation need and their locations, 2) the classification of the species habitats into distinct geophysical settings, and 3) the evaluation of each setting with respect to landscape complexity and permeability. The latter part comprises the bulk of this research and introduces new methodologies to quantify the physical and structural aspects of the landscape. The metrics used are discussed individually under the sections on landscape complexity (landform variety, elevation range, and wetland density) or landscape permeability (local connectedness and regional flow patterns). Each metric was calculated for the entire 13-state region.

We use the term "resilience" (Gunderson 2000) to refer to the capacity of a site to adapt to climate change while still maintaining diversity, but we do not assume that the species currently located at these sites will necessarily be the same species present in a century or two. Instead, we presume that each setting will support species that thrive in the conditions defined by the physical setting. For example, low elevation limestone valleys will support species that benefit from calcium rich soils, alkaline waters, and cave or karst features, while acidic outwash sands will support a distinctly different set of species. Although the value of conserving a spectrum of physical settings is based on extensive empirical evidence (Anderson and Ferree 2010), there are many more conservation choices to make beyond geophysical representation because, for example, there are many possible low elevation limestone valleys that can be selected. This project focuses specifically on prioritizing between examples of the same setting, using characteristics that increase resilience. These characteristics fall into two categories. The first, landscape complexity is defined as the number of microhabitats and climatic gradients available within a given area, and is measured as the variety of landforms present, the elevation range, and the degree of moisture accumulation. Because topographic diversity buffers against climatic effects, the persistence of most species within a given area increases in landscapes with a wide variety of microclimates (Weiss et al. 1988). Landscape permeability, the second factor, is defined as the degree of barriers within a landscape. A highly permeable landscape promotes resilience by facilitating range shifts and the reorganization of communities. Roads, development, dams, and other structures create resistance that interrupts or redirects movement and, therefore, lowers landscape permeability. Maintaining a connected landscape is the most widely cited strategy in the scientific literature for building resilience (Heller and Zavaleta 2009) and has been suggested as an explanation for why there were few extinctions during the last period of comparable rapid climate change, the so-called "Quaternary conundrum" (Botkin et al. 2007).

Our research followed the progression of this report. First we identified the species of concern and mapped their distributions. Next, we examined the 1000 acre area surrounding each species location and classified similar landscapes into geophysical settings based on their geology, elevation, and landforms. Then, we individually mapped the components of site resilience: landscape complexity (3 components) and landscape permeability (2 components). Lastly, we applied the analysis to the 1000 acre sites and scored each one for estimated resilience. The final section presents and describes the results at several different scales, from individual 1000 acre sites to large focal areas.

Summary: Resilience concerns the ability of a living system to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with consequences; in short, its capacity to adapt (IPCC 2007). In this project we aim to identify the most resilient examples of key geophysical settings (sand plains, granite mountains, limestone valleys, etc.) in relation to species of greatest conservation need, to provide conservationists with a nuanced picture of the places where conservation is most likely to succeed. Developing a quantitative estimate of the resilience of a physical place is the essence of the project, and we accomplish this by measuring the landscape complexity and permeability of every 30 by 30 meter square of land in the region to create a set of wall-to-wall maps of the individual and collective components of adaptive resilience. Lastly, we apply the information to species sites representing the full spectrum of geophysical diversity in the region, and compare the scores among sites with a similar geophysical composition. This step allows us to identify a subset of sites that have the highest ecological resilience and that collectively represent all the ecological settings critical to maintaining diversity in the region.

Identifying Species and Their Locations

Over 2,300 species and subspecies were listed as species of concern in the 13 Northeast and Mid-Atlantic State Wildlife Action Plans. Here, we identify and examine a subset of species that emerged as species of the greatest regional conservation need (hereafter SGCN species), and we use this subset as the basis for the focal areas. The species include both: 1) **high responsibility species**: species for which the region contains over 50 percent of their entire range and 2) **high concern species**: species that a majority of the Northeast and Mid-Atlantic states listed in their Wildlife Action Plans, usually due to extreme rarity, rapid declines, or high vulnerability. The criteria for assigning species to these categories are briefly described below, a full explanation may be found in Anderson and Olivero 2011.

Characterizing the Species: To identify the SGCN species, we followed the recommendations put forth by the Northeast Partners in Amphibian and Reptile Conservation Wildlife Action Plan Working Group (2008) using methods described in Anderson and Olivero (2011). Briefly, we identified species that had either the majority of their distribution centered in this region and/or had recognized high levels of concern in the northeast as evidenced by 50 percent or more of the states in the northeast range listing them as State Wildlife Action Plan (SWAP) species of concern. Although 2,378 unique species and subspecies were named in the SWAPs (Kantor 2007, 13 states plus D.C.), we narrowed this down to 234 species for this project. We excluded marine species (88), subspecies (106), and arthropods (1,243) to focus specifically on terrestrial and freshwater vertebrates as well as mussels, crayfish, and other non-arthropod insects. We also excluded: species listed in a SWAP, but not listed by NatureServe (2010) as present in any of the 13 states (38), species with no distributional information (3), and species that occurred in only one state (211). Lastly, we excluded species with no usable location information, which reduced the total to 234 species (see below).

For the species central to this report we used information from NatureServe (2010) to tabulate: 1) how many U.S. states did each species occur and 2) in how many of this region's 13 states did each species occur. States' records were not counted if the species was currently extirpated (SX), possibly extirpated (SH, known from only historic records), or ranked as not applicable (SNA, species was not a suitable target for conservation activities, e.g. an occasionally seen non-breeding migrant). From this we calculated the regional responsibility as**:**

- High responsibility: >= 50 percent of the U.S. distribution in the 13 states.
- Low responsibility: <= 50 percent of the U.S. distribution in the 13 states.

Using the information from the SWAP plans we tabulated the percentage of the Northeast and Mid-Atlantic States that contained the species listed as a species of concern in their SWAP. From this information, we grouped the species into four levels of regional concern (13 Northeast and Mid-Atlantic States only):

- Low concern: listed in less than 25 percent of states that contained it.
- Moderate concern: listed in >=25-50 percent of the states that contained it.
- High concern: listed in >=50-75 percent of the states that contained it.
- Widespread concern: listed in >=75 percent of the states that contained it.

We summarized information on seven categories of species, with each category representing a combination of regional concern and regional responsibility. Regional responsibility species were divided into groups corresponding to the levels of concern (Table 2.1)

Table 2.1: The seven species categories used in this report. The groups are combinations of regional concern, regional responsibility, and distribution. The three numbers in parentheses within each box summarize for each group: 1) the # of species falling in this group, 2) the # of species with any usable element occurrences available for analysis, and 3) the # of species with adequate distribution for reporting on trends.

<table>
<tr><th></th><th>Low Responsibility</th><th colspan="2">High Responsibility</th><th></th></tr>
<tr><th></th><th>Found in 4+ states</th><th>Found in 2-3 states</th><th>Found in 4+ states</th><th>Total</th></tr>
<tr><td>Low Concern</td><td></td><td></td><td>Low concern,
High responsibility
(39:7:0)</td><td></td></tr>
<tr><td>Moderate Concern</td><td></td><td rowspan="3">Limited distribution, High responsibility
(51:25:25)</td><td>Moderate concern,
High responsibility
(22:10:2)</td><td></td></tr>
<tr><td>High Concern</td><td>High concern,
Low responsibility
(78:54:36)</td><td>High concern,
High responsibility
(15:9:5)</td><td></td></tr>
<tr><td>Widespread Concern</td><td>Widespread concern,
Low responsibility
(117:98:80)</td><td>Widespread concern,
High responsibility
(36:31:28)</td><td></td></tr>
<tr><td>Total Species</td><td>195:152:116</td><td>51:25:25</td><td>112: 57:35</td><td>358: 234: 176</td></tr>
</table>

Species Locations: For each species, we obtained information on all its known locations. Data came from two sources: NatureServe (10 states plus D.C.) and the State Natural Heritage and Endangered Species programs (3 states: PA, MA, and DE). In most cases, species occurrences were precise locations of populations or breeding areas, but the occurrences represented a variety of situations with a range of precision in the locations. The data was current to January 2011.

We filtered out species occurrences that were not useable for this project, including occurrences where the last date of observation was prior to 1970, occurrences where the rank was historic (H) or extirpated (X), and occurrences where the location was not precise enough. We had at least one usable occurrence for 234 species (Please see Appendix III for more information on the source datasets).

Lastly, for each species we evaluated how the extent of inventoried locations matched the extent of the species' known distribution. We accomplished this by determining the percentage of states, within the species' regional range, had usable occurrences. We then assigned the species to one of our data sufficiency categories (Table 2.2). Species in the 'Not Usable' category are not suitable for determining regional trends but we did make use of the location information and included it in the summary tables.

Table 2.2: Data sufficiency for species locations throughout regional range.

Sufficient (S)	>= 75% of states where species is currently present also had precise element occurrence locations (n = 56 species)
Adequate (A)	>= 50%-74% of states where species is currently present also had precise element occurrence locations (n = 67 species)
Poor (P)	>= 25%-49% of states where species is currently present also had precise element occurrence locations (n = 73 species)
Not Usable (NU)	<25% of states where species is currently present also had precise element occurrence locations (n = 164 species)

To identify sites we used all 234 species, although some (e.g. those ranked Not Usable) may not be fully represented across their true ranges (see Table 2.3 and Appendix I for a full list of species). Moreover, the geographic distribution of occurrences was not equitable across the region, but was concentrated in Massachusetts and New Jersey presumably reflecting inventory effort not actual distribution patterns (Map 2.1). We account for this in Chapter 3 by mapping the full extent of each setting, unbiased by species inventory effort.

Map 2.1: Approximate locations of SGCN species used in this report.

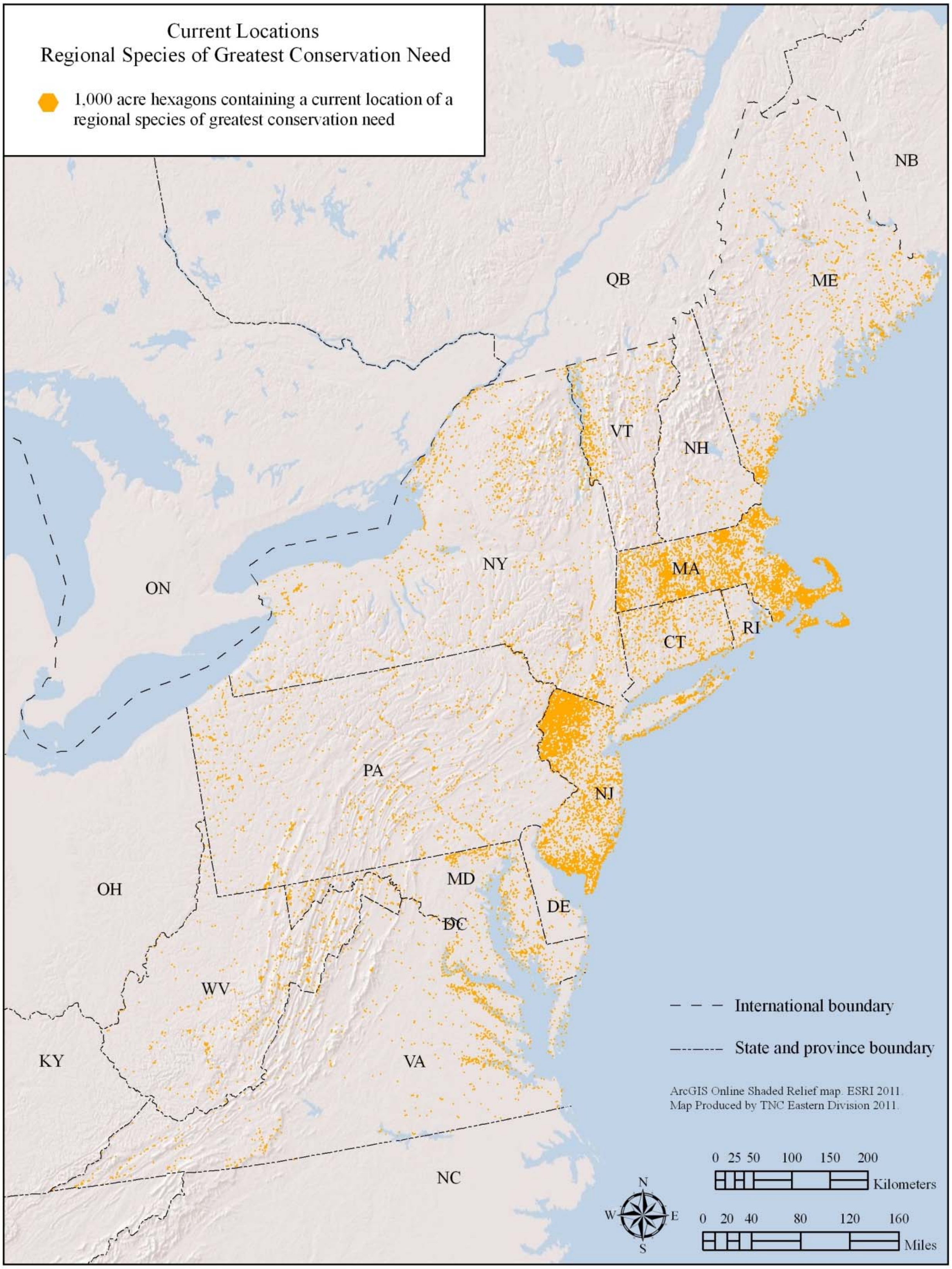

Table 2.3: List of SGCN species used in this report and their level of data adequacy.

Common Name	Standard Name	Data Adequacy
Amphibians		
Black Mountain Salamander	*Desmognathus welteri*	A
Blue-spotted Salamander	*Ambystoma laterale*	A
Carpenter Frog	*Rana virgatipes*	A
Common Mudpuppy	*Necturus maculosus*	P
Cow Knob Salamander	*Plethodon punctatus*	S
Eastern Hellbender	*Cryptobranchus alleganiensis*	S
Eastern Spadefoot Toad	*Scaphiopus holbrookii*	A
Eastern/Tiger Salamander	*Ambystoma tigrinum*	S
Fowler's Toad	*Bufo fowleri*	P
Green Salamander	*Aneides aeneus*	A
Jefferson Salamander	*Ambystoma jeffersonianum*	A
Longtail Salamander	*Eurycea longicauda*	NU
Marbled Salamander	*Ambystoma opacum*	P
Mountain Chorus Frog	*Pseudacris brachyphona*	P
Northern Leopard Frog	*Rana pipiens*	P
Upland//Southeastern Chorus Frog	*Pseudacris feriarum*	P
Wehrle's Salamander	*Plethodon wehrlei*	NU
Reptiles		
Blanding's Turtle	*Emydoidea blandingii*	S
Bog Turtle	*Glyptemys muhlenbergii*	S
Broadhead Skink	*Plestiodon laticeps*	P
Copperhead	*Agkistrodon contortrix*	NU
Corn Snake	*Pantherophis guttatus*	P
Eastern Box Turtle	*Terrapene carolina*	NU
Eastern Hognose Snake	*Heterodon platirhinos*	P
Northern Map Turtle	*Graptemys geographica*	A
Queen Snake	*Regina septemvittata*	NU
Redbelly/Red-bellied Cooter/Turtle	*Pseudemys rubriventris*	NU
Rough Green Snake	*Opheodrys aestivus*	NU
Smooth Green Snake	*Opheodrys vernalis*	NU
Spotted Turtle	*Clemmys guttata*	A
Timber/Canebrake Rattlesnake	*Crotalus horridus*	A
Wood Turtle	*Glyptemys insculpta*	S
Mammals		
Allegheny Woodrat	*Neotoma magister*	A
Appalachian Cottontail	*Sylvilagus obscurus*	S
Bobcat	*Lynx rufus*	NU
Eastern Red Bat	*Lasiurus borealis*	NU
Eastern Small-footed Bat	*Myotis leibii*	S
Fisher	*Martes pennanti*	NU
Hoary Bat	*Lasiurus cinereus*	NU
Indiana Bat	*Myotis sodalis*	S
Least Shrew	*Cryptotis parva*	P
Least Weasel	*Mustela nivalis*	A
Long-tailed or Rock Shrew	*Sorex dispar*	A
New England Cottontail	*Sylvilagus transitionalis*	P
Silver-haired Bat	*Lasionycteris noctivagans*	NU
Smoky Shrew	*Sorex fumeus*	NU
Southern Bog Lemming	*Synaptomys cooperi*	P
Birds		
Acadian Flycatcher	*Empidonax virescens*	P
American Bittern	*Botaurus lentiginosus*	A
American Oystercatcher	*Haematopus palliatus*	P
American Three-toed Woodpecker	*Picoides dorsalis*	S
Arctic Tern	*Sterna paradisaea*	S
Atlantic Puffin	*Fratercula arctica*	P
Bald Eagle	*Haliaeetus leucocephalus*	S
Barn Owl	*Tyto alba*	A
Bay-breasted Warbler	*Dendroica castanea*	P
Bicknell's Thrush	*Catharus bicknelli*	S
Black Rail	*Laterallus jamaicensis*	A
Black Skimmer	*Rynchops niger*	A
Black Tern	*Chlidonias niger*	S
Black-and-White Warbler	*Mniotilta varia*	NU
Black-billed Cuckoo	*Coccyzus erythropthalmus*	NU
Blackburnian Warbler	*Dendroica fusca*	P
Black-crowned Night-heron	*Nycticorax nycticorax*	A
Blackpoll Warbler	*Dendroica striata*	P
Black-throated Blue Warbler	*Dendroica caerulescens*	NU
Black-throated Green Warbler	*Dendroica virens*	NU
Blue-winged Warbler	*Vermivora pinus*	NU
Bobolink	*Dolichonyx oryzivorus*	P
Broad-winged Hawk	*Buteo platypterus*	NU
Brown Pelican	*Pelecanus occidentalis*	P
Brown Thrasher	*Toxostoma rufum*	NU
Canada Warbler	*Wilsonia canadensis*	NU
Cape May Warbler	*Dendroica tigrina*	P
Cattle Egret	*Bubulcus ibis*	A
Cerulean Warbler	*Dendroica cerulea*	P
Chuck-will's-widow	*Caprimulgus carolinensis*	P
Common Loon	*Gavia immer*	A
Common Moorhen	*Gallinula chloropus*	A
Common Nighthawk	*Chordeiles minor*	P
Common Tern	*Sterna hirundo*	A
Cooper's Hawk	*Accipiter cooperii*	P
Dickcissel	*Spiza americana*	P
Eastern Meadowlark	*Sturnella magna*	NU
Field Sparrow	*Spizella pusilla*	NU
Forster's Tern	*Sterna forsteri*	P
Glossy Ibis	*Plegadis falcinellus*	A
Golden Eagle	*Aquila chrysaetos*	P
Golden-winged Warbler	*Vermivora chrysoptera*	A
Grasshopper Sparrow	*Ammodramus savannarum*	A
Gray-Cheeked Thrush	*Catharus minimus*	P
Great Black-backed Gull	*Larus marinus*	NU
Great Blue Heron	*Ardea herodias*	A
Great Cormorant	*Phalacrocorax carbo*	NU
Great Egret	*Ardea alba*	A
Gull-billed Tern	*Gelochelidon nilotica*	S
Harlequin Duck	*Histrionicus histrionicus*	P
Henslow's Sparrow	*Ammodramus henslowii*	S
Hooded Warbler	*Wilsonia citrina*	NU
Horned Lark	*Eremophila alpestris*	NU
Kentucky Warbler	*Oporornis formosus*	P
King Rail	*Rallus elegans*	A
Least Bittern	*Ixobrychus exilis*	S
Least Tern	*Sternula antillarum*	S
Little Blue Heron	*Egretta caerulea*	A
Loggerhead Shrike	*Lanius ludovicianus*	S
Long-eared Owl	*Asio otus*	A
Marsh Wren	*Cistothorus palustris*	P
Northen Bobwhite	*Colinus virginianus*	NU
Northern Goshawk	*Accipiter gentilis*	P
Northern Harrier	*Circus cyaneus*	S
Northern Parula	*Parula americana*	P
Olive-sided Flycatcher	*Contopus cooperi*	NU
Osprey	*Pandion haliaetus*	P
Peregrine Falcon	*Falco peregrinus*	S
Pied-billed Grebe	*Podilymbus podiceps*	A
Piping Plover	*Charadrius melodus*	S
Prothonotary Warbler	*Protonotaria citrea*	P
Razorbill	*Alca torda*	P
Red Knot	*Calidris canutus*	P
Red-headed Woodpecker	*Melanerpes erythrocephalu*	P
Red-shouldered Hawk	*Buteo lineatus*	NU
Roseate Tern	*Sterna dougallii*	S
Royal Tern	*Thalasseus maximus*	P
Rusty Blackbird	*Euphagus carolinus*	P
Saltmarsh Sharp-tailed Sparrow	*Ammodramus caudacutus*	P
Seaside Sparrow	*Ammodramus maritimus*	P
Sedge Wren	*Cistothorus platensis*	S
Sharp-Shinned Hawk	*Accipiter striatus*	P
Short-eared Owl	*Asio flammeus*	S
Snowy Egret	*Egretta thula*	A
Sora Rail	*Porzana carolina*	S
Spruce Grouse	*Falcipennis canadensis*	S
Swainson's Thrush	*Catharus ustulatus*	NU
Tricolored Heron	*Egretta tricolor*	P
Upland Sandpiper	*Bartramia longicauda*	S
Veery	*Catharus fuscescens*	NU
Vesper Sparrow	*Pooecetes gramineus*	P
Whip-poor-will	*Caprimulgus vociferus*	NU
Willet	*Tringa semipalmata*	NU
Wood Thrush	*Hylocichla mustelina*	NU
Yellow Rail	*Coturnicops noveboracensi*	P
Yellow-breasted Chat	*Icteria virens*	NU
Yellow-crowned Night-heron	*Nyctanassa violacea*	A
Fish		
American Brook Lamprey	*Lampetra appendix*	P
American Eel	*Anguilla rostrata*	NU
Appalachia Darter	*Percina gymnocephala*	A
Atlantic Sturgeon	*Acipenser oxyrinchus*	P
Banded Sunfish	*Enneacanthus obesus*	NU
Bigmouth Chub	*Nocomis platyrhynchus*	A
Blackbanded Sunfish	*Enneacanthus chaetodon*	P
Blackchin Shiner	*Notropis heterodon*	A
Blue Ridge Sculpin	*Cottus caeruleomentum*	NU
Blueback Herring	*Alosa aestivalis*	NU
Bluebreast Darter	*Etheostoma camurum*	A
Bridle Shiner	*Notropis bifrenatus*	NU
Burbot	*Lota lota*	P
Candy Darter	*Etheostoma osburni*	A
Channel Darter	*Percina copelandi*	A
Cheat Minnow	*Pararhinichthys bowersi*	A
Checkered Sculpin	*Cottus sp. 7*	A
Comely Shiner	*Notropis amoenus*	NU
Eastern Sand Darter	*Ammocrypta pellucida*	S
Eastern Silvery Minnow	*Hybognathus regius*	NU
Glassy Darter	*Etheostoma vitreum*	P
Ironcolor Shiner	*Notropis chalybaeus*	P
Kanawha Minnow	*Phenacobius teretulus*	A
Least Brook Lamprey	*Lampetra aepyptera*	NU
Longhead Darter	*Percina macrocephala*	A
Longnose Sucker	*Catostomus catostomus*	P
Mooneye	*Hiodon tergisus*	A
Mountain Brook Lamprey	*Ichthyomyzon greeleyi*	P
Mountain Redbelly Dace	*Phoxinus oreas*	A
Mud Sunfish	*Acantharchus pomotis*	P
New River Shiner	*Notropis scabriceps*	A
Northern Brook Lamprey	*Ichthyomyzon fossor*	S
Ohio Lamprey	*Ichthyomyzon bdellium*	A
Pearl Dace	*Margariscus margarita*	NU
Potomac Sculpin	*Cottus girardi*	P
River Redhorse	*Moxostoma carinatum*	P
Round Whitefish	*Prosopium cylindraceum*	A
Sauger	*Sander canadensis*	NU
Shortnose Sturgeon	*Acipenser brevirostrum*	A
Silver Lamprey	*Ichthyomyzon unicuspis*	A
Slimy Sculpin	*Cottus cognatus*	NU
Spotfin Killfish	*Fundulus luciae*	NU
Spotted Darter	*Etheostoma maculatum*	A
Stonecat	*Noturus flavus*	P
Streamline Chub	*Erimystax dissimilis*	P
Stripeback Darter	*Percina notogramma*	P
Swallowtail Shiner	*Notropis procne*	NU
Swamp Darter	*Etheostoma fusiforme*	NU
Tessellated Darter	*Etheostoma olmstedi*	NU
Threespine Stickleback	*Gasterosteus aculeatus*	NU
Tonguetied Minnow	*Exoglossum laurae*	A
Torrent Sucker	*Thoburnia rhothoeca*	A
Trout-perch	*Percopsis omiscomaycus*	A
Variegate Darter	*Etheostoma variatum*	P
Warmouth	*Lepomis gulosus*	P
Invertebrates		
Alewife Floater	*Anodonta implicata*	NU
Angular Disc	*Discus catskillensis*	NU
Appalachian Springsnail	*Fontigens bottimeri*	S
Black Sandshell	*Ligumia recta*	A
Blue Ridge Springsnail	*Fontigens orolibas*	P
Brook Floater	*Alasmidonta varicosa*	S
Cave Lumbriculid Worm	*Stylodrilus beattiei*	S
Cherrystone Drop Snail	*Hendersonia occulta*	A
Coastal Marsh Snail	*Littoridinops tenuipes*	NU
Creek heelsplitter	*Lasmigona compressa*	P
Cylindrical Papershell	*Anodontoides ferussacianus*	P
Deertoe	*Truncilla truncata*	A
Dwarf Wedgemussel	*Alasmidonta heterodon*	S
Eastern Lampmussel	*Lampsilis radiata*	NU
Eastern Pearlshell	*Margaritifera margaritifera*	P
Eastern Pond Mussel	*Ligumia nasuta*	A
Elktoe	*Alasmidonta marginata*	P
Fragile Papershell	*Leptodea fragilis*	P
Green Floater	*Lasmigona subviridis*	A
Groundwater Planarian s	*Procotyla typhlops*	A
Hoffmaster's Cave Planai	*Macrocotyla hoffmasteri*	S
James Spinymussel	*Pleurobema collina*	A
Mossy Valvata/Boreal Tu	*Valvata sincera*	P
New England Siltsnail	*Floridobia winkleyi*	P
Northern Lance Mussel	*Elliptio fisheriana*	P
Pocketbook Mussel	*Lampsilis ovata*	A
Rainbow	*Villosa iris*	P
Spruce Knob Three-tootl	*Triodopsis picea*	P
Striped Whitelip	*Webbhelix multilineata*	A
Tidewater Mucket	*Leptodea ochracea*	A
Triangle Floater	*Alasmidonta undulata*	P
Virginia River Snail	*Elimia virginica*	NU
Wavyrayed Lampmussel	*Lampsilis fasciola*	A
Yellow Lampmussel	*Lampsilis cariosa*	S
Yellow Lance	*Elliptio lanceolata*	A

CHAPTER

3

Defining Sites and Geophysical Settings

This section describes the process of characterizing the local landscapes (sites) containing the SGCN species. This was necessary to get an estimate of the full range of each setting unbiased by species inventory effort.

Analysis Unit, 1,000 Acre Hexagon: Our primary unit of analysis for identifying sites was a 1,000 acre hexagon. We chose this unit because the size allowed for assessing relatively fine-scale detail and the shapes match edge-to-edge and thus perfectly tessellate the entire landscape – like a dragonfly's eye or a soccer ball. Additionally, the size of the unit allowed us to maintain the sensitivity of the element occurrences exact locations, and also accounted for some spatial fuzziness in the mapped location of the element occurrence. The entire 13 state region divides into 156,581 hexagons and we calculated the variables described below for each one.

To begin, we attributed each hexagon with basic information about the land, water, and species it encompassed. These attributes included basic location information such as state and TNC ecoregion, as well as geophysical information such as: the percent of each geology class, elevation zone, and landform type (see below). Additionally, we tabulated information about any SGCN species located within the boundary of the hexagon. For this step, all source species occurrence datasets (points and polygons) were converted to point features based on the polygon's centroid. Points location with adequate precision to overlay with 1,000 acre hexagons were then tagged with the id of the hexagon in which they fell. If multiple occurrences of the same species fell in the same hexagon, the number of occurrences was recorded, but the attributes of the hexagon were only counted once for that species. See Appendix III for more details on the mapping and overlay of the species known locations.

Geophysical Settings: Information on geology, elevation, and landforms was used to characterize the physical attributes of the hexagon area and to cluster them into groups representing the same setting. Here, we use descriptive terms to describe and refer to characteristics that are mapped using a carefully defined quantitative criteria. For example, what we call a "flat summit" refers to the level top of a mountain or ridge, but is defined in mapping terms as a landform with 0-2 degrees slope, found in the highest land position. We provide maps and illustrations to help users understand how the characteristics lay out on the landscape and further explanation of the landform model is given in Chapter 4. Additionally, greater detail about the process of defining and mapping each attribute is provided in Appendix II and in Anderson (1999) and Anderson and Ferree (2010). The categories used were:

Elevation Zones (Map 3.1)

Coastal = 0-20' elevation
Very low = 20-800' elevation
Low = 800 – 1700' elevation
Moderate = 1700-2500' elevation
High = 2500-3600' elevation
Very high/alpine and subalpine = 3600'+

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Geology Classes (Map 3.2)
Acidic sedimentary: fine to coarse-grained, acidic sedimentary or meta-sedimentary rock. Mudstone, claystone, siltstone, non-fissile shale, sandstone, conglomerate, breccia, greywacke, arenites. Metamorphic equivalents: slates, phyllites, pelites, schists, pelitic schists, granofels.

Acidic shale: Fine-grained loosely compacted acidic fissile shale.

Calcareous: alkaline, soft, sedimentary or metasedimentary rock with high calcium content. Limestone, dolomite, dolostone, marble, other carbonate-rich clastic rocks.

Moderately Calcareous: Neutral to alkaline, moderately soft sedimentary or meta-sedimentary rock with some calcium but less so than above – often of mixed acidic and calcareous sediments. Calcareous shales, pelites and siltstones, calcareous sandstones, lightly metamorphosed calcareous pelites, quartzites, schists and phyllites, calc-silicate granofels.

Acidic Granitic: quartz-rich, resistant acidic igneous and high grade meta-sedimentary rock. Granite, granodiorite, rhyolite, felsite, pegmatite, granitic gneiss, charnockites, migmatites, quartzose gneiss, quartzite, quartz granofels.

Mafic: quartz-poor alkaline to slightly acidic rock. Ultrabasic: anorthosite. Basic: gabbro, diabase, basalt. Intermediate, quartz-poor: diorite/ andesite, syenite/ trachyte, greenstone, amphibolite, epidiorite, granulite, bostonite, essexite.

Ultramafic: magnesium-rich alkaline rock. Serpentine, soapstone, pyroxenites, dunites, peridotites, talc schist.

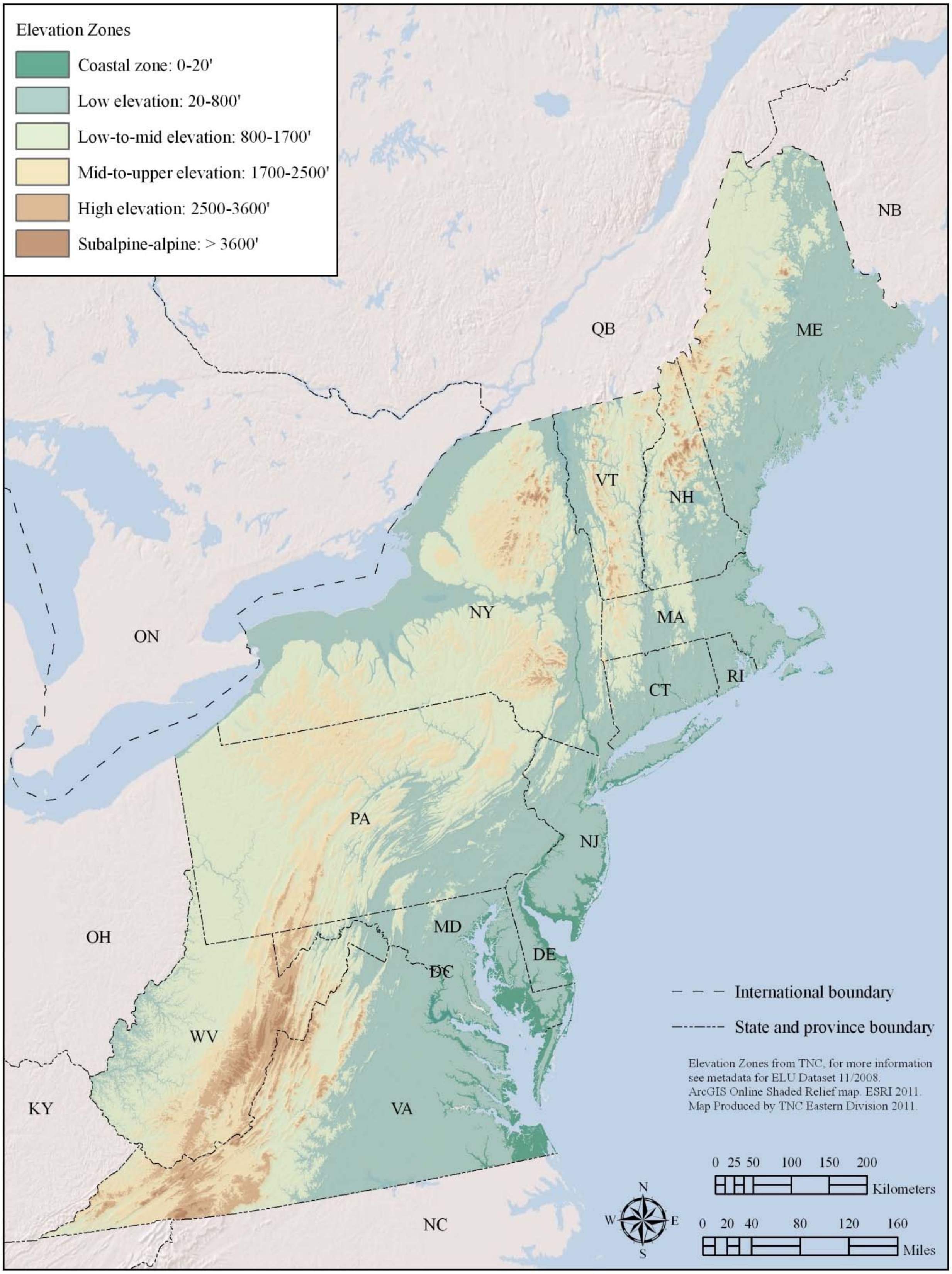
Coarse surficial sediment: mostly unconsolidated sand and gravel.

Fine surficial sediment: mostly unconsolidated silts and mud.

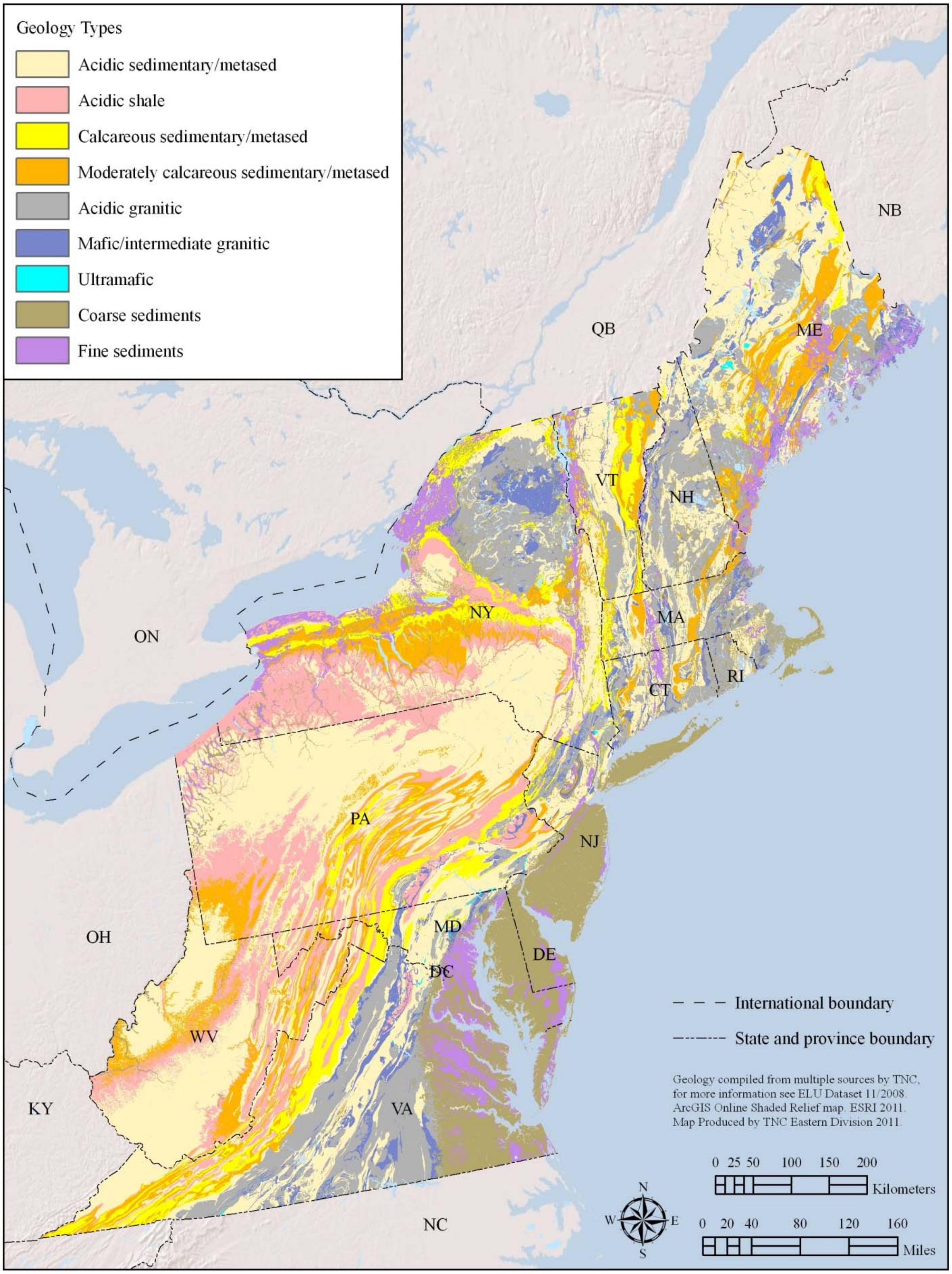
Landform Types (Map 3.3)
Landform modeling is described in detail in Chapter 4.1 and in Appendix II. The landform types mapped were:

Cliff
Flat summit/ridgetop
Steep slope cooler aspect
Steep slope warmer aspect
Slope crest
Low hilltop flat
Low hill
Sideslope cooler aspect
Siedeslope warmer aspect
Cove or footslope cooler aspect
Cove or footslope warmer aspect
Valley/toe slope.
Flat a bottom of steep slope
Dry flat
Wet flat
Lake/pond/river

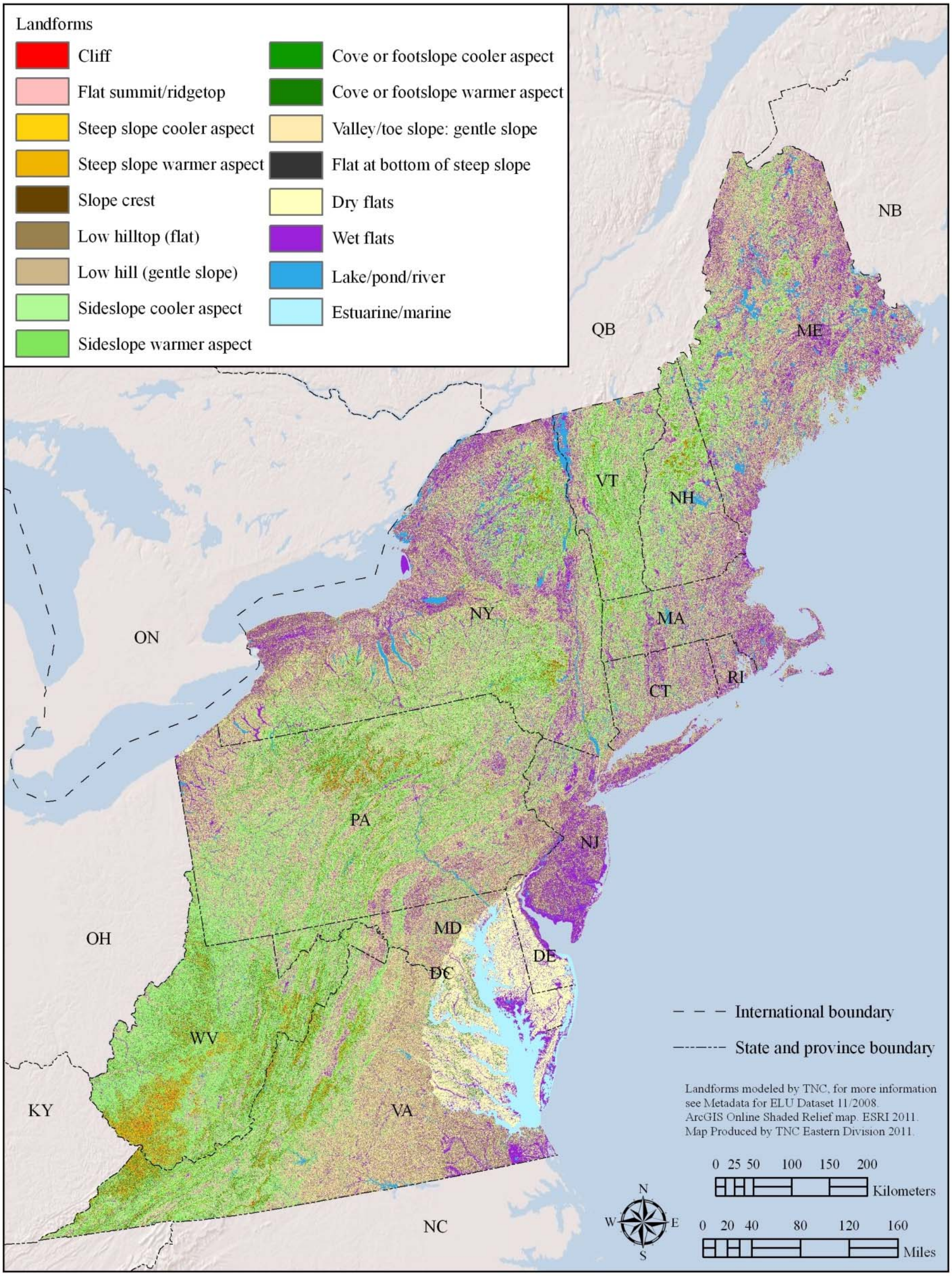
Map 3.1: Elevation zones.



Map 3.2: Geology classes.



Map 3.3: Landform types.



We tabulated the abundance and percentage of each physical element described above for each hexagon, and this information formed the basis for measuring similarity among hexagons in the cluster analysis.

Clustering Hexagons into Geophysical Settings: We clustered all hexagons containing SGCN species into hexagon groups based on the type and abundance of their geology classes, elevation zones, and landform types. Ultimately, we identified 38 distinct settings that grouped into 17 broad geophysical settings for the region, but it took several steps to perform this classification due to the large number of hexagons, and the inability of the software tools to process this much information at once.

First, we grouped the hexagons together based solely on their geophysical attributes, combined elevation and geology plus landforms. For example, a single hexagon might be:
90 percent high elevation granite
10 percent high elevation mafic
50 percent side slopes
35 percent steep slopes
15 percent summits
5 percent wet flat
0 percent all other attributes

Clustering was performed using a hierarchical cluster analysis (PCORD, McCune and Grace 2002) using the Sorenson similarity index applied to the geophysical attributes, using a flexible beta linkage technique with Beta set at ¬25 (McCune and Grace 2002). After clustering the samples, we performed an indicator species analysis (Dufrene and Legendre 1997) to identify the geophysical attributes that were the most faithful and exclusive to each setting. Because of the large size of the dataset, we initially define only two large groups (which corresponded with elevations above and below 800') and we then defined 20 groups within each of those for a grand total of 40 groups. However, two of these groups were so similar in composition that we combined them in to one group, and another group was so close to the coastline that it had only partial information. The final result was 38 distinct settings.

Next, we further aggregated the 38 groups into 17 geophysical settings using information on both the physical characteristics and the SGCN species found in each group. To do this, we tabulated all the SGCN species found in each of the 38 groups and examined the group for similarities in the composition of SGCN species. We quantified these similarities by treating each of the group as if it were a sample, listing the presence of all SGCN species known for the group, and using a cluster analysis to examine the similarities among the 38 groups. By combining groups that had a similar composition of SGCN species as well as somewhat comparable geophysical attributes (e.g. moderately calcareous with calcareous, or granitic with mafic) we aggregated them into 17 broadly recognizable geophysical settings. These settings form the framework of the resilience analysis and the results section is organized around them. However, in some cases, parts of the analysis were performed at the level of the 38 groups (such as the weighting of areas with extensive wetlands) so as not to lose some important distinctions important to common species.

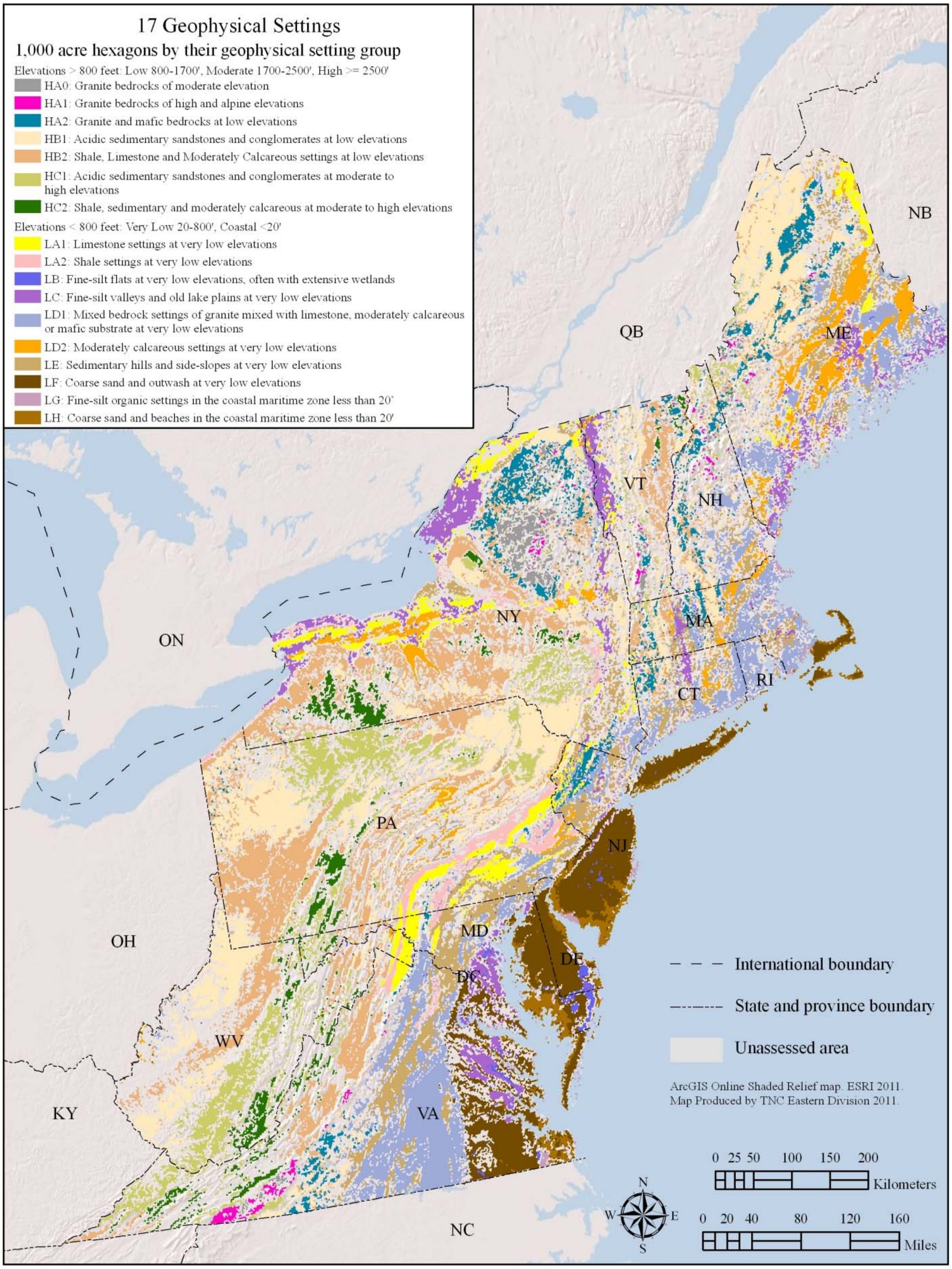
Mapping the Full Range of each Setting: The hexagon clustering was only performed on hexagons that contained one of the 234 mapped SGCN species with our objective being to explicitly identify geophysical settings relevant to those species. However, the settings defined by the clustering occurred more extensively across the region, and in the next step we identified and mapped the full range of each geophysical setting using the criteria identified by the cluster analysis. We accomplished this by summarizing the dominant features of each cluster group and using a query to identify other hexagons that contained the same dominant features. For example, one group (cluster H994) was composed of hexagons that averaged 87 percent granite, 77 percent high elevation, and 38 percent side-slopes, and we queried the database for other hexagons that shared the same dominant properties. This produced a conservative estimate of the full geographic range of the setting as it only added areas that match the average dominant expression of the type, ignoring the wider range of variation (Table 3.1, Map 3.4).

Table 3.1: Geophysical attributes and signatures for the 38 fine scale and 17 broader settings. The cells highlighted in yellow are dominant properties averaging over 66 percent. The green cells are supporting cells averaging over 33 percent and were not used in the categorization, but can provide information about group composition.

Group 17	Group 38	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coast	Very Low	Low	Mod-erate	High	Very High	Summit / Ridge	Cliff / Steep	Side-slope	Cove / foot	Hill / Valley	Dry Flat	Wet Flat	Water
HA0	H1303	0.10		0.01	0.00	0.83	0.01		0.04				0.11	0.87	0.02		0.01	0.01	0.21	0.01	0.39	0.08	0.22	0.05
HA0 Average		0.10		0.01	0.00	0.83	0.01		0.04				0.11	0.87	0.02		0.01	0.01	0.21	0.01	0.39	0.08	0.22	0.05
HA1	H944	0.02			0.00	0.87	0.10	0.00	0.00					0.21	0.77	0.02	0.05	0.06	0.38	0.04	0.27	0.04	0.12	0.04
HA1 Average		0.02			0.00	0.87	0.10	0.00	0.00					0.21	0.77	0.02	0.05	0.06	0.38	0.04	0.27	0.04	0.12	0.04
HA2	H1	0.05	0.00	0.03	0.00	0.77	0.10	0.00	0.05	0.00	0.00	0.11	0.88	0.01	0.00		0.00	0.00	0.13	0.00	0.43	0.09	0.29	0.05
HA2	H24	0.03		0.01	0.01	0.74	0.19	0.00	0.03		0.00	0.16	0.78	0.06	0.00		0.05	0.06	0.47	0.06	0.23	0.02	0.07	0.03
HA2	H15	0.05	0.01	0.01	0.00	0.08	0.63	0.00	0.21	0.02		0.02	0.95	0.04	0.00		0.02	0.03	0.23	0.02	0.32	0.07	0.19	0.12
HA2	H14	0.06	0.04	0.11	0.02	0.09	0.43	0.00	0.05	0.19		0.25	0.47	0.15	0.10	0.03	0.01	0.01	0.16	0.01	0.42	0.09	0.25	0.05
HA2 Average		0.05	0.02	0.04	0.01	0.42	0.34	0.00	0.08	0.07	0.00	0.13	0.77	0.06	0.03	0.03	0.02	0.03	0.25	0.02	0.35	0.07	0.20	0.06
HB1	H2	0.79	0.05	0.02	0.05	0.01	0.01	0.00	0.06	0.01		0.10	0.85	0.05			0.00	0.00	0.11	0.00	0.45	0.11	0.28	0.04
HB1	H7	0.89	0.01	0.01	0.03	0.01	0.01		0.04	0.01		0.06	0.89	0.05			0.03	0.04	0.38	0.04	0.33	0.04	0.10	0.04
HB1 Average		0.84	0.03	0.01	0.04	0.01	0.01	0.00	0.05	0.01		0.08	0.87	0.05			0.02	0.02	0.25	0.02	0.39	0.08	0.19	0.04
HB2	H4	0.08	0.74	0.02	0.06	0.00			0.08	0.03		0.09	0.88	0.02			0.00	0.00	0.12	0.01	0.41	0.12	0.30	0.04
HB2	H59	0.04	0.01	0.79	0.07	0.03	0.00		0.05			0.02	0.94	0.04	0.00		0.01	0.01	0.21	0.01	0.36	0.08	0.24	0.06
HB2	H101	0.03	0.03	0.06	0.81	0.02	0.00		0.06	0.00		0.07	0.89	0.04			0.01	0.01	0.25	0.02	0.38	0.07	0.22	0.03
HB2	H49	0.32	0.21	0.01	0.16	0.19	0.03	0.00	0.06	0.01		0.07	0.74	0.18	0.02		0.01	0.01	0.10	0.01	0.18	0.04	0.09	0.56
HB2	H6	0.23	0.58	0.02	0.05	0.00	0.00		0.11	0.01		0.07	0.81	0.12	0.00		0.05	0.06	0.50	0.06	0.22	0.03	0.06	0.02
HB2 Average		0.14	0.31	0.18	0.23	0.05	0.01	0.00	0.07	0.01		0.07	0.85	0.08	0.01		0.02	0.02	0.24	0.02	0.31	0.07	0.18	0.14
HC1	H97	0.66	0.19	0.01	0.08	0.02	0.01		0.01	0.01		0.07	0.49	0.33	0.10	0.02	0.00	0.00	0.01	0.00	0.12	0.08	0.74	0.06
HC1	H353	0.59	0.15	0.04	0.22	0.00			0.00				0.00	0.15	0.78	0.07	0.01	0.01	0.13	0.02	0.35	0.21	0.18	0.09
HC1	H16	0.91	0.03	0.00	0.03	0.01	0.01	0.00	0.01			0.00	0.15	0.82	0.03		0.02	0.03	0.27	0.03	0.33	0.10	0.17	0.05
HC1	H530	0.74	0.13	0.01	0.07	0.01	0.03	0.01					0.01	0.16	0.72	0.11	0.06	0.12	0.55	0.08	0.12	0.01	0.04	0.01
HC1	H517	0.46	0.17	0.06	0.26	0.00	0.01		0.04	0.00		0.05	0.35	0.25	0.24	0.10			0.01	0.00	0.09	0.65	0.17	0.08
HC1 Average		0.67	0.13	0.02	0.14	0.01	0.02	0.00	0.01	0.01		0.04	0.20	0.34	0.38	0.07	0.02	0.04	0.19	0.03	0.20	0.21	0.26	0.06
HC2	H254	0.08	0.85	0.00	0.04				0.03				0.06	0.88	0.06		0.02	0.04	0.25	0.03	0.28	0.18	0.14	0.05
HC2	H35	0.13	0.06	0.23	0.57				0.01				0.13	0.82	0.06		0.03	0.05	0.39	0.05	0.29	0.09	0.07	0.03
HC2 Average		0.11	0.46	0.12	0.31				0.02				0.09	0.85	0.06		0.02	0.04	0.32	0.04	0.29	0.14	0.11	0.04
LA1	L1	0.08	0.02	0.64	0.02	0.06	0.02		0.13	0.03	0.00	0.95	0.05	0.00			0.00	0.00	0.09	0.00	0.41	0.12	0.31	0.06
LA1 Average		0.08	0.02	0.64	0.02	0.06	0.02		0.13	0.03	0.00	0.95	0.05	0.00			0.00	0.00	0.09	0.00	0.41	0.12	0.31	0.06
LA2	L64	0.07	0.71	0.12	0.01	0.01	0.03		0.04	0.02		0.99	0.01	0.00			0.01	0.01	0.22	0.02	0.37	0.10	0.24	0.03
LA2 Average		0.07	0.71	0.12	0.01	0.01	0.03		0.04	0.02		0.99	0.01	0.00			0.01	0.01	0.22	0.02	0.37	0.10	0.24	0.03
LB	L39	0.25	0.03	0.05	0.13	0.04	0.05		0.15	0.29	0.09	0.87	0.04				0.00		0.01	0.00	0.11	0.05	0.77	0.05
LB	L1712	0.14	0.02	0.03	0.06	0.01	0.08	0.00	0.15	0.46	0.19	0.79	0.02				0.00		0.02	0.01	0.11	0.64	0.15	0.08
LB Average		0.20	0.02	0.04	0.10	0.02	0.06	0.00	0.15	0.38	0.14	0.83	0.03				0.00		0.01	0.00	0.11	0.34	0.46	0.07
LC	L51	0.04	0.00	0.04	0.03	0.02	0.03	0.00	0.05	0.79	0.04	0.95	0.00				0.00	0.00	0.12	0.01	0.42	0.10	0.25	0.11
LC	L91	0.06	0.00	0.03	0.03	0.02	0.01		0.06	0.75	0.13	0.86	0.01				0.05	0.09	0.50	0.06	0.17	0.02	0.07	0.04
LC Average		0.05	0.00	0.04	0.03	0.02	0.02	0.00	0.05	0.77	0.09	0.91	0.01				0.03	0.04	0.31	0.03	0.30	0.06	0.16	0.07
LD1	L2	0.10	0.00	0.01	0.02	0.07	0.64	0.00	0.15	0.02	0.03	0.94	0.03	0.00			0.01	0.01	0.15	0.01	0.40	0.09	0.27	0.06
LD1	L28	0.02	0.00	0.00	0.01	0.67	0.06	0.00	0.21	0.02	0.03	0.96	0.01				0.00	0.00	0.12	0.00	0.44	0.10	0.28	0.05
LD1	L6	0.05	0.01	0.20	0.12	0.47	0.04	0.00	0.08	0.02	0.05	0.89	0.05				0.03	0.04	0.45	0.04	0.27	0.03	0.10	0.04
LD1 Average		0.06	0.00	0.07	0.05	0.40	0.25	0.00	0.15	0.02	0.04	0.93	0.03	0.00			0.02	0.02	0.24	0.02	0.37	0.07	0.22	0.05
LD2	L57	0.05		0.01	0.40	0.32	0.03		0.14	0.03	0.12	0.88	0.00				0.00	0.00	0.03	0.00	0.14	0.05	0.12	0.66
LD2	L9	0.06	0.01	0.04	0.69	0.01	0.01		0.12	0.05	0.02	0.95	0.04				0.00	0.00	0.11	0.00	0.47	0.11	0.28	0.03
LD2 Average		0.06	0.01	0.02	0.55	0.17	0.02		0.13	0.04	0.07	0.91	0.02				0.00	0.00	0.07	0.00	0.30	0.08	0.20	0.35
LE	L4	0.71	0.00	0.00	0.02	0.03	0.02	0.00	0.18	0.03	0.01	0.97	0.02				0.00	0.00	0.11	0.00	0.46	0.10	0.29	0.03
LE	L5	0.79	0.01	0.02	0.02	0.01	0.02	0.00	0.12	0.01	0.01	0.95	0.04				0.04	0.04	0.43	0.05	0.22	0.03	0.09	0.10
LE Average		0.75	0.01	0.01	0.02	0.02	0.02	0.00	0.15	0.02	0.01	0.96	0.03				0.02	0.02	0.27	0.02	0.34	0.07	0.19	0.06
LF	L135	0.00	0.00	0.00	0.00	0.00	0.00		0.97	0.02	0.05	0.95	0.00				0.01	0.01	0.14	0.01	0.34	0.13	0.30	0.06
LF	L176	0.02	0.01	0.00	0.02	0.00	0.00		0.80	0.11	0.41	0.59	0.01				0.05	0.13	0.44	0.07	0.19	0.03	0.07	0.03
LF Average		0.01	0.01	0.00	0.01	0.00	0.00		0.88	0.06	0.23	0.77	0.00				0.03	0.07	0.29	0.04	0.27	0.08	0.19	0.04
LG	L115	0.27		0.00	0.02	0.37	0.09		0.18	0.06	0.69	0.31					0.01	0.00	0.12	0.01	0.40	0.09	0.34	0.04
LG	L71	0.03		0.00	0.00	0.01	0.01		0.04	0.90	0.86	0.14					0.01	0.01	0.10	0.01	0.33	0.15	0.29	0.11
LG	L3241								0.37	0.15	0.95	0.05												
LG Average		0.15		0.00	0.01	0.19	0.05		0.19	0.37	0.83	0.17					0.01	0.01	0.11	0.01	0.36	0.12	0.31	0.07
LH	L87	0.00		0.00	0.00	0.00	0.00	0.00	0.95	0.03	0.87	0.13					0.00	0.00	0.04	0.01	0.27	0.16	0.39	0.13
LH	L133	0.01	0.00		0.00	0.00	0.01		0.94	0.03	0.93	0.07					0.04	0.06	0.53	0.07	0.20	0.02	0.06	0.03
LH Average		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.03	0.90	0.10					0.02	0.03	0.28	0.04	0.23	0.09	0.23	0.08
	Grand	0.23	0.05	0.06	0.07	0.14	0.06	0.00	0.28	0.11	0.15	0.56	0.20	0.06	0.02	0.00	0.01	0.02	0.18	0.02	0.35	0.10	0.25	0.07
Grand Average		0.23	0.13	0.07	0.11	0.16	0.08	0.00	0.17	0.13	0.26	0.45	0.31	0.22	0.17	0.05	0.02	0.03	0.22	0.02	0.30	0.11	0.22	0.08

Finally, we emphasize that even after we expanded the cluster information to map the full range of each setting, *the settings assessed cover only about half of the region*. Thus, the portion of the region with no occurrences of the mapped SGCN species, or the equivalent geophysical settings, was left out of this report.

Map 3.4: Geophysical settings used in this report.



Results: The results of the hexagon clustering and the properties of the 17 geophysical habitats are described in the upcoming pages where we list the tracked SGCN species associated with each setting. By "tracked" species we mean those species whose locations in a state are inventoried and monitored by State agency biologists. All patterns presented here were tabulated directly from the species locations but we emphasize that they do not necessarily indicate the patterns of common species, plants or communities. Moreover, species differ widely in their individual preferences and the degree of selectivity they show in relation to various physical gradients. The data compiled for this project can help illuminate these preferences. For example, the average setting of the 77 known tiger salamander locations were almost all under 800' and in areas that averaged 90 percent coarse sand, while the average setting of 147 marbled salamander were in the same elevation range but occurred across all types of geology classes (Table 3.2).

Table 3.2: Comparison of the geophysical composition of two amphibians based on their known locations and the average composition of the 1000 acre hexagonal area in which the location occurs. Count refers to the number of tracked locations in the heritage databases (77 and 147 respectively). Elevation zone and geological class definitions are given above.

		GEOLOGY CLASS									ELEVATION ZONE					
Species	**Count**	**Sed**	**Shale**	**Calc**	**Mod Calc**	**Granite**	**Mafic**	**Ultra**	**Coarse**	**Fine**	**coastal**	**very low**	**low**	**moderate**	**high**	**very high**
Eastern/Tiger Salamander	77			0.0					0.9	0.0	0.0	0.9	0.0	0.0		
Marbled Salamander	147	0.3	0.0	0.0	0.1	0.3	0.1	0.0	0.2	0.0	0.0	0.9	0.1			

A few species were ubiquitous across all settings or not specific to any geophysical setting, and some were not preferential to either of the two broad groups described below. Species that occurred broadly across the whole area include: **ubiquitous species**: Bald Eagle, Peregrine Falcon, Northern Harrier, Wood turtle, **non-preferential to the two broadest groups**: Henslow's Sparrow, Sedge Wren, Sharp-Shinned Hawk, Osprey, American Bittern, Common Loon, Bog Turtle, Blue-spotted Salamander, Bridal Shiner, Brook Floater, Triangle Floater.

The two broad groups were identified by the first split in the cluster analysis that divided the hexagons into two sets: areas below 800', essentially a coastal and very low elevation cluster (Group L) and areas above 800', essentially high elevations mountainous and alpine areas, and low inland hills and valleys (Group H). These two clusters were each further subdivided, Group L into ten settings and Group H into seven settings.

Group L: Coastal and Very Low Elevation Settings.

Settings below 800’ including coastal plains, large floodplains, river mouths and deltas, coastal shorelines, beaches and dunes, tidal marshes and other low elevation settings.

Tracked species found across most Group L settings includes the following:
Birds: Cooper's Hawk, Grasshopper Sparrow, Pied-billed Grebe, Red-headed Woodpecker, Sharp-Shinned Hawk, Yellow-breasted Chat, American Bittern, Bobolink, Long-eared Owl, Red-shouldered Hawk, Vesper Sparrow, Yellow Rail, Upland Sandpiper, Black Tern, Eastern Meadowlark, Common Nighthawk, Brown Thrasher. **Herptiles**: Spotted Turtle, Carpenter Frog, Tiger Salamander. **Mammals:** New England Cottontail, **Fish and Mussels**: Eastern Lampmussel, Eastern Pond Mussel, Fragile Papershell, Tidewater Mucket, Yellow Lampmussel, Glassy Darter

Geophysical Settings in Group L (only a few example species listed here)

LA1: Limestone settings at very low elevations, hilly landscape with wet flats. Example species include: Checkered Sculpin, Fowler's Toad, Trout-perch, Bog turtle, Stonecat, Indiana Bat.

LA2: Shale settings at very low elevations, hilly landscapes. Example species include: Green Floater, Comely Shiner, Pearl Dace, Swallowtail Shiner, Tessellated Darter, Upland Chorus Frog.

LB: Fine-silt flats at very low elevations, often with extensive wetlands. Example species include: Cherrystone Drop Snail, Wood turtle, Least Bittern.

LC: Fine-silt valleys and old lake plains at very low elevations. Forest or grasslands. Example species include: Creek heelsplitter, Cylindrical Papershell, Sora Rail, Virginia River Snail.

LD1: Mixed settings of granite with limestone, moderately calcareous or mafic substrate at very low elevations: Eastern Hognose Snake, American Brook Lamprey, Marbled Salamander.

LD2: Moderately calcareous settings at very low elevations. Example species include: Whip-poor-will, Grasshopper Sparrow, Red-headed Woodpecker, Blackchin Shiner, Yellow Lampmussel, Bog Turtle,

LE: Sedimentary hills and side-slopes at very low elevations. Example species include: Blue-spotted Salamander, Brook Floater, Cerulean Warbler, Eastern Red Bat, New England Cottontail, Upland Sandpiper.

LF: Coarse sand and outwash at very low elevation gentle hills and flats, often supporting pitch pine and scrub oak barrens. Example species include: Carpenter Frog, Glassy Darter, Corn Snake, Chuck-will's-widow.

LG: Fine-silt organic settings in the coastal maritime zone less than 20’ elevation. Example species include: Saltmarsh Sharp-tailed Sparrow, Willet, Black-crowned Night-heron, Common Tern.

LH: Coarse sand and beaches in the coastal maritime zone less than 20’ elevation. Example species include: Least Tern, Piping Plover, Great Egret, Snowy Egret, American Oystercatcher, Seaside Sparrow.

Group H: High, Moderate or Low Elevation Settings .
Setting above 800 feet.

Tracked species found across most Group H settings includes the following:
Birds: Northern Goshawk, plus the ubiquitous species listed above: Bald Eagle, Great Blue Heron,, Osprey, Sedge Wren, Northern Harrier. **Herptiles:** Jefferson Salamander, Timber Rattlesnake, **Mammals**: Allegheny Woodrat, Eastern Small-footed Bat, Indiana Bat, **Fish and Mussels**: Green Floater.

Geophysical Settings in Group H (only a few example species listed)

HA1: Granite bedrocks of high and alpine elevations (2500'+); mountain landscapes characterized by side-slopes, cliffs, summits and hills. Example species include: Bicknell's thrush.

HA0: Granite bedrocks of moderate elevation (1700-2500'), typically sloping landscapes with spruce and hardwood forests. Example species include: American three-toed woodpecker.

HA2: Granite and mafic bedrock settings at low elevations (800-1700'). Hilly landscapes, deciduous or mixed forest. Example species include: Black-and-White Warbler, Northern Leopard Frog.

HB1: Acidic sedimentary sandstones and conglomerates at low elevations (800-1700') in hilly landscapes; often oak or pine-oak forest. Example species include: Eastern Box Turtle, Round Whitefish, Short-eared Owl.

HB2: Shale, Limestone and Moderately Calcareous settings at low elevations (800-1700') in hilly landscapes. Example species include: Longhead Darter, Longtail Salamander, Ohio Lamprey, Upland Sandpiper.

HC1: Acidic sedimentary sandstones and conglomerates at moderate to high elevations (1700-4000'). Example species include: Appalachian Cottontail, Eastern Hellbender, Silver-haired Bat, Green Salamander.

HC2: Shale, sedimentary and moderately calcareous settings at moderate to high elevations (1700-4000'). Example species include: Loggerhead Shrike, Stonecat, James Spinymussel, Bobolink.

CHAPTER

Estimating Resilience

4

Section 1: Landscape Complexity

A central premise of this report is that the physical characteristics of a landscape can buffer an area from the direct effects of a changing climate by offering a connected array of microclimates that allow species to persist. We call this quality the site's adaptive capacity, or its **resilience**. In this section we describe the concepts, methods, and data used to estimate the relative resilience of any given site. The two factors important to the estimate - landscape complexity and landscape permeability – are discussed separately, as the tools for assessing and measuring them are quite different.

<u>Background:</u> The climate experienced by individual organisms may differ dramatically from the regional norm because the land's surface features break up climate into a variety of microclimates influenced by landforms like hills, hollows, and water bodies. As the regional climate changes, species are likely to shift their locations to take advantage of this variation. Here, we use the phrase **landscape complexity** to refer to the variety of microclimates present in a landscape based on its topography, elevation range, and moisture gradients. Topography describes the natural surface features of an area and these can be classified into landforms (e.g. cliffs, summits, coves, basins, valleys) that break topography into local units. Each landform represents a local expression of solar radiation, soil development, and moisture availability. Thus, landform variety results in a variety of meso and micro climates. Even without climate considerations, the variation in rates of erosion and deposition, in soil depth and texture, in nutrient availability, and in the distribution of moisture, combine to make landforms a primary edaphic controller of species distributions. When climate is considered, landform variation increases the persistence of species and buffers against direct climate effects by providing many combinations of temperature and moisture within a local neighborhood.

Researchers have documented how topographic variation can create surprisingly large temperature ranges in close proximity. For example, in the South Carolina's Blue Ridge Mountains south-facing slopes were measured at 104^0 in July, while a few hundred yards away the sheltered ravines were a cool 79^0 (P. McMillan, personal communication, October 2010). Weiss et al. (1988) measured mico-topographic thermal climates in relation to butterfly and their host plants, and concluded that areas of high local landscape complexity, even on a scale of tens of meters, appear particularly important for long-term population persistence under variable climatic conditions. Extinctions predicted from coarse-scale climate envelope models have recently come into question because many current models fail to capture the effects of topographic and elevation diversity in creating "microclimatic buffering" (Willis and Bhagwat 2009). For example, Randin et al. (2008) found that models predicting the loss of all suitable habitats for plants in the Swiss Alps conversely predicted the persistence of suitable habitats for all species when they were rerun at local scales that captured topographic diversity. Similarly, a model that included topographic diversity and elevation range predicted only half the species losses of butterflies in a mountainous area compared to a model base solely on climate (Luato and Heikkinen 2008). Thus, we hypothesized that sites with a large landform variety, elevation range, and wetland density - collectively landscape complexity - will retain more species throughout a changing climate by offering ample microclimates and thus more options for rearrangement. Below we describe how we measured each of these landscape elements.

Landform Variety: To be explicit about the number of microclimatic settings created by an area's surface features we created a landform model that delineated local environments with distinct combinations of moisture, radiant energy, deposition, and erosion. The model, based on Ruhe and Walker's (1968) five-part hillslope model of soil formation, and Conacher and Darymple's (1977) nine-unit land surface model, categorizes various combinations of slope, land position, aspect, and moisture accumulation (Figure 4.1 and 4.2). The methods to develop the model were based on Fels and Matson (1997) and are described in Anderson (1999) and in Appendix II. The major divisions are based on relative land position and slope (Figure 4.3) with side slopes further subdivided by aspect, and flats further subdivided by flow accumulation. In total, the landform model can distinguish up to 30 landform units but we commonly use a simplified 14 unit model that captures the major differences in settings. However, for use in this project we reduced the number of landforms further to 11 types because some types almost always occur as pairs (e.g. cliff/steep slope, cove/slope bottom) and we did not want the results of the landform variety count to be skewed toward these pairs. The types include the following (Figure 4.1-4.3, types separated by a slash were combined for the landform variety assessment):

Cliff/steep slope*	Cove/slope bottom,	Dry flat
Summit/ridgetop	Low hill	Wet flat
Upper/lower NE sideslope	Low hilltop flat	Water/lake/river
Upper/lower SE sideslope	Valley/toeslope*	

Our assumption was that separate landform settings will retain their distinct processes in spite of a changing climate; for example, a hot dry eroding upper slope will continue to offer a climatic environment different from a cool moist accumulating toe slope.

Figure 4.1: Topographic position and basic relationship to community types. The diversity of landforms within certain geologic settings leads to distinct expressions of biological diversity

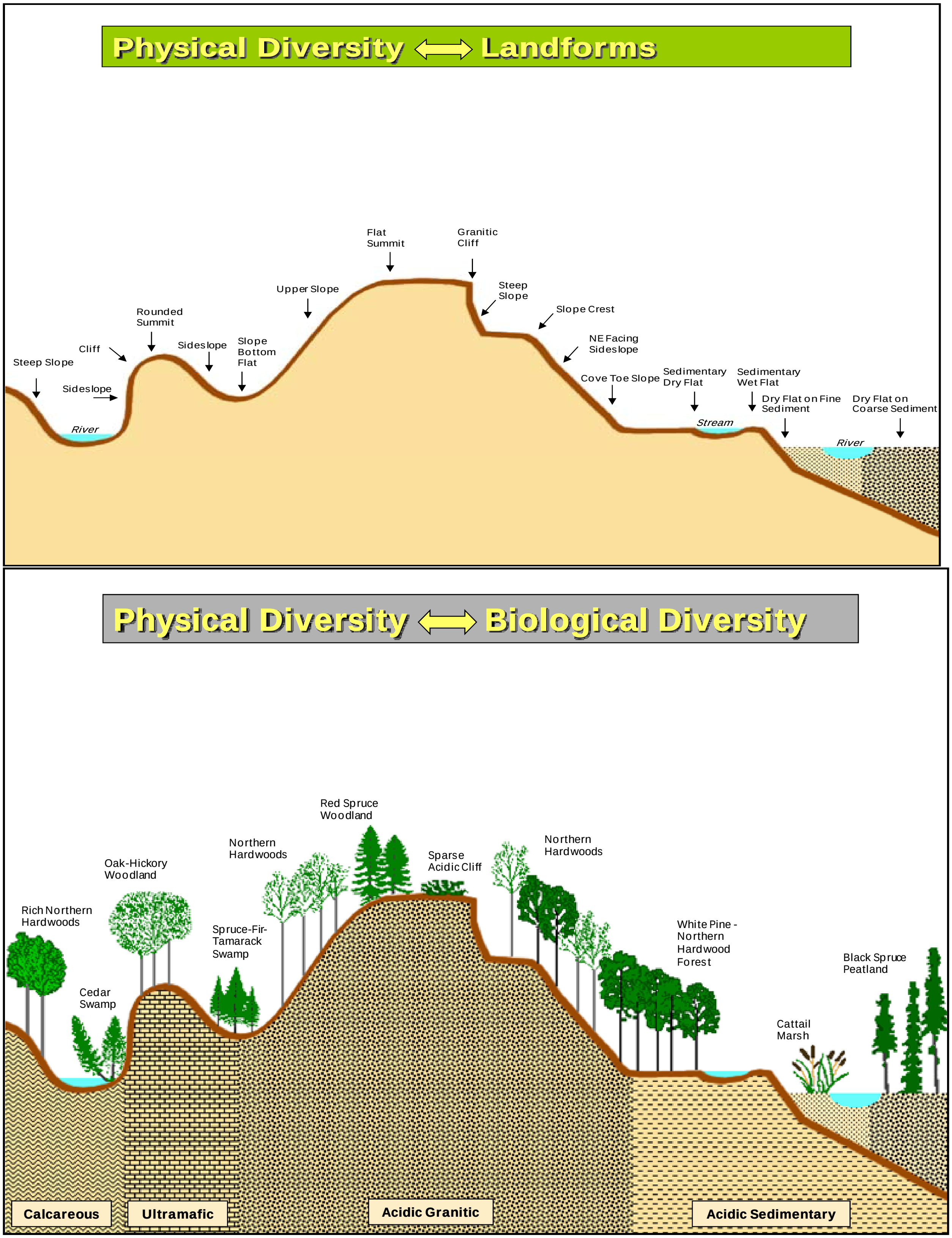


Figure 4.2: The 14 unit landform model mapped for Mount Mansfield, VT. This graphic shows how the landforms lie across on the landscape.

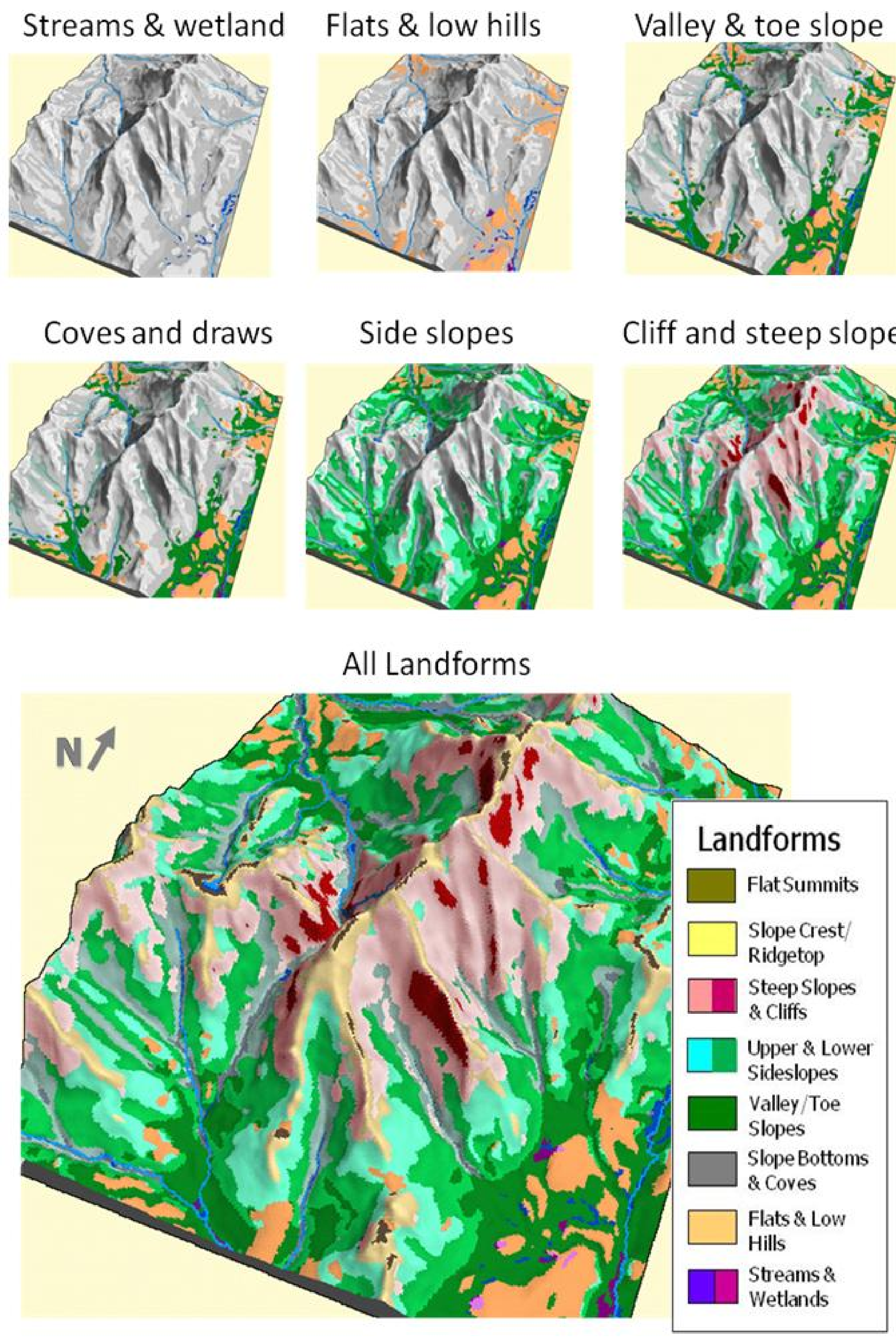
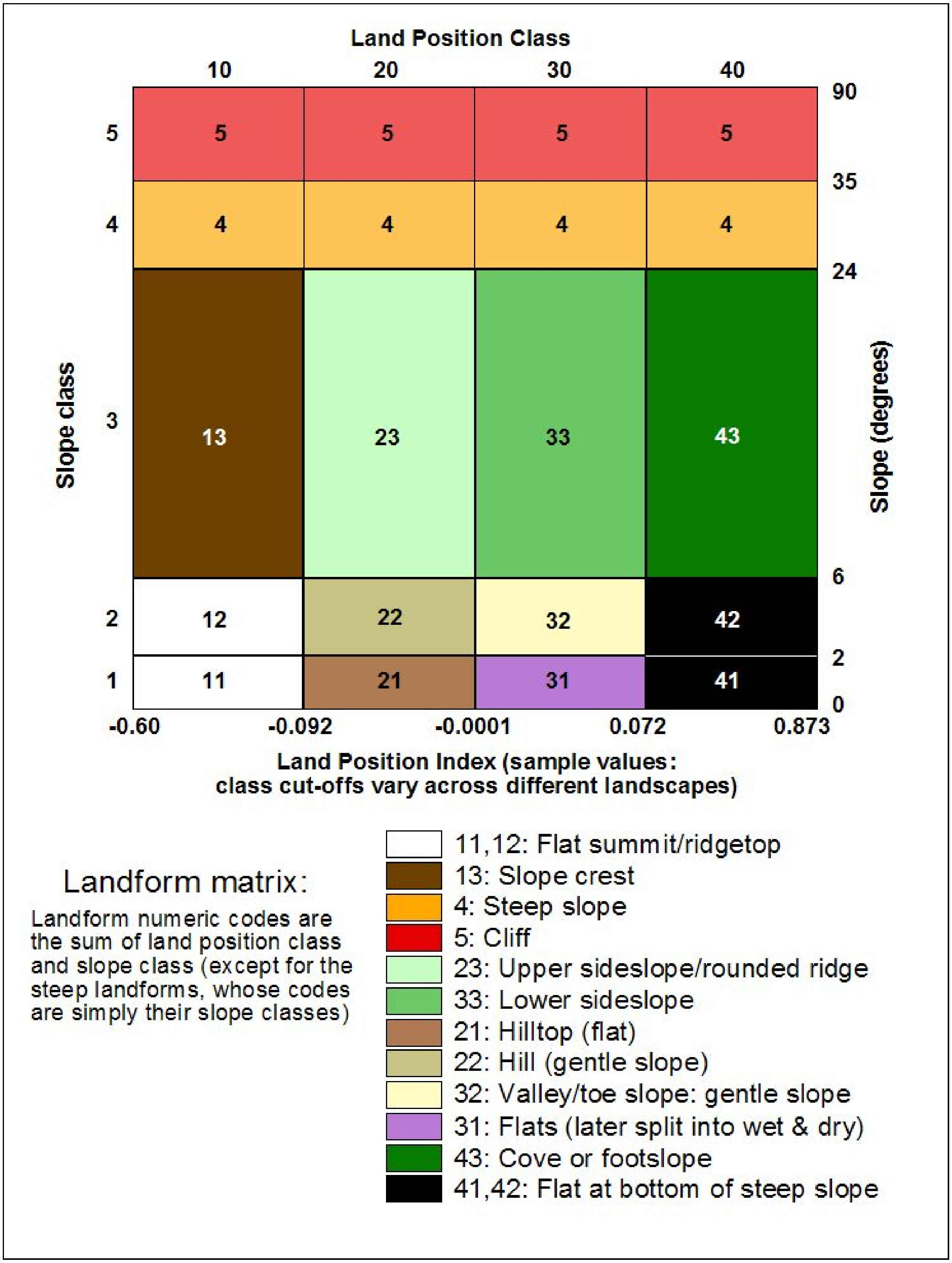


Figure 4.3: The underlying slope and land position model used to create the mapped landform grids. Adapted from Fels and Matson 1997



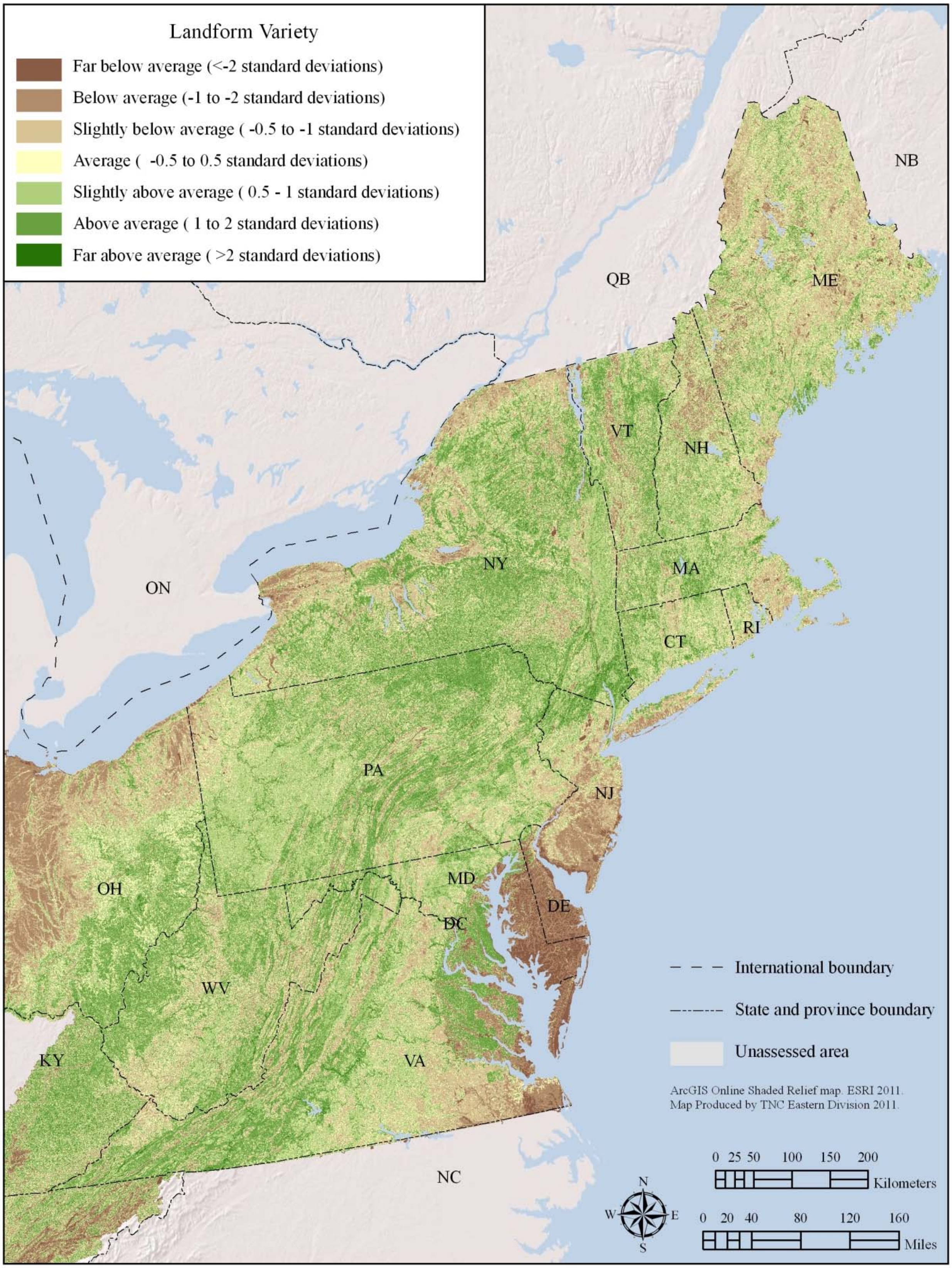
To calculate the **landform variety** metric we used the 11-part landform model and we tabulated the number of landforms within a 100 acre circle around every 30 meter cell in the region using a focal variety on the 11 landform types. Scores for each cell ranged from 1 to 11 (Map 4.1, Figure 4.4 a & b) with a mean of 6.05 and a standard deviation of 1.85

The landform model describes major difference in local climatic settings but it is theoretically possible to detect smaller gradations in topography. To examine this, we experimented with topographic rugosity as a proxy for microclimate diversity, but we found that it was hard to interpret this metric with respect to available microclimates. We tried a variety of measures including: standard deviation of elevation, standard deviation of slope, and surface rugosity. To test these measures, elevation data were processed and analyzed to calculate rugosity using a 10x10 meter kernel size. Rugosity for a single point was calculated by taking the surface area of the derived surface for the analysis kernel area and dividing it by the flat planar area of the same kernel area (100 square meters). Rugosity tiles were then clipped and masked to match the corresponding published elevation tiles from which they were derived. All of these methods produced somewhat similar results, and we made visual comparison of each metric at known sites. After studying the results, we decided that the landform variety metric conveyed the same information and was easier to interpret because it was constructed from ecologically meaningful thresholds that were not readily apparent in the rugosity data sets.

Elevation Range: Species distributions appear to be increasing or decreasing in elevation in concert with climate changes, particularly in hilly and mountainous landscape where the effects of elevation are magnified by slope. In flat landscapes, small elevation changes may have a dramatic effect on hydrologic processes such as flooding. To measure local elevation range we created an elevation range index by compiling a 30 meter digital elevation model for the region (USGS 2002) and using a focal range analysis to tabulate the range in elevation within a 100 acre circle around each cell. Scores for each cell ranged from 1 to 795 meters (Map 4.2, Figure 4.4 c) with a mean of 59.4 m and a standard deviation of 54.3. The data were highly skewed towards zero and were log transformed for further analysis (mean 3.64 and standard deviation of 1.08).

Wetland Density**:** A large part of this region is wet and flat, the result of past glaciation. Moreover, climate models disagree on whether the region will get wetter or drier, or both. In these flat areas, landform variety is low, elevation change is minimal, and wetlands are extensive. Visual examination of the landform variety and elevation range maps suggested that, while the concepts and data were relevant in these areas, this information alone did not always provide enough separation between sites, with respect to the long term resilience of extensive wetland areas. Further, modeled measures of moisture accumulations had the highest rates of error in extremely flat landscapes. Thus we determined that directly measuring wetland density provided the best available gauge of total freshwater accumulation at a scale finer than we could detect with a 30 meter topography model. Our assumption was that small isolated wetlands were more vulnerable to shrinkage and disappearance than wetlands embedded in a landscape crowded with other wetlands. Thus, our hypothesis was that wetland dependent species and communities would be more resilient in a landscape where there was a higher density of wetland features corresponding to more opportunities for suitable habitat nearby.

Map 4.1: Landform variety.



Map 4.2: Elevation range.

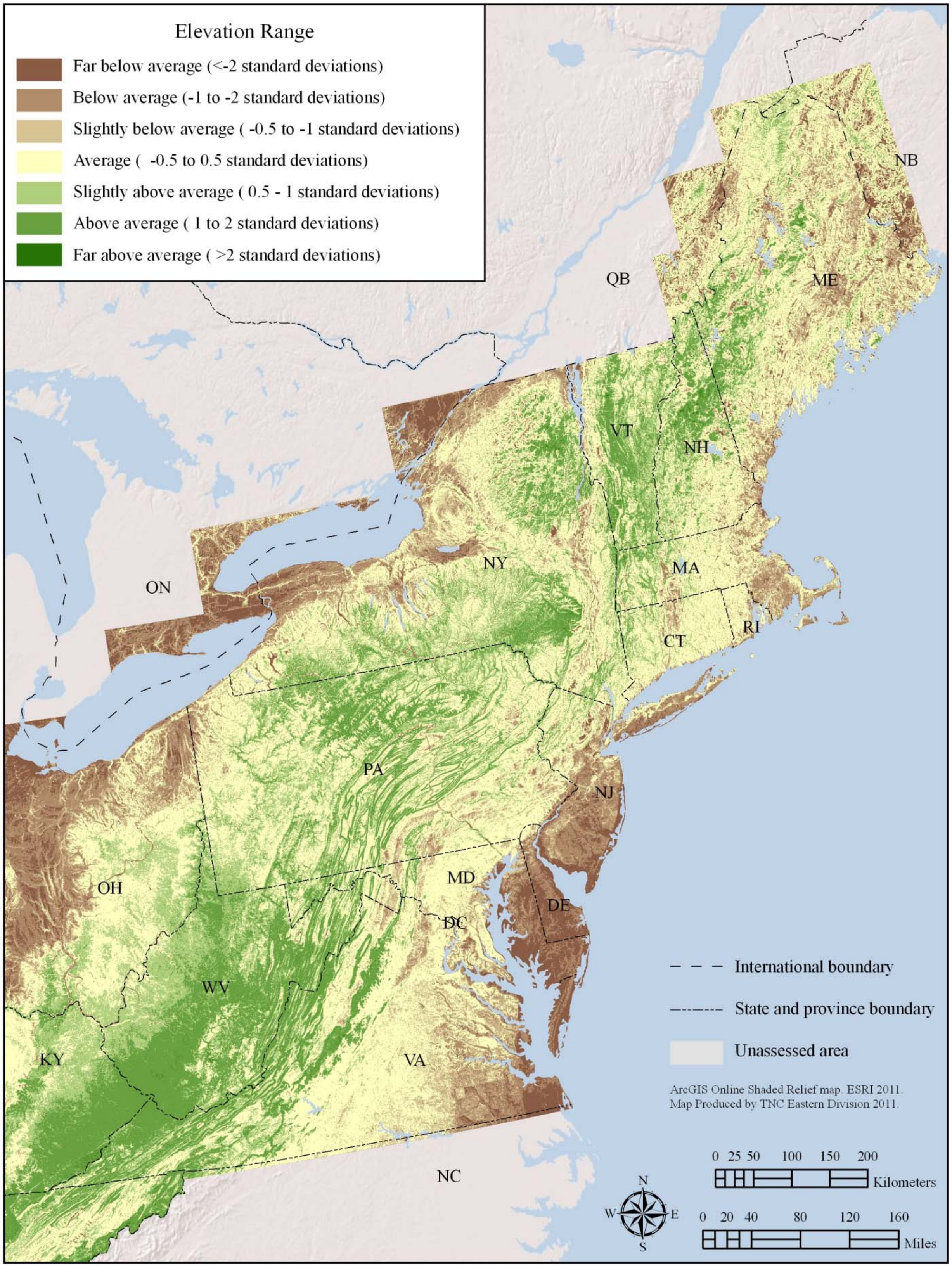
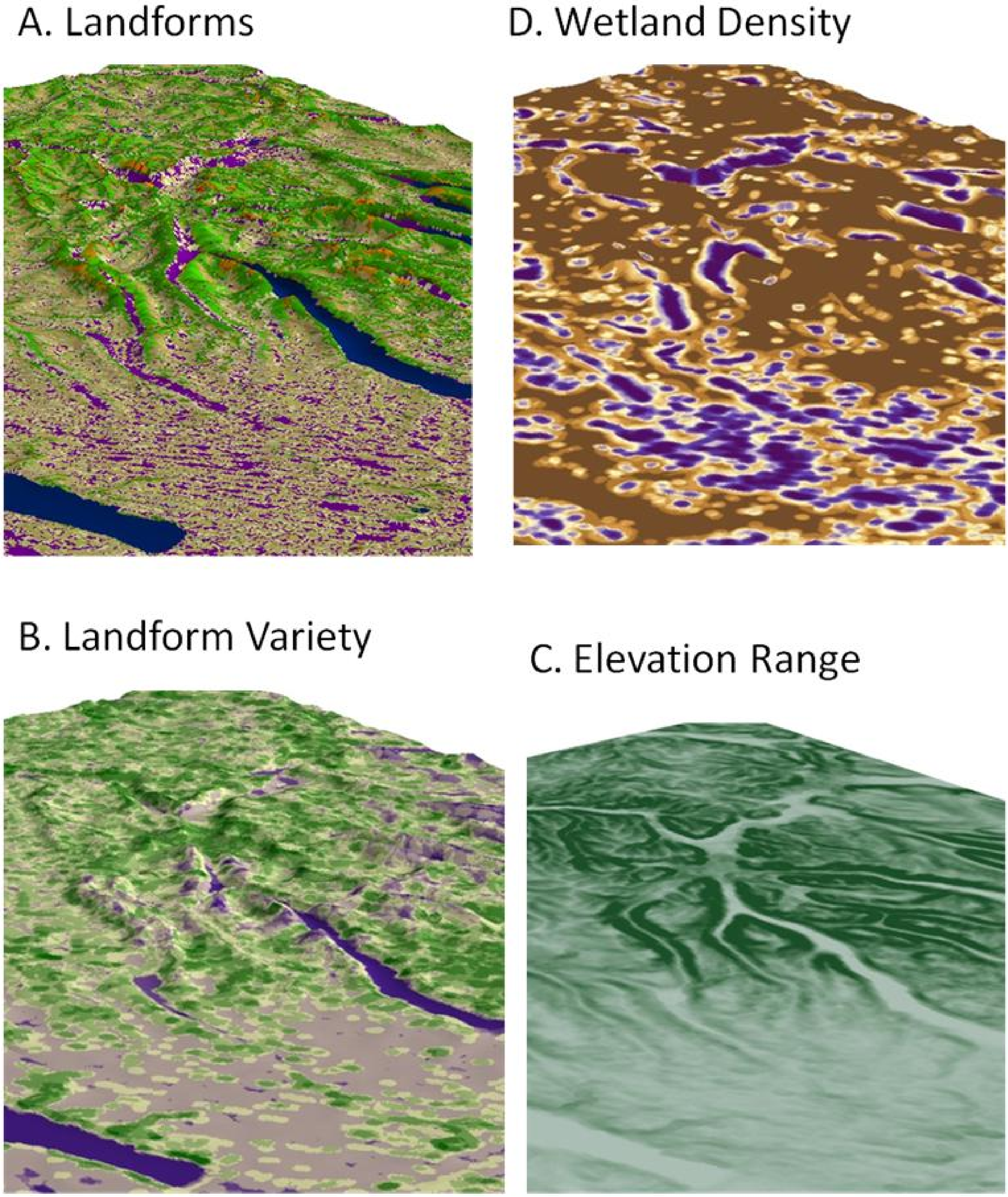


Figure 4.4 a-d: A three-dimensional look at the metrics of landscape complexity, Finger Lakes region of NY. All metrics are measured in 100 acre circles around every point (30 m cell) on the landscape. A. Landforms show the original landform model. B Landform Variety show the number of landforms with dark green as high and dark purple as low. C. Elevation Range shows the range of elevation with darker greens indicating a wider range. D. Wetland density is shown with purple as high and brown as low.



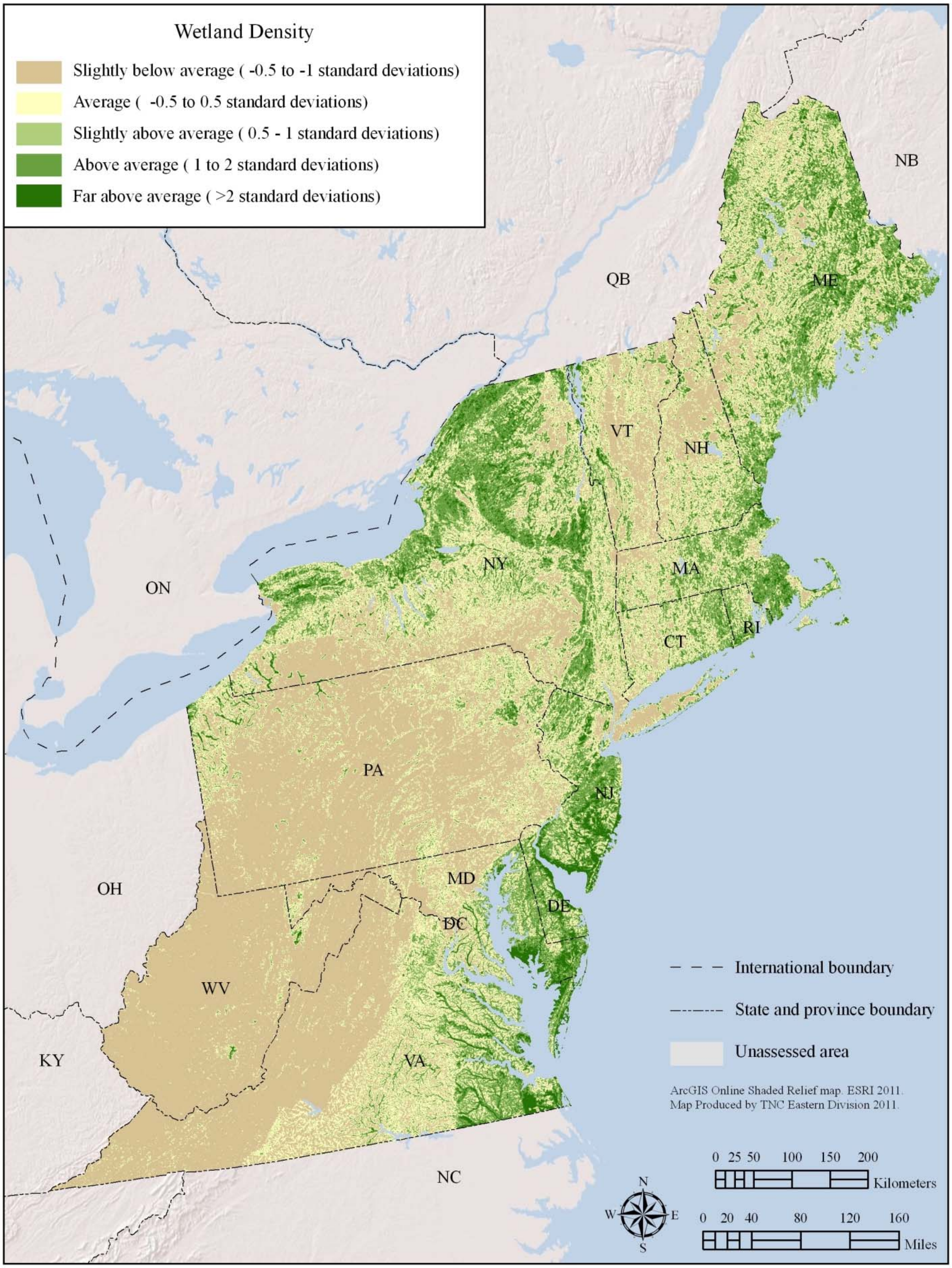
To assess the density of wetlands, we created a wetland grid for the region by combining the National Wetland Inventory, NLCD (2001) wetlands, and Southern Atlantic GAP programs wetlands datasets (http://www.basic.ncsu.edu/segap/index.html). We revised this source wetland dataset using the landform models to identify and remove erroneously mapped wetlands on summits, cliffs, steep slopes, and ridgetop landforms. To match the 100 acre scale of landform variety and elevation range, we generated the percent of wetlands within a 100 acre circle for each 30 meter cell in the region using a focal sum function in GIS. Additionally, to gauge the wetland density of the larger context, we generated the percent of wetlands of an area one magnitude larger (1000 acre circle) around each 30 meter cell in the region (Note for the coastal areas where much of the area within the 100 acre or 1000 acre circles was actually ocean, the percent of wetlands was based on only the percent of the land area, not ocean area, within the 100 acre or 1000 acre circle around each cell).

To summarize the wetland density for each cell, we combined the values from both search distances, weighting the 100 acre wetland density twice as much as the 1000 acre wetland density and summing the values into a integrated metric. Lastly, we log transformed the values to approximate a normal distribution and divided by the maximum value to yield a dataset normalized between 0-100 (Map 4.3, Figure 4.4d). Raw scores for each cell ranged from 0 to 100 percent with a mean of 7.1 percent and a standard deviation of 15.6 percent for the 100 acre search radius and a mean of 7.1 percent and standard deviation of 12.4 percent for the 1000 acre radius. The combined weighted value had a mean of 10.5 and standard deviation of 21.1.

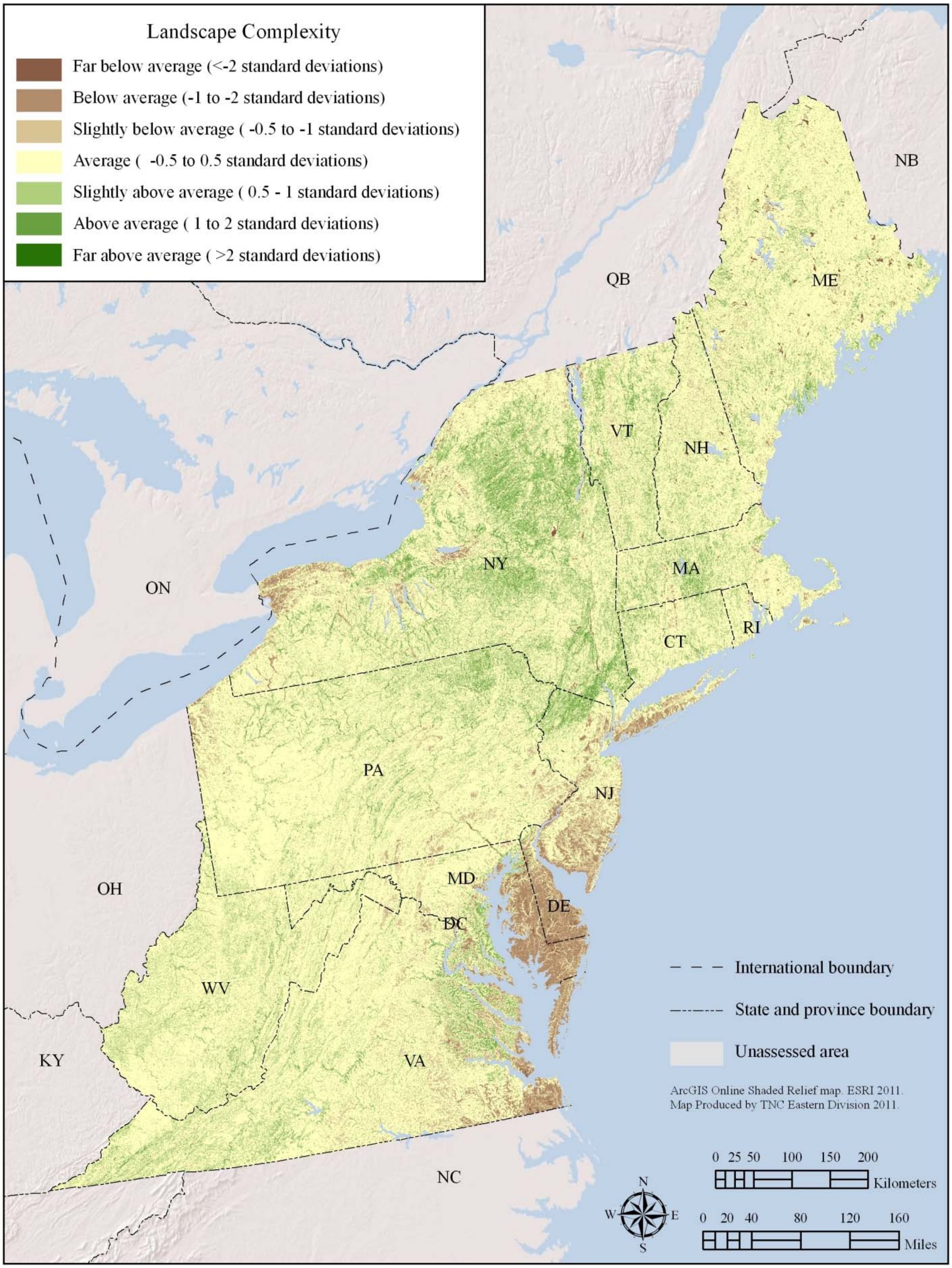
<u>Landscape Complexity Combined Index:</u> To create a standardized metric of landscape complexity (LC) we transformed all three indices (landform variety (LV), elevation range (ER), and wetland density (WD) to standardized normal distributions ("Z-scores" with a mean of 0 and standard deviation of 1) then combined them into a single index. In the combined index we weighted landform variety twice as much as the other to values due to the importance of this feature in creating well defined microclimates (Map 4.4). The final index was:

Landscape Complexity = (2 LV + 1 ER + 1WD)/4

Map 4.3: Wetland density.



Map 4.4: Landscape complexity.



Section 2: Landscape Permeability

The natural world constantly rearranges, but climate change is expected to shift seasonal temperature and precipitation patterns and significantly alter disturbance cycles of fire, wind, drought, and flood. Rapid periods of climate change in the Quaternary, when the landscape was comprised of continuous natural cover, saw shifts in species distributions but few extinctions (Botkin et al. 2007). However, with landscape fragmentation already altering ecological processes and impeding the ability of many species to respond, move, or adapt to changes, the concern is that the impaired ability of nature to adjust will result in wide-scale degradation. Fragmentation then, in combination with habitat loss, poses one of the greatest challenges to conserving biodiversity in a changing climate. Not surprisingly, the need to maintain **connectivity** has emerged as a point of agreement among scientists (Heller and Zavaleta 2009, Krosby et al. 2010). In theory, maintaining a permeable landscape, when done in conjunction with protecting and restoring sufficient areas of high quality habitat, should facilitate the expected range shifts and community reorganization.

Here we use the term '**permeability**' instead of 'connectivity' because in the conservation literature 'connectivity' is commonly defined as the capacity of individual species to move between areas of habitat via corridors and linkage zones (Lindenmayer and Fischer 2006). Accordingly, the analysis of landscape connectivity typically entails identifying linkages between specific places, usually patches of good habitat or natural landscape blocks, with respect to a particular species (Beier et al. 2011). In contrast, facilitating the type of ecological reorganization expected from climate change - many kinds of organisms, over many years, in all directions – requires a broader and more inclusive analysis, one appropriate to thinking about the transformation of whole landscapes.

Landscape permeability, as used here, is not based on individual species movements, but is a measure of landscape structure: the hardness of barriers, the connectedness of natural cover, and the arrangement of land uses. It 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* (Definition modified from Meiklejohn et al. 2010). To measure landscape permeability, we used and developed methods that map permeability as a continuous surface, not as a set of discrete cores and linkages typical of connectivity models. In line with our definition, we aimed for an analysis that quantified the physical arrangement of natural and modified habitats, the potential connections between areas of similar habitat within the landscape, and the quality of the converted lands separating these fragments. Essentially, we wanted to create a surface that revealed 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. Hence we use the term "ecological flows" or just "flows" to refer to both species movements and ecological processes.

Because permeability is a multidimensional characteristic, we developed two separate analytical models to assess different aspects of its local and regional nature. The first, **local connectedness**, starts with a focal cell and looked at the resistance to flows outward in all direction through the cell's local neighborhood. The second, **regional flow patterns**, looked at broad east-west and north-south flow patterns across the entire region and measures how flow patterns become slowed, redirected, or channeled into concentration areas, due to the spatial arrangements of cities, towns, farms, roads, and natural land.

Our basic assumption in both models was that the permeability of two adjacent cells increases with the similarity of those cells and decreases with their contrast. If adjacent landscape elements are identical (e.g. developed next to developed, or natural next to natural), then there is no disruption in permeability. Contrasting elements are presumed less permeable because of differences in structure, surface texture, chemistry, or temperature, which alters flow patterns (e.g. developed land adjacent to natural land). Our premise was that organisms and processes can, and do, move from one landscape element to another, but that sharp contrasts alter the natural patterns, either by slowing down, restricting, or rechanneling flow depending on the species or process. We expect the details of this to be complex and that in many cases, such as with impervious surfaces, some processes may speed up (overland flow) while others (infiltration) slow down.

Both of the models discussed below are based on land cover / land use maps consisting of three basic landscape elements subdivided into finer land cover types, and we used these categories in the weighting schemes described below:

Natural lands: landscape elements where natural processes are unconstrained and unmodified by human intervention such as forest, wetlands, or natural grasslands. Human influences are common but are mostly indirect, unintentional, and not the dominant process.

Agricultural or modified lands: landscape elements where natural processes are modified by direct, sustained, and intentional human intervention. This usually involves modifications to both the structure (e.g. clearing and mowing), and ecological processes (e.g. flood and fire suppression, predator regulation, nutrient enrichment).

Developed lands: landscape elements dominated by the direct conversion of physical habitat to buildings, roads, parking lots, or other infrastructure associated with human habitation and commerce. Natural processes are highly disrupted, channeled or suppressed. Vegetation is highly tended, manicured and controlled.

Our analyses were intentionally focused on natural land, but we recognize that there are species that thrive in both developed and modified lands.

Local Connectedness: The **local connectedness** metric measures how impaired the structural connections are between natural ecosystems within a local landscape. Roads, development, noise, exposed areas, dams, and other structures all directly alter processes and create resistance to species movement by increasing the risk (or perceived risk) of harm. This metric is an important component of resilience because it indicates whether a process is likely to be disrupted or how much access a species has to the microclimates within its given neighborhood.

The method used to map local connectedness for the region was resistant kernel analysis, developed and run by Brad Compton using software developed by the UMASS CAPS program (Compton et al. 2007, http://www.umass.edu/landeco/research/caps/caps.html). Connectedness refers to the connectivity of a focal cell to its ecological neighborhood when it is viewed as a source; in other words, it asks the question: to what extent are ecological flows outward from that cell impeded or facilitated by the surrounding landscape? Specifically each cell is coded with a resistance value base on land cover and roads, which are in turn assigned resistance weights by the user. The theoretical spread of a species or process outward from a focal cell is a function of the resistance values of the neighboring cells and their distance from the focal cell out to a maximum distance of three kilometers (Figure 4.5).

To calculate this metric, resistance weights were assigned to the elements of a land cover/road map. A variety of methods have been developed for determining resistance weights, in particular metrics of ecological similarity in community types (e.g. oak forest to oak forest assumed to be more connected than oak forest to spruce forest) have been used to good effect (B. Compton personal communication 2009, Compton et al. 2007). However, our weighting scheme was intentionally more generalized, such that any natural cover adjacent to other natural cover was scored as highly connected. We did not differentiate between forest types, and only slightly between open wetland and upland habitats (Table 4.1). Our assumption was that the requirements for movements and flows through natural landscape were less specific than the requirements for breeding, and that physical landscapes are naturally composed of an interacting mosaic of different ecosystems. Our goal was to locate areas where these arrays occur in such a way as to maintain their natural relationships and the connections between all types of flows, both material processes and species movements, not to maximize permeability for a single species (Hunter and Sulzer 2002, Ferrari and Ferrarini 2008, Forman and Godron 1986).

The resistance grid we created was based on a 90 meter classified land use map with roads embedded in the grid. The source data was the 2001 NLCD for United States and NALC 2005 for Canada that identify each grid cell as one of 16 classes of land cover (NALCMS 2005). We used 90 meter grid cells to make a reasonable processing time because the CAPS software program is computationally intense. Weights assigned to the land cover grid are shown in Table 4.1.

Table 4.1: Land Cover classes and the assigned resistance weights.

Land Cover Class	Land Element Category	Weight
Developed Medium Intensity/Minor Roads	Developed: Medium/High Intensity	100
Developed High Intensity/Major Roads	Developed: Medium/High Intensity	100
Developed Open Space	Developed: Low Intensity	90
Developed Low Intensity	Developed: Low Intensity	90
Pasture/Hay	Agriculture	80
Cultivated Crops	Agriculture	80
Barren Land (Rock/Sand/Clay)	Barren Land (Rock/Sand/Clay)	50
Open Water Natural	Water	50
Deciduous Forest	Natural	10
Evergreen Forest	Natural	10
Mixed Forest	Natural	10
Shrub/Scrub	Natural	10
Grassland/Herbaceous	Natural	10
Woody Wetlands	Natural	10
Emergent Herbaceous Wetlands	Natural	10

The final result was a grid of 90 meter cells (later converted to 30 meters) for the entire region where each cell was scored with a local connectivity value from 0 (least connected) to 100 (most connected). Actual scores had a mean of 31.8 and standard deviation of 30.6 for the region (Map 4.5, Figure 4.6, 4.7, and 4.8)

Figure 4.5: Examples of four resistant kernel cells shown against the land cover and roads map. The focal cell is the central point of each kernel and the spread, or size, of the kernel is the amount of constraints, so the score for the focal cell reflects the area around the cell. Kernel A is the most constrained and D is the least constrained

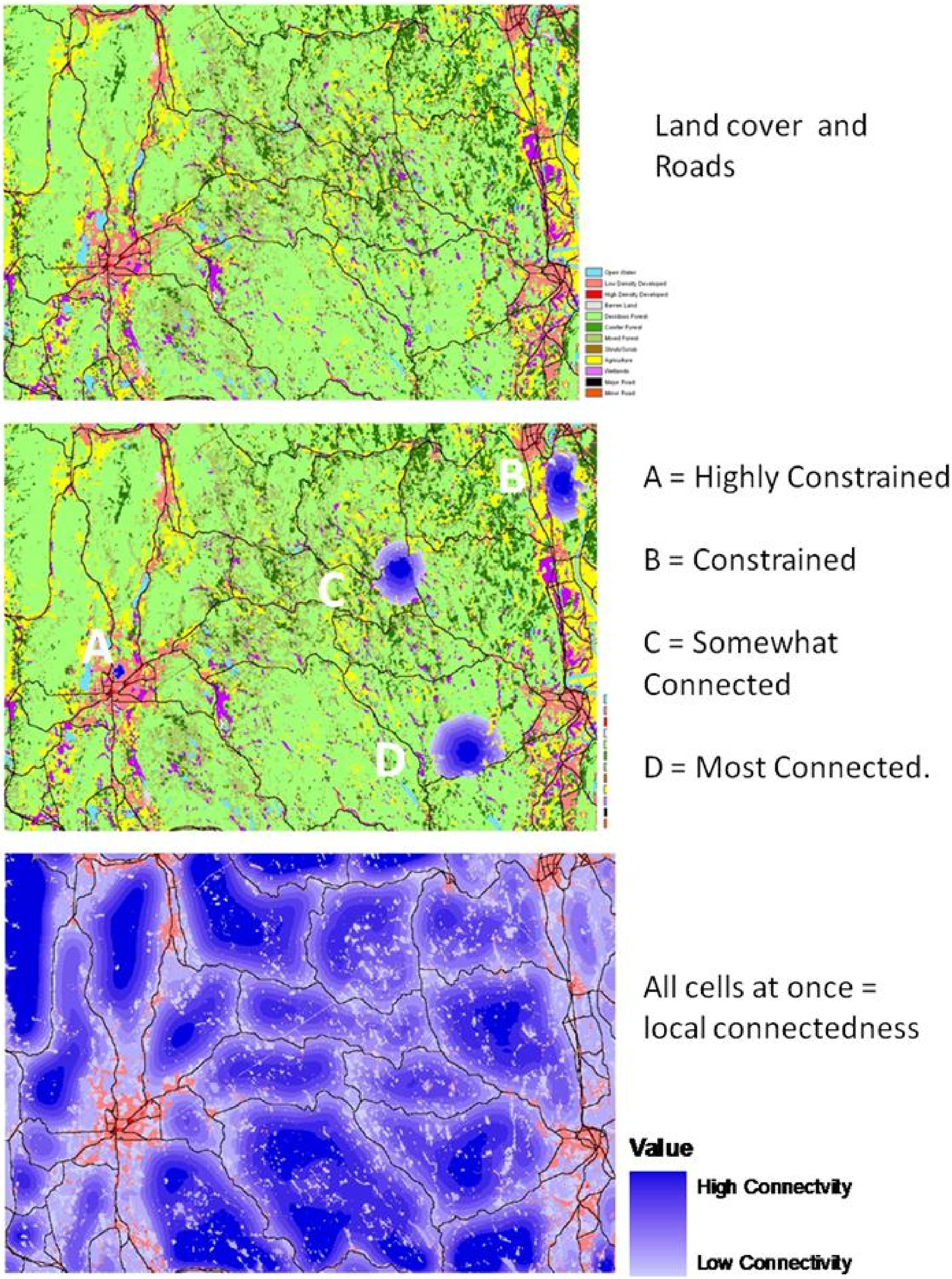


Figure 4.6: Detailed look at Kernal B in Figure 4.5. The top left image shows the topographic map for a rough location. The top right shows detail of the landuse grid. The bottom left shows the aerial and the 3km circular resistant kernel distance. The bottom right shows the kernel spread. Kernal B is constrained on the west by roads and railroads and on the east by water. The kernel can flow well through the natural landscape in the north and south direction.

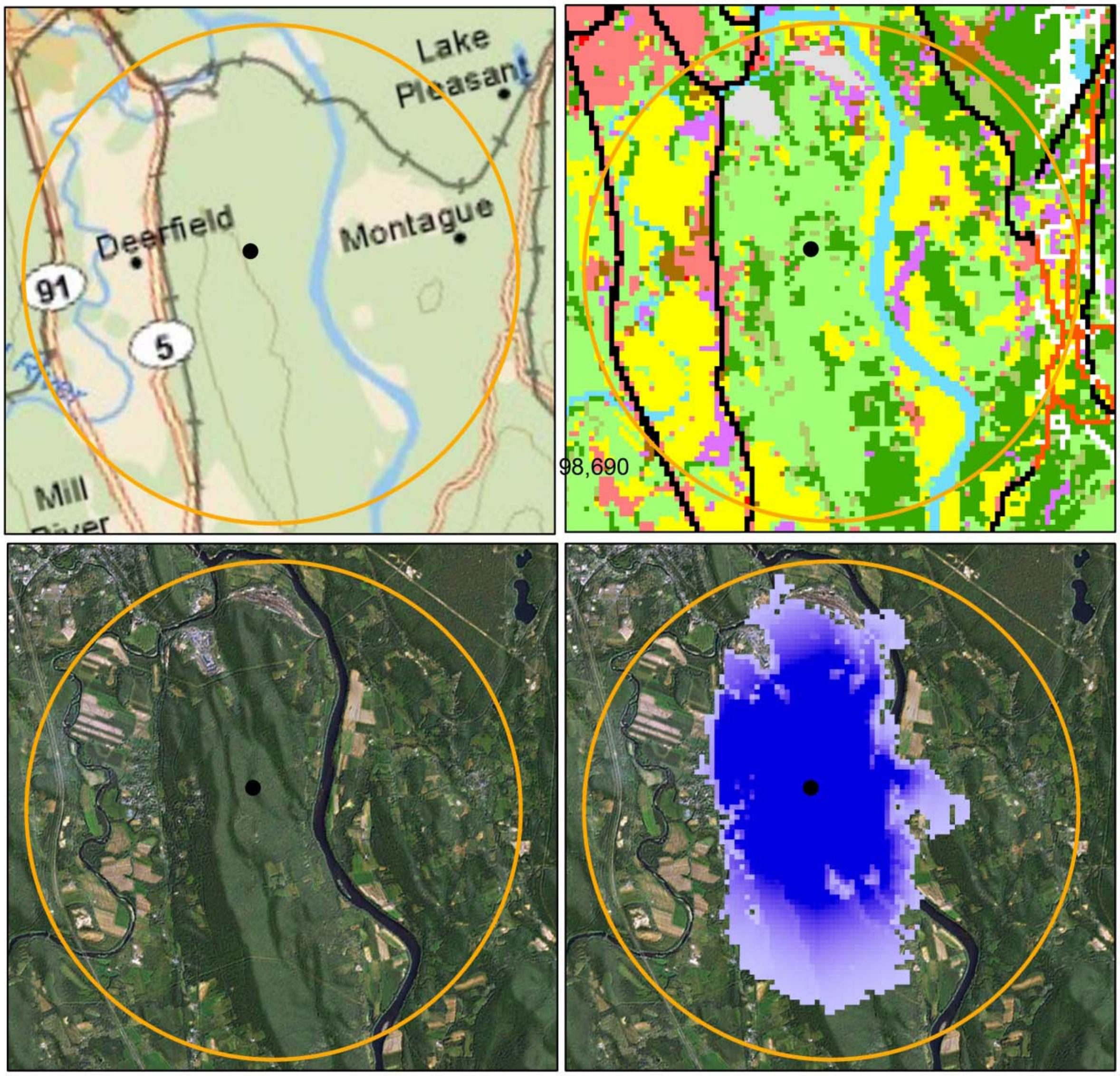


Figure 4.7: Visual comparison of local connectedness grid (top) with aerial photo of site (bottom). This shows a fragmented landscape on Prince Edward Island. The top image is a close up of the local connectedness surface with the site shown in blue outline. The bottom image shows a photo of the area with the approximate site area shown as a blue circle.

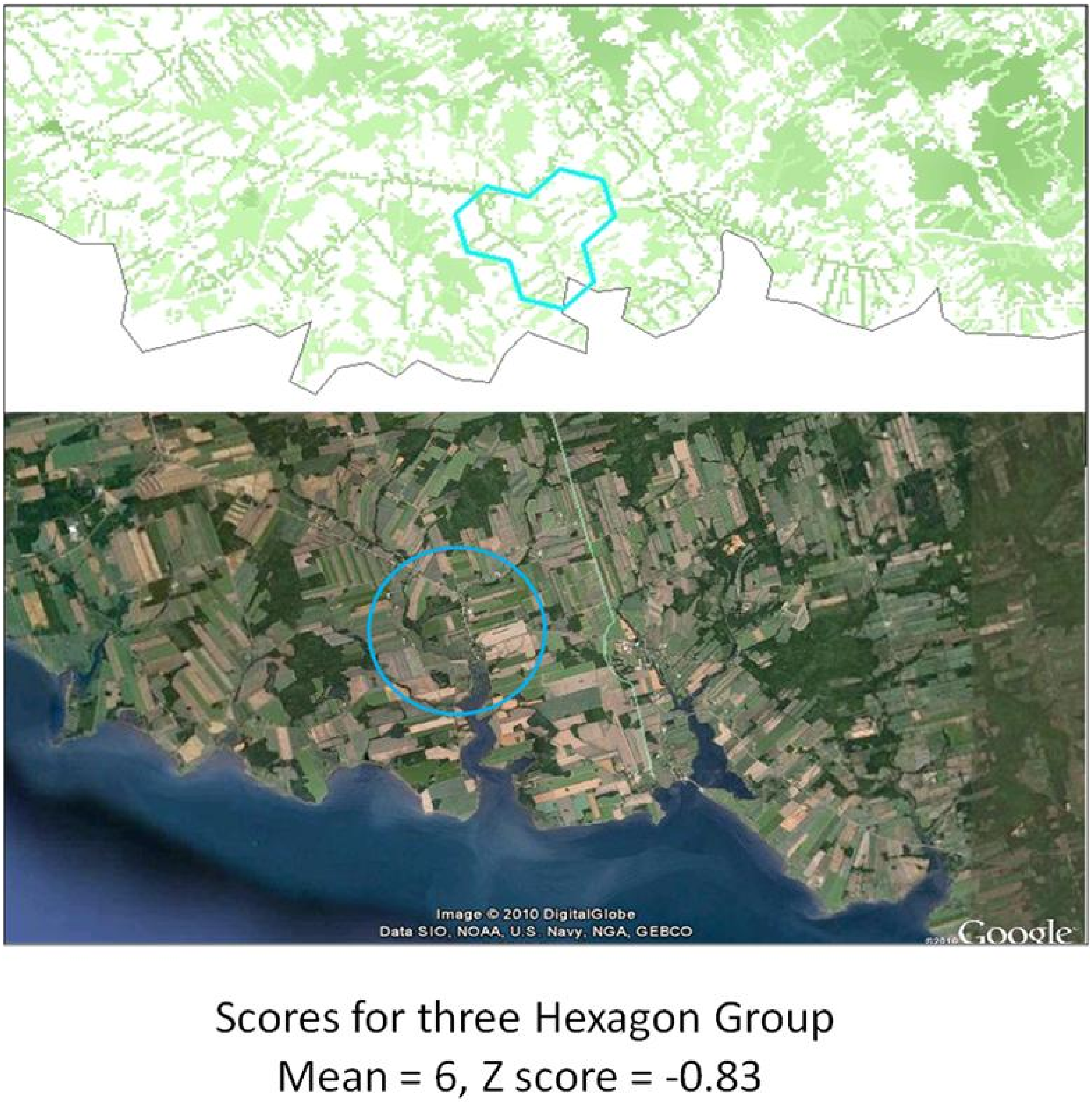
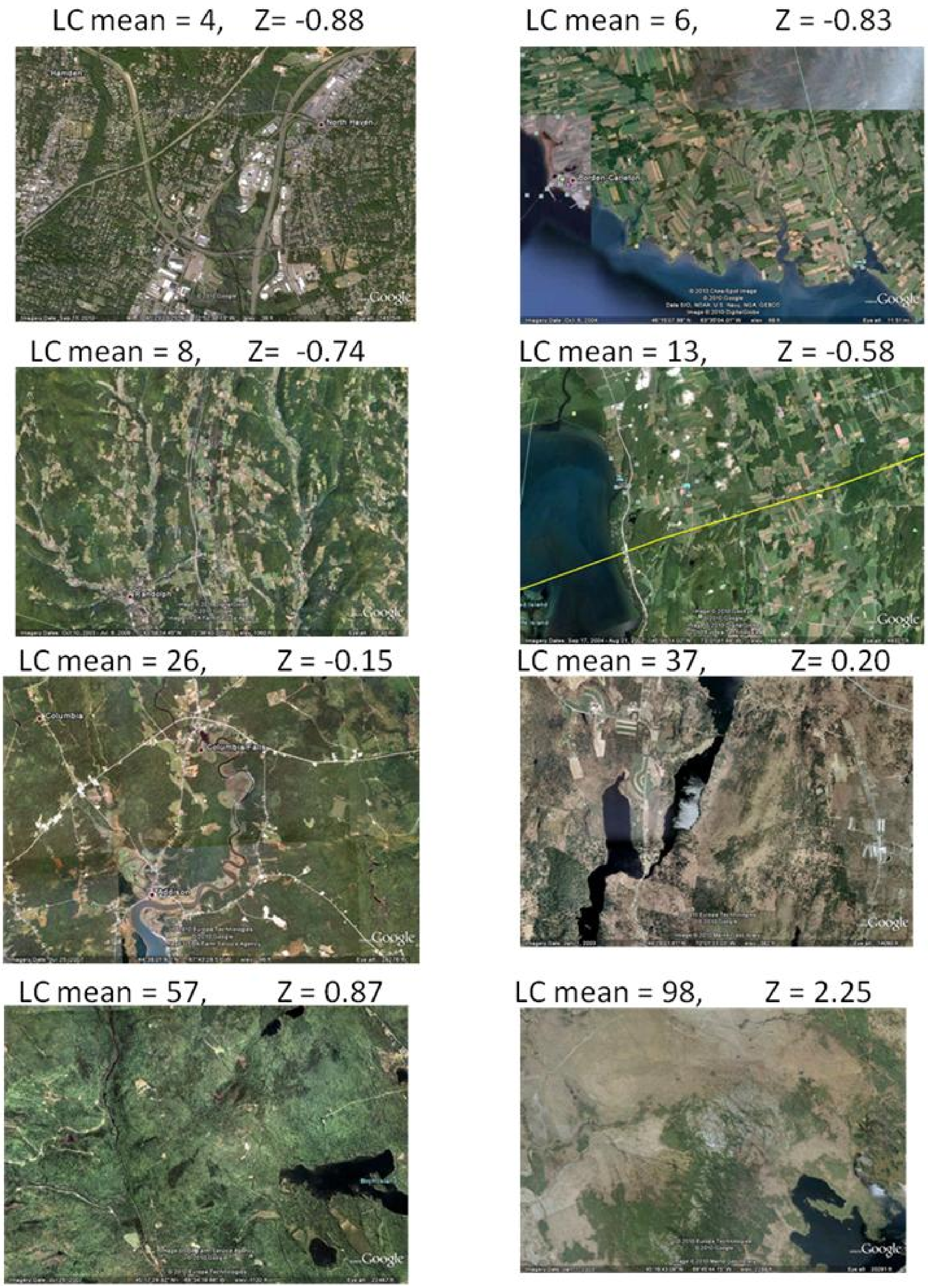
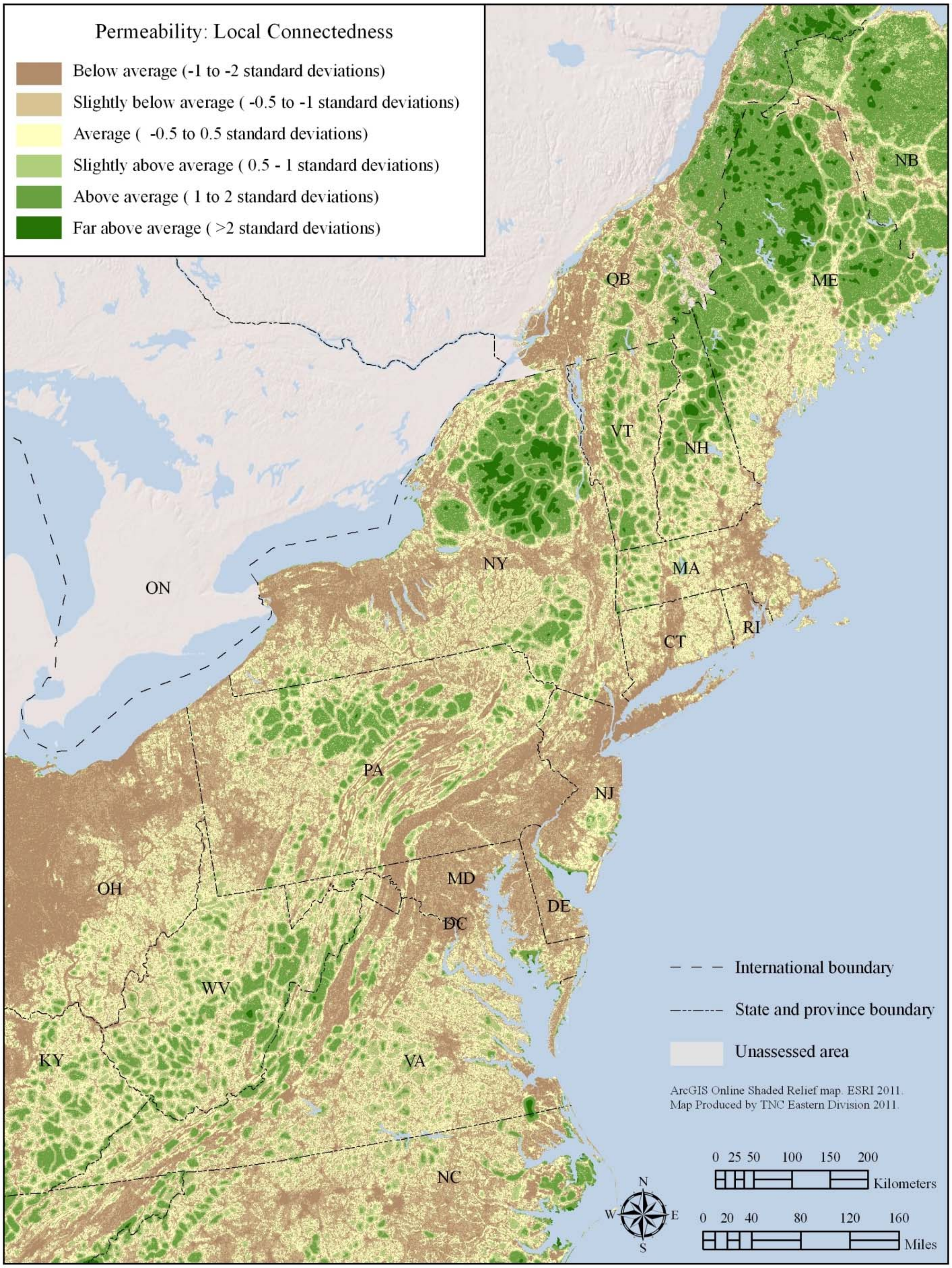


Figure 4.8: A gallery of satellite images and their corresponding local connectedness (lc) scores. The mean scores are based on a roughly circular site positioned at the center of each image (not shown). Z is units of standard deviation from the regional mean.



Map 4.5: Local connectedness.

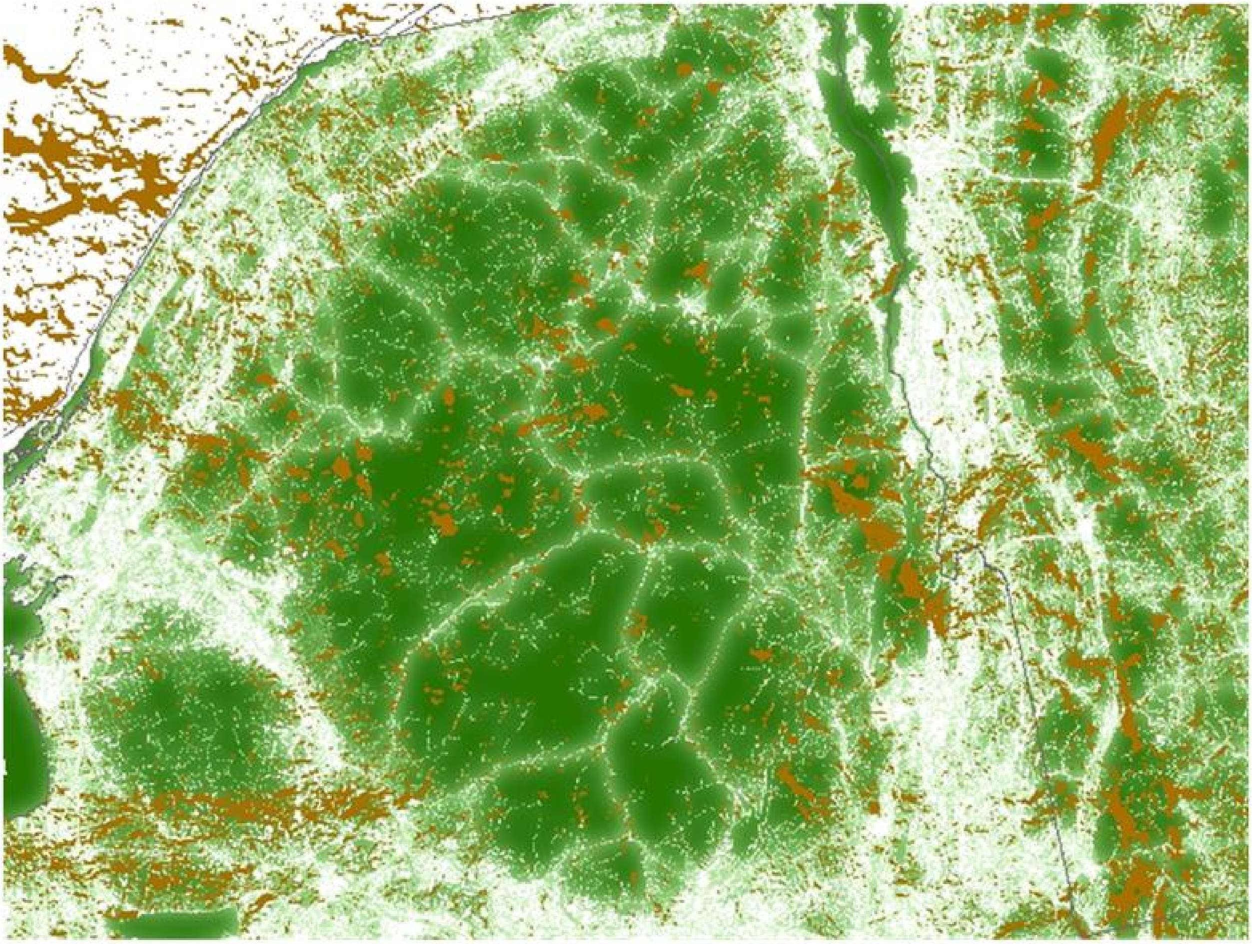


Regional Flow Patterns: The previous "local connectedness" metric measured and mapped the permeability of the landscape based on the local neighborhood surrounding each cell in the region, but does not account for broader scale movements such as directional range shifts, north-south migrations, or accumulating alterations to dispersal patterns. This metric, **regional flow patterns**, was designed to identify those areas where larger-scale directional movements become concentrated, diffused, or rerouted, due to the structure of the landscape. We used the software tool Circuitscape (McRae and Shah 2009), based on electric circuit theory, to model these larger flow patterns for the region. Like the resistant kernel analysis, the underlying data for this analysis was a land-cover and road data converted to a resistance grid by assigning resistance weights to the cell types, but the Circuitscape program calculates a surface of effective resistance to current moving through the landscape surface. The output of the program, an effective resistance surface, shows the behavior of directional flows. These patterns are analogous to the behaviors of water or electricity in that they either: 1) avoid areas of low permeability, 2) disperse in highly intact/highly permeable areas, or 3) concentrate in key linkages where flow accumulates or is channeled though a pinch point. Concentration areas are recognized by their high *current density*, and the program's ability to highlight concentration areas and pinch-points made it particularly useful for identifying the linkage areas that may be important to maintaining a base level of permeability across the whole region.

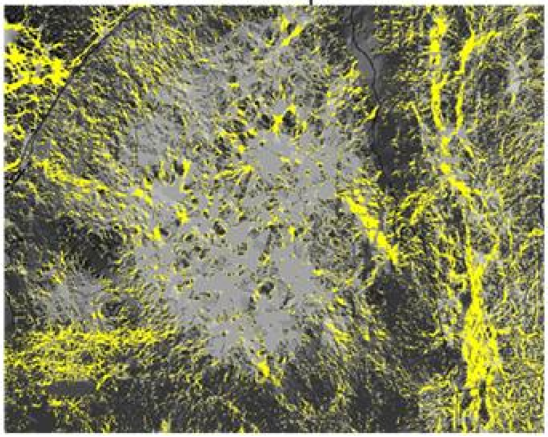
Before we applied the model to the entire region we calibrated it by focusing on a few places with well studied linkage areas, such as the region surrounding the Adirondacks (Figure 4.9). Our aim was to adjust the scale of the analysis and experiment with a variety of parameters, until the model could systematically identify these known linkages. The results in Figure 4.8 show where the Circuitscape analysis revealed something quite different from the local connectedness analysis. In this figure, the highest flow concentration areas are mapped in brown on top of the local connectedness grid mapped in green. The figure illustrates how east-west ecological flows become dispersed in the highly intact central region of the Adirondacks (where local connectedness is very high), and how the flows concentrate in the broad linkages in and out of the Adirondacks, that are highlighted in several places. This was the scale of concentration that we wanted to identify across the region, although the analysis also reveals many smaller and more diffuse concentration areas.

The Circuitscape program "sees" the landscape as made up of individual cells. For this analysis we used a 270 meters cell size and each cell was coded with a resistance derived by assigning it a value based on land cover and roads, with a proportional weight. We used the same land cover maps supplemented with major and minor roads, and the same weighting scheme as for the resistant kernel analysis. In the scheme, natural lands have the least resistance, agriculture or modified lands have more resistance and developed lands have the highest resistance (Table 4.1). In the Circuitscape program, the landscape is converted into a graph, with every cell in the landscape represented by a node (or a vertex) in the graph and connections between cells represented as edges in the graph with edge weights based on the average resistance of the two cells being connected (Shah and McRae 2008). The program performs a series of combinatorial and numerical operations to compute resistance-based connectivity metrics, calculating net passage probabilities for random walkers passing through nodes or across edges. Unlike a least cost path approach, Circuitscape incorporate multiple pathways which can be helpful in identifying corridors (McRae and Beier 2007). More detail about the model, its parameterization, and potential applications in ecology, evolution, and conservation planning can be found in McRae and Brier (2007) and McRae and Shah (2009).

Figure 4.9: Flow concentration areas. This figure shows the flow concentration areas in brown overlaid on the resistant kernel analysis (green) for the Adirondack region. In this figure the flow concentration areas are regions where east-west flows become concentrated because the structure of the landscape provides limited options for movement. Areas within the center of the region have moderate scores because the flow is dispersed across a highly intact landscape.

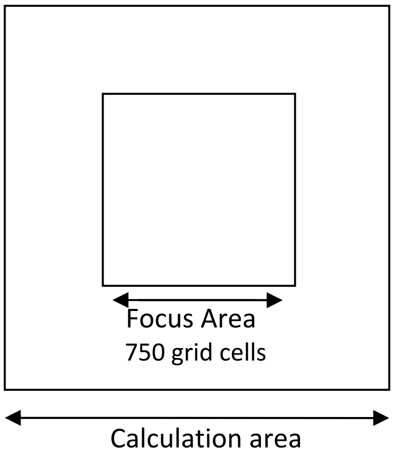


Raw Circuitscape Grid

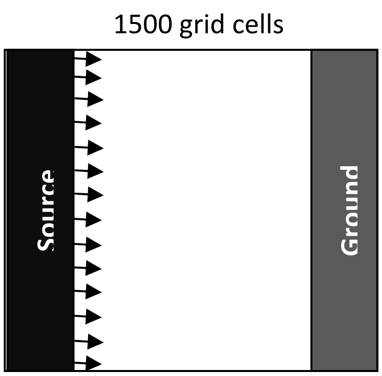


Circuitscape was originally designed to run resistance-based connectivity metrics from one focal area (habitat patch) to another. To get at overall landscape permeability, however, we did not provide a specific set of points/patches to connect, but instead measured current accumulation using continuous equal inputs across the entire landscape. After many trials, test runs, and conversations with the software developer, we developed a method to get complete wall-to-wall coverage by running the model in gridded landscape squares where one whole side was assigned to be source and the other side the ground, repeating the run for each of four directions: east-west, west-east, north-south, south-north, and then summing the results. This method gave stable and repeatable results for the central region of each square but was subject to edge effect around the perimeter. Thus to create a continuous surface we clipped out the central area of each square and tiled them together. Our final methods were as follows:

First, the study area was divided into 53 tiles – or calculation areas – comprised of 1500 cells by 1500 cells (~ 405 kilometers). Each tile was intersected with a land cover and road map coded for resistance using the weighting scheme in Table 4.1. (The analysis was run for all tiles with complete land cover information, but tiles that were solely water were ignored).



Second, within each tile we identified a focus area that was one quarter the size of the total calculation area. In the final results we used only the results from the central focus area because the results in this region stayed consistent even as the calculation area is increased. This eliminated the margin of the calculation area which appeared, based on many trials, to have considerable noise created by the starting points.



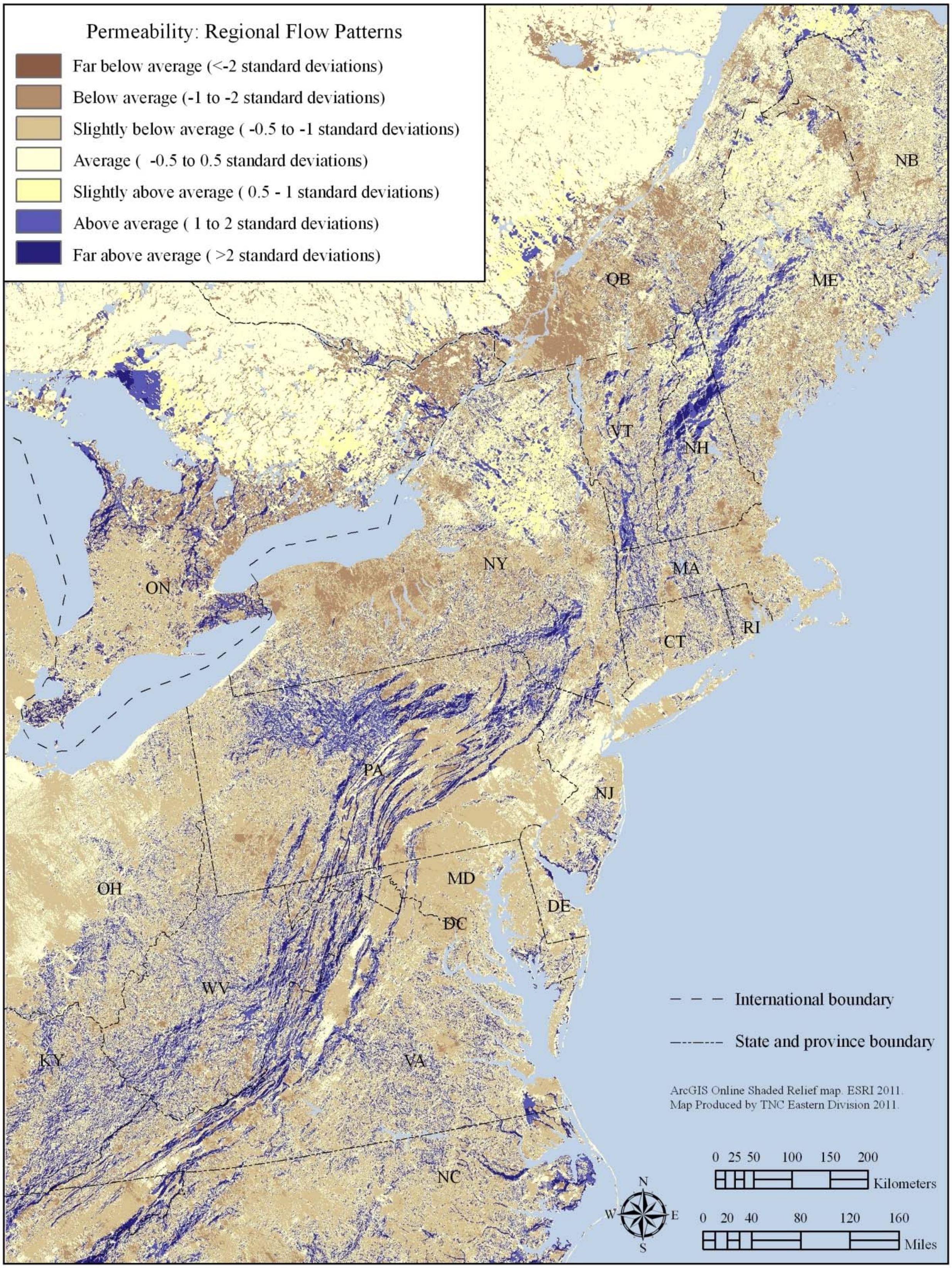
Third, we ran Circuitscape for each of the 53 calculation areas. To calculate the resistant surface, we set one side of the square to be the source and the other side area to be the ground. Current was injected into the system from each grid cell on the source side of the square. Because current seeks the path of least resistance from the source cells to any grid cell on the ground side, a square run with the west edge as source and the east side as ground will not produce the same current map as a square run with the east edge as source and west edge as ground. To account for these differences, we ran the program for all four of the direction possibilities - west to east, east to west, north to south, south to north, and summed the results.

Lastly, the focus area was clipped out of each calculation area and joined together to create a continuous coverage of results for the region (Map 4.6). The square focus areas had scores that were normalized to their calculation area, and we also created a surface where all scores were normalized to the whole region. When we compared these two results we found that the former map, normalized to each calculation area, was more effective at highlighting local concentration areas and pinch points while still revealing regional scale patterns as well. Thus, this was the data used in the analysis and shown here.

<u>Integration with Other Metrics</u>: The flow concentration attribute differs from the previous resilience metrics in that it was primarily concerned with the long term resilience of the network, not necessarily an individual site, thus we did not integrate this attribute directly into the cell and hexagon based resilience score but treated it as a separate score providing information on the importance of the site's location in maintaining large scale processes.

Notes on the use of Circuitscape: As suggested by McRae we did try using the source side as focal region. This allowed the current to flow not from every point on the source side, but to flow from the optimum point on the source side to the ground side. This did show the most direct flow of current from the source to the ground, but did not represent how current would flow through the landscape as a whole. Additionally, the primary reason for using the 270 m grid cell was that Circuitscape is a memory intensive program and we ran the program for a very large area. This also had the nice property of highlighting meaningful groups of cell at the scale we were interested in. At the 30 meter scale, more individual grid cells are highlighted making the patterns more dispersed. To change the spatial resolution from 90 meters eastern region dataset to 270 meters the aggregate function was used. When aggregating, the maximum value of the 9 smaller 90 meter grid cells was used. This insured that the barriers (roads, developed areas) were not averaged out. Cell size is important, but as long as it remains fine enough to capture relevant landscape elements, such as narrow corridors and barriers, the program has a great flexibility to get similar results with varying cell size (McRae et al 2008). The developers note that it is particularly important to capture absolute barriers (such as roads and railroads) to movement that may not be detectable at larger cell sizes (McRae et al 2008). A 270 meter grid cell size is much smaller than was used in published case studies. For a landscape genetic example using wolverine, McRae and Beier (2007) used a grid cell size of 5 kilometers, which they thought was course enough for computation on a desktop computer, but allowed them to capture major landscape features and minimizing categorization errors.

Map 4.6: Regional flow patterns.



Section 3: Combining Resilience Factors

In this section we describe our methods for combining the separate resilience factors into an integrated score. The integrated score is useful for thinking about how the factors combine to create resilience but we encourage users to look closely at the individual factors because they reveal interesting and different information about the landscape

A Common Scale: In order to combine and compare resilience factors, we transformed each metric to standardized normalized scores (Z-scores) so that each had a mean of zero and a standard deviation of 1 (the standard normal distribution- see below). This ensured that the data sets could be combined with each factor receiving equal weight, allowing us to manipulate the weights systematically. Due to the large size of the source datasets, each dataset was transformed into an integer grid and the Z distribution was multiplied by 1000 (e.g. 1 standard deviation = value of 1000) for more efficient data processing and storage.

Using the mean μ ("mu"), and standard deviation σ ("sigma") of the scores for all cells in the region, we converted it into a z score by using the following formula on each individual score "x":

$$z = \frac{x - \mu}{\sigma}$$

Landscape Complexity: Integrated Score: Based on the distribution of species locations within 100 acre areas, the variety of landforms was the factor most directly related to the number of microclimates, and thus we gave twice the weight to this factor in the combined score:

> **Landscape Complexity** = (2*LV + 1* ER + 1 WD)/4).
> Where LV = landform variety, ER = elevation range, and WD = wetland density.

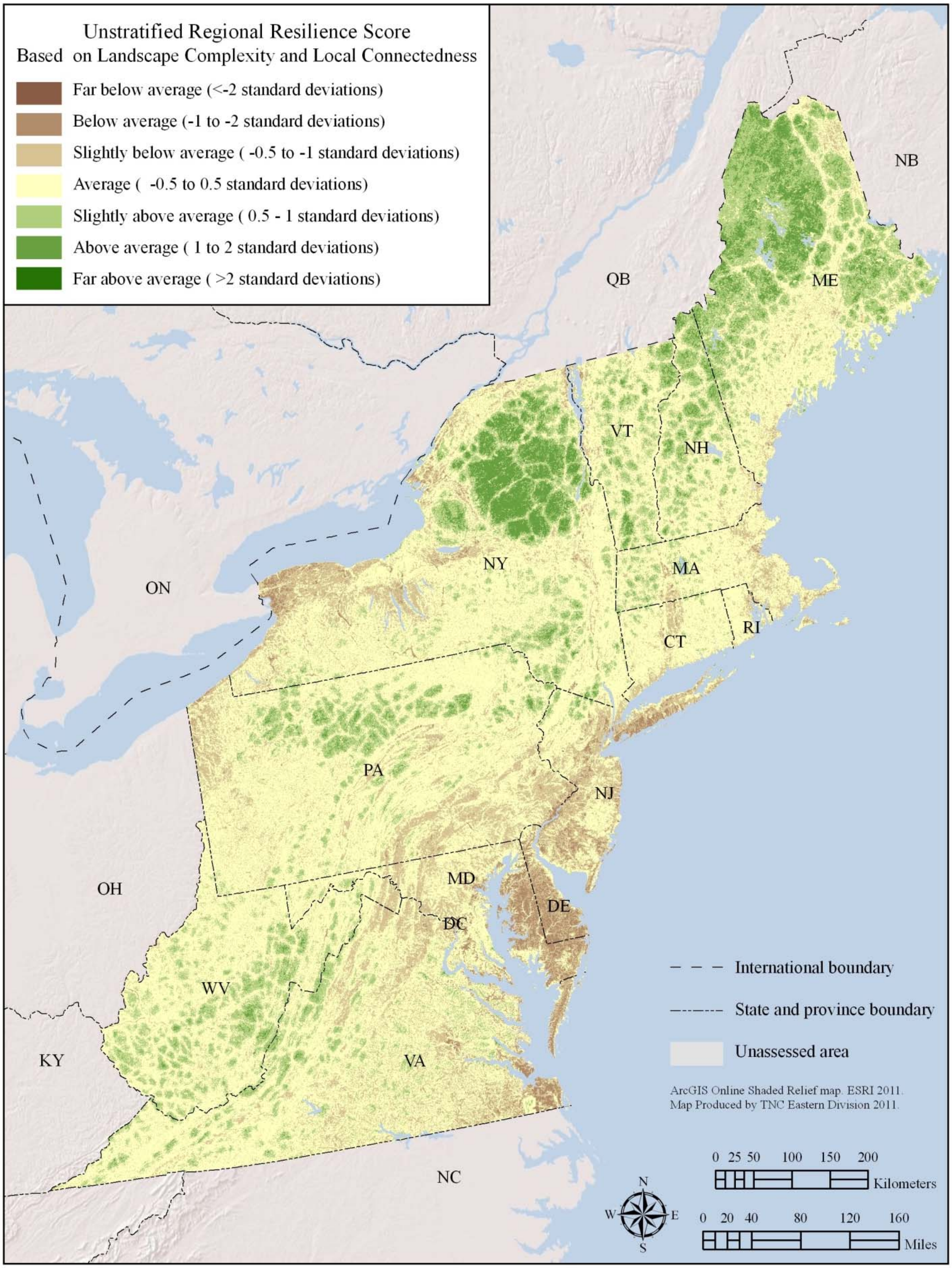
In areas dominated by wetland systems, we created a separate combined metric that more weight to wetland density higher and ignore elevation. This was applied only in the hexagon analysis (see below) when the 1000 acre hexagon was composed of over 66% wet flat as determined by the landforms. This only applied to two groups: H97 and L39.

> If 1000 acre area was > 66% wet flat, LC = (1*LV+ 3* WD)/4

Estimates of Resilience: Integrated Score: We created a basic estimate of resilience for each cell by summing the Z-values for: 1) **local connectedness** and 2) **landscape complexity**, and taking the average. Both inputs had equal weights and we transformed the resultant grid into a Z distribution (Map 4.7). Regional flow patterns were not used in this calculation.

> Estimated Resilience = (LC1 +LC2)/2
> Where LC1 = local connectedness and LC2 = landscape complexity

Map 4.7: Estimated resilience score.



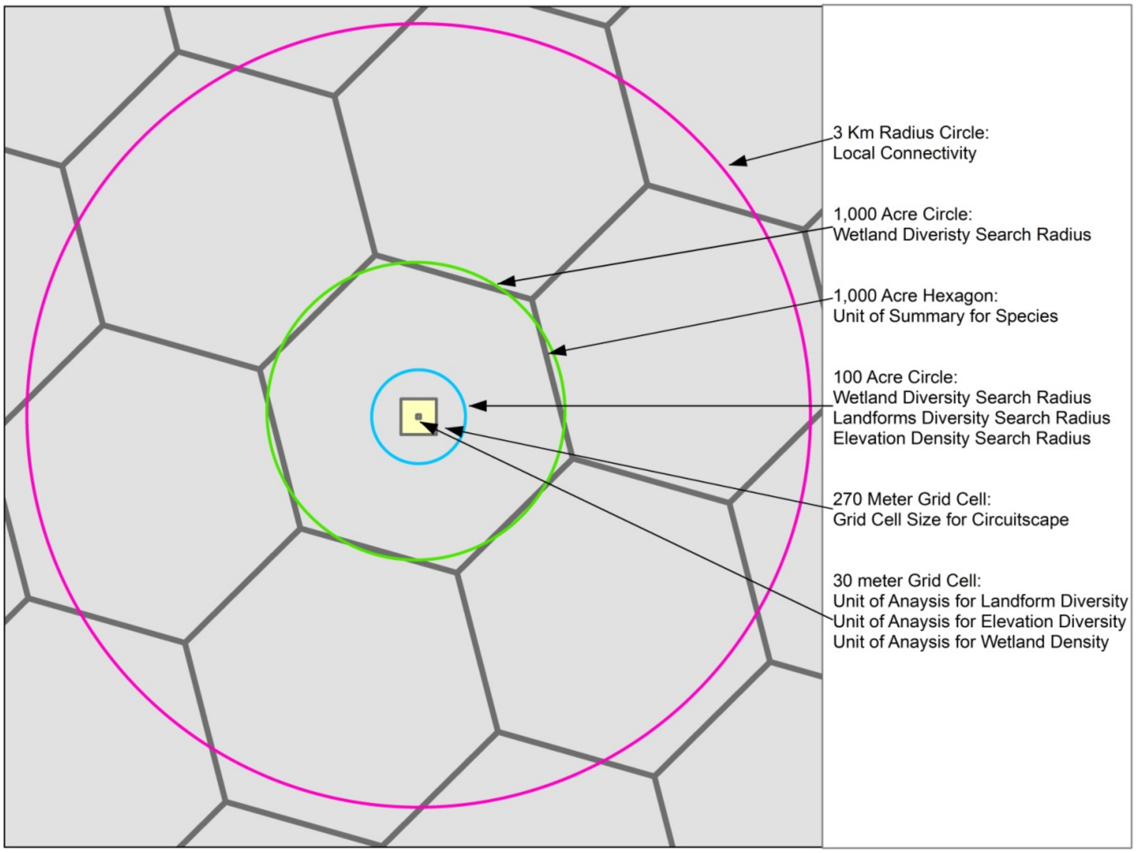
CHAPTER

5

Results: Scores for Sites and Species

This section describes how we applied the estimates and attributes of resilience to each site to identify: 1) the most resilience areas of each geophysical setting, 2) the most resilient areas in the whole region, and 3) the largest focal areas that have high resilience scores and confirmed species locations. The maps are accompanied by summaries of how well the individual species are captured by the sites, with summaries in this chapter and detailed charts in Appendix I. All the maps are presented together after a summary of the information and queries associated with each. When we integrated the information across scales we tried to be cognizant of how the data scales nested within each other (Figure 5.1) so that each data set contributed equally to the final scores.

Figure 5.1: The variety of local neighborhood sizes used in this assessment. The information was all tagged to the 30 meter cell (the smallest center point) and summarized by 1000 acre hexagons. Landscape variety, elevation range, and wetland density all used a 100 acre search radius around each 30 meter cell, with the later also weighted by a 1000 acre search. The regional flow patterns were assessed as a 270 meter grid (the square box). Local connectivity was scored to the 30 meter cell but evaluated over a search radius covering 3 kilometer (pink circle).



Sites (1000 Acre Hexagons): We attributed each hexagon with information and scores for the resilience factors described in the previous chapters: landform variety, elevation range, wetland density, local connectedness, regional flow concentrations, and the integrated variables of landscape complexity and estimated resilience. For each factor, we calculated the minimum, maximum, range, mean, standard deviation, sum, variety, majority, minority, and median for each hexagon using zonal statistics in ArcGIS Toolbox. Additionally, we did the same for five condition values (described below) for use with the species tables: development, agriculture, road density, and the mean and maximum length of connected stream networks.

Geophysical Settings: For each geophysical setting we identified the area with the highest resilience scores by calculating the mean estimated resilience score for all cells of each setting, and then identifying those hexagons that scored above the mean **OR** that were above the mean for the entire region. The end of this chapter presents each habitat individually with a list of the associated SGCN species, the geophysical characteristics, the geophysical subtypes, and the final resilience scores (Maps 5.1 - 5.17).

Most Resilient Examples of each Geophysical Setting: This analysis identified the highest scoring sites in the region stratified by the geophysical settings – the major result of this project (Map 5.18). Essentially, it is the combination of the previous individual setting maps rolled into one integrated map. In it, a hexagon was scored high if it was above the mean for its setting **OR** if was above the mean for the whole region. This accounts for areas that scored high for the region, and are thus expected to be highly resilient, even if they were below the mean when compared to their own setting. We overlaid the confirming species points on this map to identify areas where SGCN species are currently found (Map 5.19), although the distribution of confirming locations is skewed towards some coastal states (Map 2.1). Collectively the resilient sites cover 58 percent of the hexagons that contain SCGN species including over 50 percent of each individual taxonomic group (Example Table 5.1 and Full Table Appendix I, Table F-J).

Whole Region Unstratified: Estimated resilience scores were also calculated for the whole region regardless of the setting. We refer to this as the **unstratified** map (Map 5.20) as it shows the highest scoring sites in the region based on a single ruler and without stratifying the results among different geophysical settings. The map is strongly biased toward certain types of settings emphasizing the high granite mountains that score high when compared to the sedimentary low lands. However, the map and table are useful for comparing scores across species to evaluate the relative resilience of each set of species locations compared to others in its taxonomic group. These scores can be compared across taxonomic groups (Table 5.1 and Appendix I, Table F-J).

Table 5.1: Summary of species occurrences within the resilient sites (hexagons) and within the largest focal areas. Counts are by total number of hexagons that contain the species of interest. Sites are summarized by the total number of hexagons distributed across the Z-score classes based on the mean values (e.g. 0+ equals 0 to 1 standard deviations above the mean, 1+ equals 1 to 2 standard deviations above the mean, etc.). The 'Hexagons by Settings' column corresponds to Maps 5.18 and 5.19, and the 'Hexagons Unstratified' corresponds to Map 5.20. Focal areas are summarized by the number of individual hexagons with species point locations and shown as either in or out of a focal area (Map 5.19). The full tables are in Appendix I, Tables F-H.

			Sites: Hexagons by Setting (Map 5.18, 5.19)										Sites: Hexagons Unstratified (Map 5.20)								Largest Focal Areas (Map 5.21)			
Taxa Group	Sp	Data Adequacy	Total Hexagons with Species	1-	0-	0+	1+	2+	3+	(blank)	Total Above Ave	% Above Average BY SETTING	Total Hexagons with Species	1-	0-	0+	1+	(blank)	Total above average	% Above Average: UNSTRATIFED	Total Hexagons with Species	OUT	IN	% Within Large Focal Areas
Mammal Total			1021		284	613	104	20			737	72%	1021		341	671	9		680	67%	1021	876	145	14%
Bird Total			11135	###	3895	4700	1592	359	49	345	6700	60%	11135	###	6168	4201	214	345	4415	40%	11135	8846	2289	21%
Fish Total			708	4	289	336	71	7		1	414	58%	708	4	390	306	7	1	313	44%	708	646	62	9%
Amphibian Total			1042	11	468	457	89	16	1		563	54%	1042	11	628	402	1		403	39%	1042	920	123	12%
Inverts Total			1242	7	578	490	122	36	4	5	652	52%	1242	7	806	418	6	5	424	34%	1242	1079	163	13%
Reptile Total			3718	2	1827	1470	351	60	7	1	1888	51%	3718	2	2432	1262	21	1	1283	35%	3719	3154	565	15%
Grand Total			18866	219	7341	8066	2329	498	61	352	10954	58%	18866	231	10765	7260	258	352	7518	40%	18867	15521	3347	18%

Largest Focal Areas: To identify the largest focal areas for species and settings we created polygons (blobs) around areas with a high density of hexagons with high resilience scores. In order to do this, we extracted all hexagons with a resilience score one-half standard deviation above the mean or greater (>0.5), and created a point indicating the centroid of each. Next, we ran a point density analysis using a 10,000 acre circular neighborhood around every cell in the region. This resulted in a surface where each cell (90 meter) was coded with the density of high scoring hexagon centroids within its neighborhood. Cell values ranged from 0 to 12, with the number indicating the number of high scoring hexagons within the 10,000 acre radius, (as each hexagon is 1000 acres, a value of 12 indicates that 100 percent on the area plus the boundary regions scored high. The cells had a mean value of 7 but, after visual inspection, we choose a somewhat more generous threshold of >= 5 as a cutoff to represent areas of high density. Contiguous grid cells with values >= 5 were grouped into polygons using the regiongroup and gridpoly ArcGIS functions.

We used a size criteria of >= 1000 acres to filter out small polygons and focus on larger areas, which resulted in 821 potential focal areas for the regional SGCN species and their geophysical settings (presumably, size and resilience are positively related, but we were using this filter primarily to simplify the results). Each polygon was then intersected with the species element occurrence current locations to distinguish those focal areas that were confirmed by the presence of a current location of a species from those that were not confirmed but represented highly resilience potential habitat (Map 5.21). For each polygon we tabulated the area of each geophysical setting and the number and type of species present (Table 5.2, and Appendix I. Table F-H).

Table 5.2: Summary of the settings and SGCN species occurring within largest focal areas. Settings are summarized by proportion of area of each setting in the focal area. Species are summarized by the proportion of hexagons that contain the species and fall within a focal area, relative to all hexagons that contain the species.

Largest Focal Areas (Map 5.21)				
Geophysical Setting	**OUT**	**IN**	**Total Area**	**% Within Focal areas**
HA0	540,658	717,427	1,258,085	57
HA2	1,989,037	1,747,026	3,736,063	47
HB1	11,127,809	4,093,863	15,221,672	27
LD2	3,067,774	1,080,777	4,148,552	26
LF	6,284,303	1,691,550	7,975,853	21
LC	3,591,808	899,130	4,490,938	20
LD1	9,138,821	2,070,192	11,209,012	18
LB	642,561	132,494	775,055	17
HC1	5,783,003	1,175,453	6,958,456	17
LH	1,756,683	345,381	2,102,064	16
LE	6,276,883	1,113,808	7,390,692	15
HA1	390,497	65,459	455,956	14
HB2	13,410,167	2,083,258	15,493,425	13
LA1	2,960,307	417,793	3,378,101	12
LG	664,367	83,745	748,112	11
HC2	2,124,000	239,102	2,363,103	10
LA2	1,544,631	145,384	1,690,015	9
Taxa Group	**OUT**	**IN**	**Total Locations**	**% Within Focal areas**
Amphibian Total	920	123	1043	12%
Bird Total	8846	2289	11135	21%
Fish Total	646	62	708	9%
Inverts Total	1079	163	1242	13%
Mammal Total	876	145	1021	14%
Reptile Total	3154	565	3719	15%
Grand Total	15521	3347	18868	17%

<u>Key Areas for Regional Flow Concentrations:</u> We used the results of the circuitscape regional flow pattern analysis to identify areas where, due to the patterns of human use, ecological flows and species movements potentially become concentrated or channelized. We mapped these pathways by selecting areas where “current density” was above the mean for the region. In this analysis, areas with a low score have low permeability, average scores indicate the most connected areas, and high scores are places where flows become concentrated. We also calculated the score for the subset of areas where we had hexagons of species and geophysical settings and overlaid the ones that scored high for regional flow patterns on the flow concentration surface (Map 5.22). This map illustrates the overlap between the hexagons and the high current density areas, as well as the areas between the sites that might merit attention for connectivity. Lastly, we queried the data base for hexagons that scored high for both resilience and for regional flow concentrations and mapped them on top of the resilience scores (Map 5.23). This analysis shows the sites that, on top of being resilient themselves, might have added significance due to their location and configuration, in maintaining region-wide connectivity.

Species Tables: In order to assess the characteristics and qualities of the landscapes in which individual species are located, we summarized the individual components of resilience and the integrated resilience scores by individual species and taxonomic groups. Additionally we summarized five condition values for the species locations including: road density, percent developed land, percent agricultural land, mean and maximum length of the connected stream network (Table 5.3, and Appendix I Table A-E). The tables contain information that might be of interest to users. For example, black mountain salamander (*Desmognathus welteri*), a species of moderate to high elevation associated with steep slopes, occurred in 20 hexagons and they had an average resilience score above the mean (0.40). The high score was based on above-average scores for landform variety (7.1 types), elevation range (129 meters) and connectedness (46 percent), although wetlands were absent (Table 5.3). The hexagons also had moderate road density and development. In contrast, blue-spotted salamander (*Abystoma laterale*), a forest dwelling low elevation species, scored worse on every factor except wetland density.

Table 5.3: An example of the average resilience and condition Scores for individual species. Full Table in Appendix I, Table A-E

				Resilience: Average Z-scores					Components: Average Values					Flow Values		Condition Values				
Common Name	*Standard Name*	Number of Hexagon Locations	Data Adequacy	Ave Resilience (Z)	Landform Variety (Z)	Elevation Range (Z)	Wetland Density (Z)	Connectedness (Z)	Landform Variety	Elevation range	Wetland C	Wetland M	Connectedness	Flow Concentrations	Flow Conentrations (Z)	Road Density	Developed (%)	Agriculture (%)	Max connected streams	Mean connected streams
Black Mountain Salamander	*Desmognathus welteri*	11	A	0.40	0.58	1.05	-0.92	0.48	7.1	128.8	0.0	0.0	46.4	12.7	0.38	11.3	5.1	5.6	737.4	737.4
Blue-spotted Salamander	*Ambystoma laterale*	315	A	-0.20	0.15	-0.45	1.07	-0.62	6.3	30.3	19.5	19.0	12.6	9.5	-0.39	33.3	24.6	10.3	55.3	50.9

Condition Factors for Species Table : Five additional factors related to current conditions across the region were compiled for each hexagon and used in the species tables. These are described below. Please see Appendix III for more information on these data sources and the methods used to create them.

Road Density: We created a wall-to-wall map of road density for the whole region by calculating the density of roads (meters/hectare) within a 1,000 meter radius of each 30 m pixel of land area in the region. We compiled roads from the following sources: 1) Roads: Tele Atlas North America, Inc., 2009. U.S. and Canada Streets Cartographic. 1:100,000 Tele Atlas StreetMap Premium v. 7.2 ESRI® Data & Maps: StreetMap. 2009 Data Update: North America. Redlands, California, USA. U.S. 2) Railroads: Tele Atlas North America, Inc. 2009. U.S. and Canada Railroads. 1:100,000. ESRI® Data & Maps: StreetMap. 2009 Data Update: North America. Redlands, California, USA. From this dataset we excluded 4-wheel drive trails, walking trails, and ferry lines because these features were not consistently mapped across states.

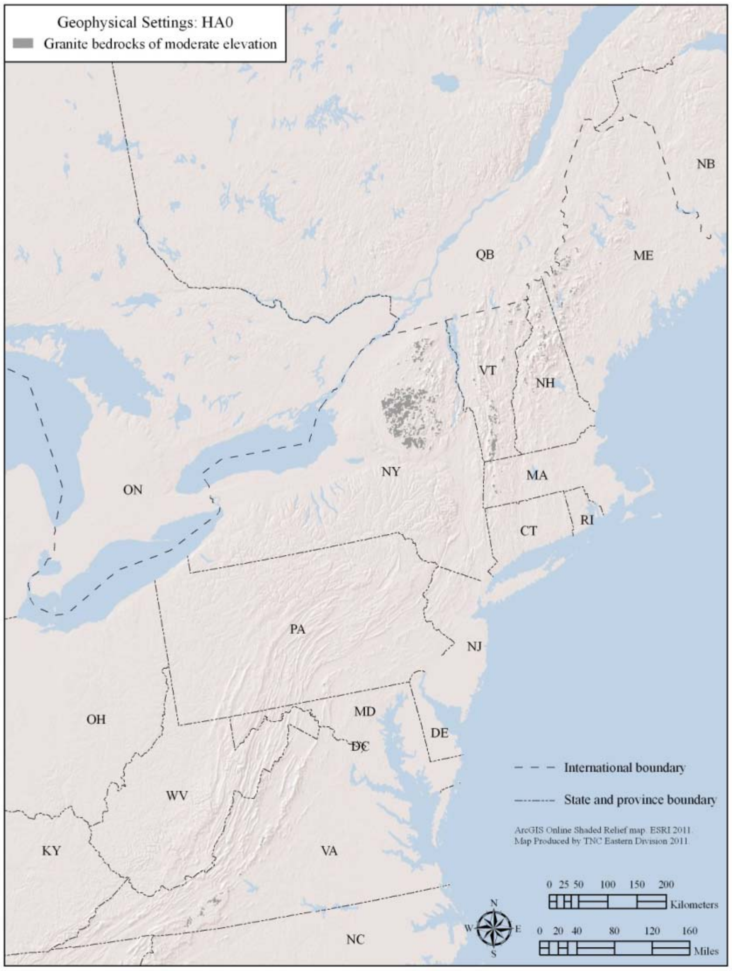
NLCD 2006 Land Cover: We used the 2006 National Land Cover Dataset to map the acreage of land in each land cover class. We were particularly interested in identifying converted lands. Converted land cover classes included low, medium, and high intensity development (summarized as “development”), as well as pasture and row crops (summarized as “agriculture”).

Length of connected stream networks: The length of connected stream and river networks in the region has been profoundly changed by dams and impassable culverts. To evaluate the current stream connectivity in the region, a connected stream network data layer was created in GIS using and waterfalls to split the stream network. The connected stream networks were bounded by fragmenting features (falls or dams) and/or the topmost extent of headwater streams. This allowed us to measure the length of every stream network between fragmenting features. Our intent was to quantify the distance that a fish or aquatic animal could move within the network until reaching one of these bounding features. Detail in Anderson and Olivero (2011).

Final Maps

The first part presents maps and descriptions for the 17 geophysical settings that collectively represent about half of the region studied and all of the known locations of 234 SGCN species (a subsequent analysis will fill in for the missing areas). Results for the individual species by taxonomic group are in Appendix I.

Group HA0: Moderate Elevation Granite Slopes and Summits



Description: Granite bedrocks of moderate elevations (1700' to 2500'). These are mountain landscapes characterized by side-slopes, cliffs, summits and hills, and typically forested with mixtures of spruce and hardwoods.

Tracked species typical of this habitat:

Birds: American Three-toed woodpecker, Rusty Blackbird, Spruce Grouse, Common Loon, Common Moorhen, American bittern, Least Bittern.

Fish and Mussels: Round Whitefish, Bridal shiner, Longnose sucker

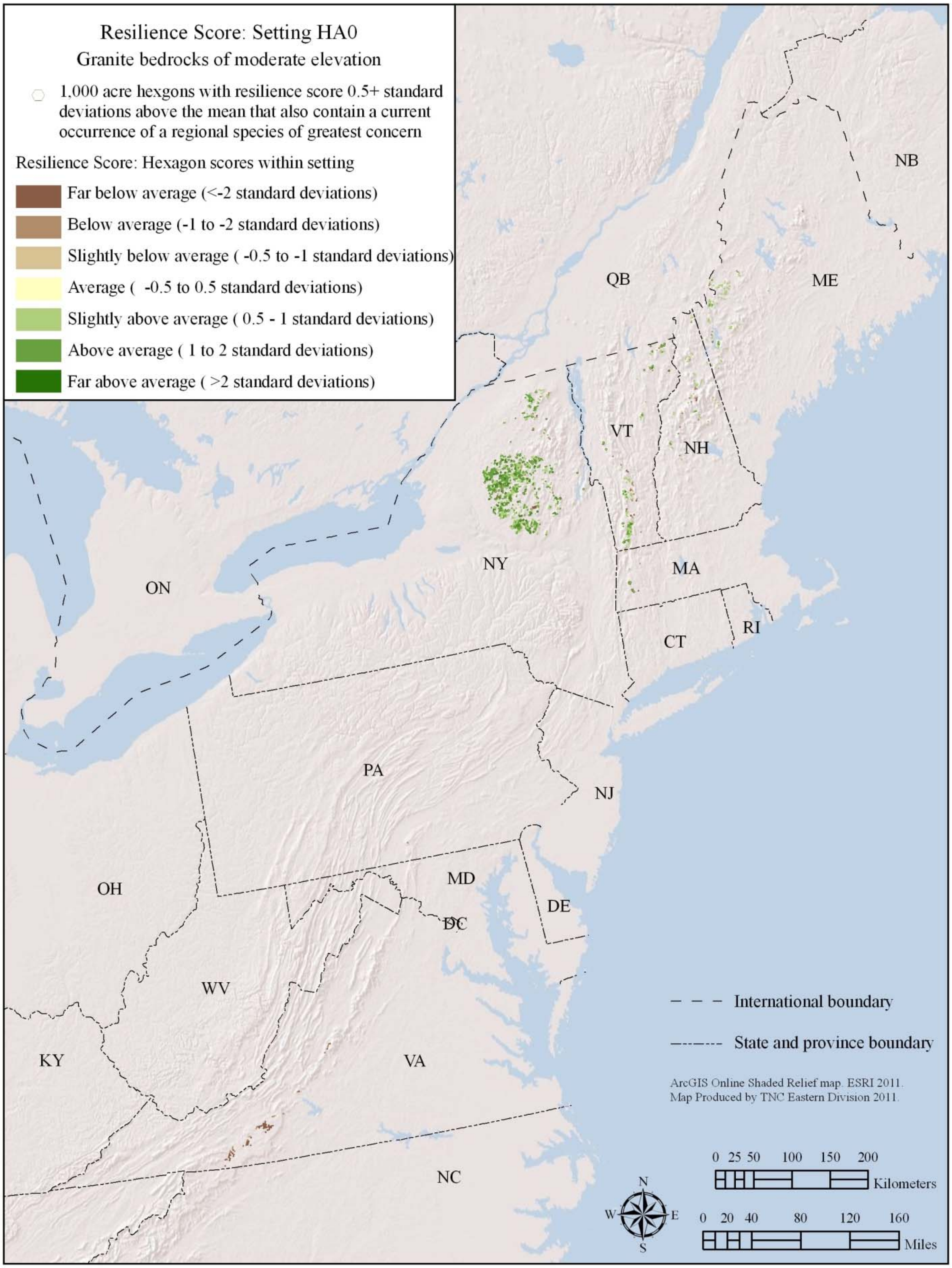
Herptiles: Bog turtle

Sub types: None

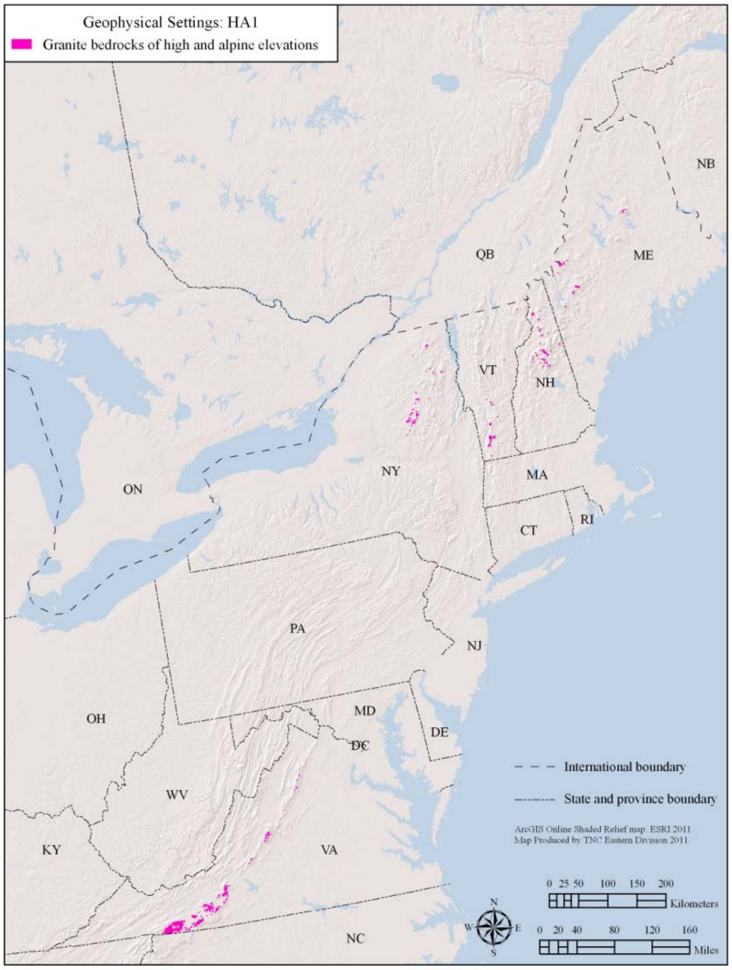
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coast	Very Low	Low	Mod-erate	High	Very High
HA0	H1303	0.10		0.01	0.00	0.83	0.01		0.04				0.11	0.87	0.02	
HA0 Average		0.10		0.01	0.00	0.83	0.01		0.04				0.11	0.87	0.02	

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / foot	Hill / Valley	Dry Flat	Wet Flat	Water
HA0	H1303	0.01	0.01	0.21	0.01	0.39	0.08	0.22	0.05
HA0 Average		0.01	0.01	0.21	0.01	0.39	0.08	0.22	0.05

Map 5.1: Resilience scores for HA0.



Group HA1: Very High Elevation Granite Slopes and Summits



Description: Granite bedrocks of high spruce-fir, subalpine and alpine elevations (>2500'). These setting are high mountain landscapes characterized by side-slopes, cliffs, summits and hills, and typically forested but with some open barrens and alpine wetlands.

Tracked species found in this habitat:
Birds: Bicknell's Thrush, American Three-toed woodpecker, Rusty Blackbird, Common Loon, Peregrine Falcon, Golden Eagle, Cape May Warbler, Bay-breasted Warbler, Black-throated Blue Warbler.

Fish and Mussels: Green floater, Kanawha Minnow

Herptiles: Bog Turtle

Sub types: None

Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coast	Very Low	Low	Mod-erate	High	Very High
HA1	H944	0.02			0.00	0.87	0.10	0.00	0.00					0.21	0.77	0.02
HA1 Average		0.02			0.00	0.87	0.10	0.00	0.00					0.21	0.77	0.02

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / foot	Hill / Valley	Dry Flat	Wet Flat	Water
HA1	H944	0.05	0.06	0.38	0.04	0.27	0.04	0.12	0.04
HA1 Average		0.05	0.06	0.38	0.04	0.27	0.04	0.12	0.04

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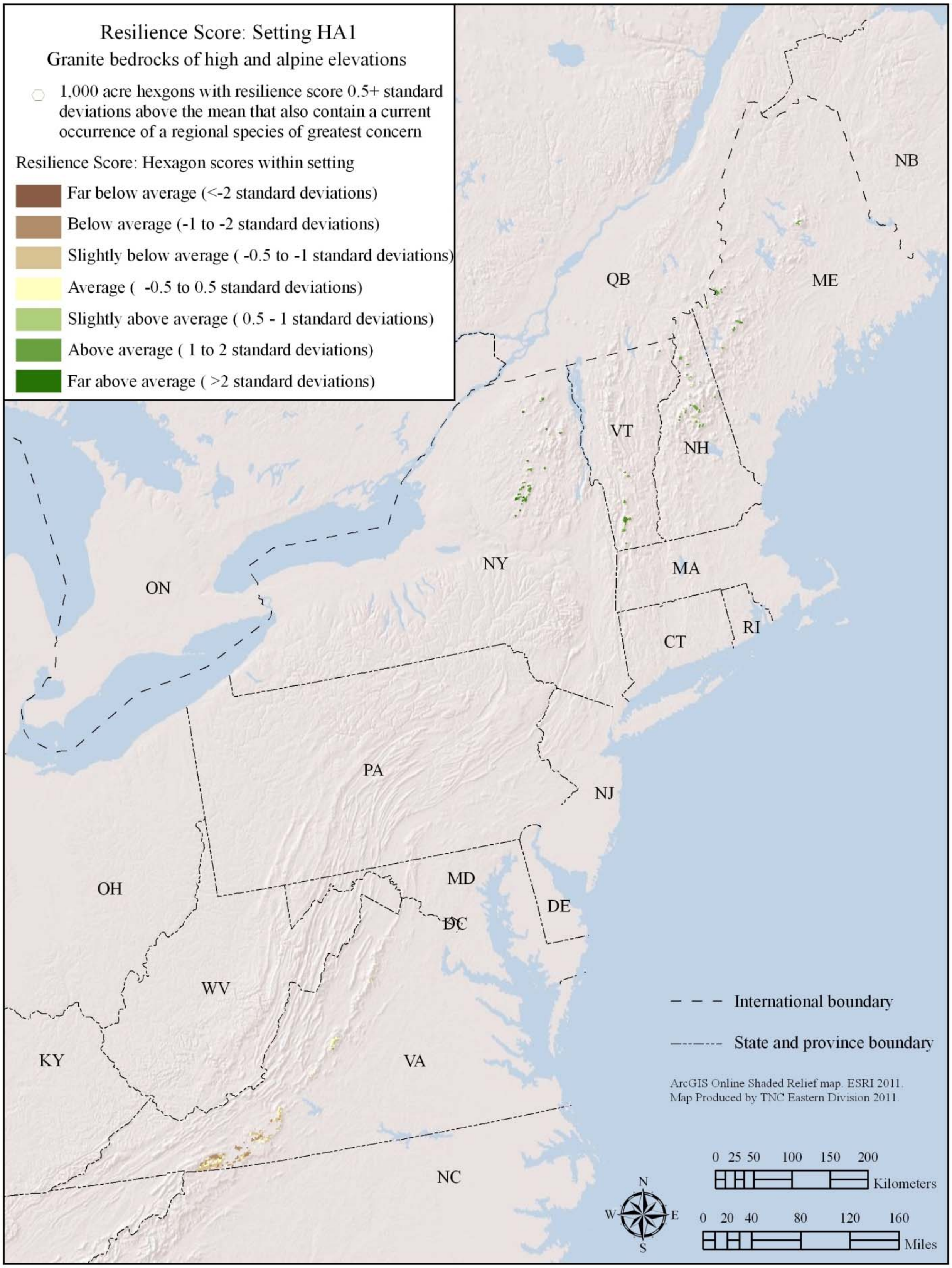
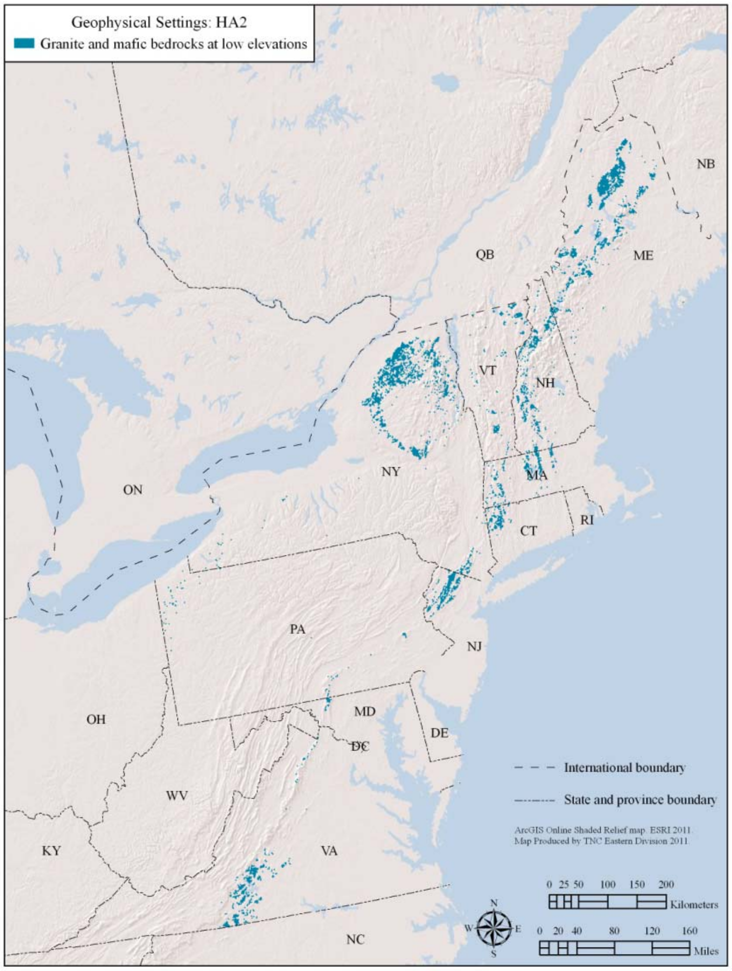
Map 5.2: Resilience scores for HA1.



Group HA2: Low Elevation Granite and Mafic Hills



Description: Granite and mafic bedrock settings at low elevations (800-1700'). Hilly landscapes, typically with deciduous or mixed forest.

Tracked species found in this habitat:
Birds: Fowler's Toad, Acadian Flycatcher, Black-and-White Warbler, Blackburnian Warbler, Broad-winged Hawk, Common Nighthawk, Olive-sided Flycatcher, Canada Warbler, Cape May Warbler, Black-billed Cuckoo, Blackpoll Warbler.

Herptiles: Fowler's Toad, Northern Leopard Frog.

Fish and Mussels: Creek heelsplitter.

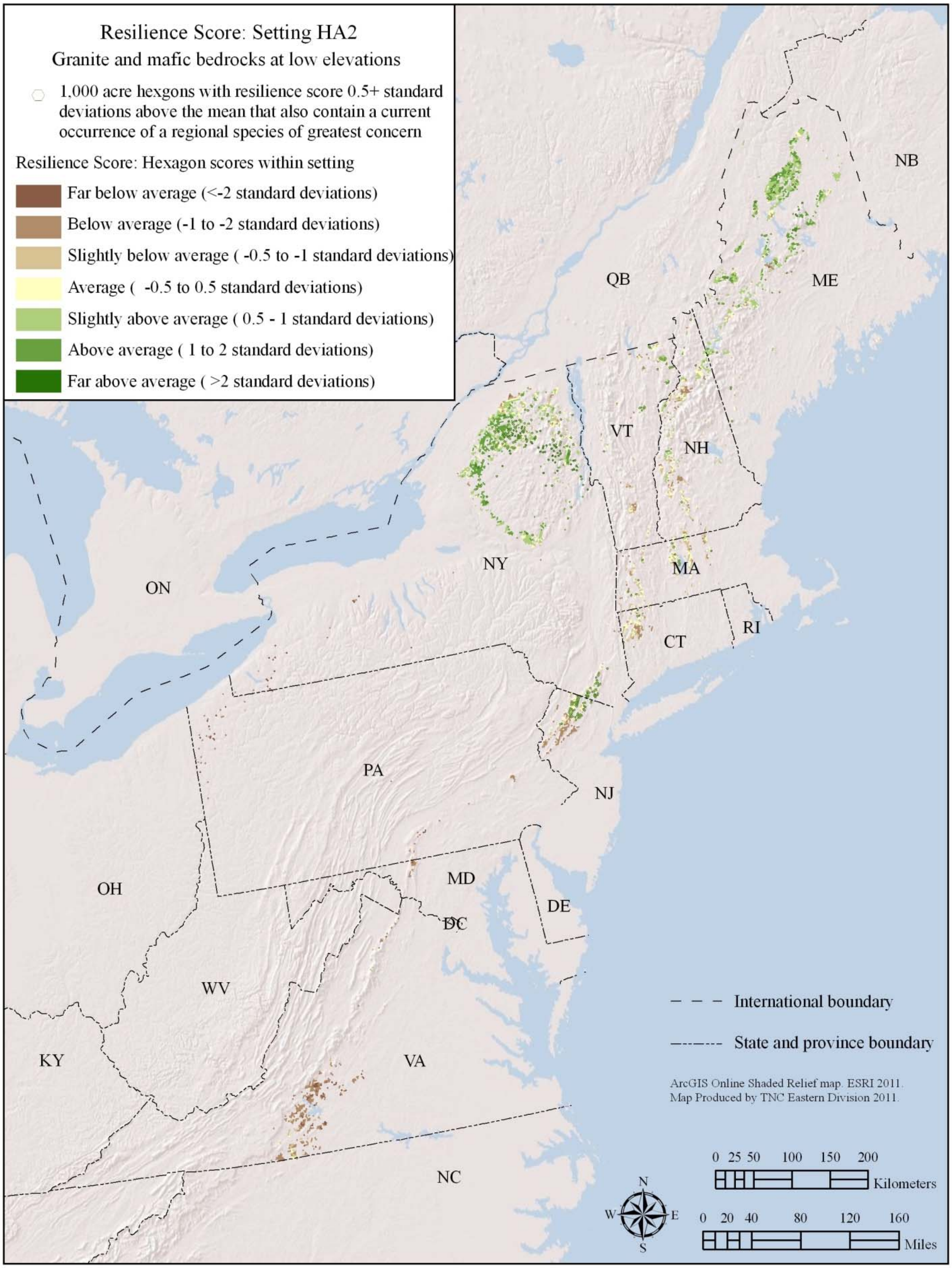
Mammals: Hoary Bat.

Sub types: Two subtypes were strongly granitic, differing in that H1 was gently sloping hills and valleys, and H24 was more mountainous with side-slopes, cliffs and summits. Two others are mostly resistant mafic rock and differ in that H15 is entirely low while H14 spans a number of elevations

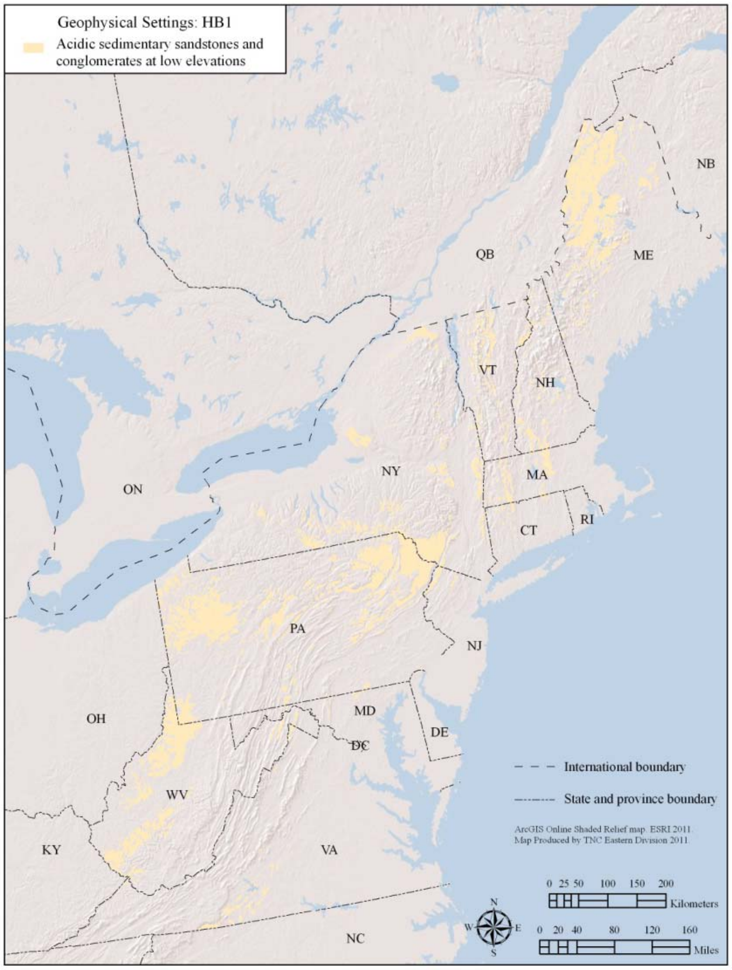
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coast	Very Low	Low	Mod-erate	High	Very High
HA2	H1	0.05	0.00	0.03	0.00	0.77	0.10	0.00	0.05	0.00	0.00	0.11	0.88	0.01	0.00	
HA2	H24	0.03		0.01	0.01	0.74	0.19	0.00	0.03		0.00	0.16	0.78	0.06	0.00	
HA2	H15	0.05	0.01	0.01	0.00	0.08	0.63	0.00	0.21	0.02		0.02	0.95	0.04	0.00	
HA2	H14	0.06	0.04	0.11	0.02	0.09	0.43	0.00	0.05	0.19		0.25	0.47	0.15	0.10	0.03
HA2 Average		0.05	0.02	0.04	0.01	0.42	0.34	0.00	0.08	0.07	0.00	0.13	0.77	0.06	0.03	0.03

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / foot	Hill / Valley	Dry Flat	Wet Flat	Water
HA2	H1	0.00	0.00	0.13	0.00	0.43	0.09	0.29	0.05
HA2	H24	0.05	0.06	0.47	0.06	0.23	0.02	0.07	0.03
HA2	H15	0.02	0.03	0.23	0.02	0.32	0.07	0.19	0.12
HA2	H14	0.01	0.01	0.16	0.01	0.42	0.09	0.25	0.05
HA2 Average		0.02	0.03	0.25	0.02	0.35	0.07	0.20	0.06

Map 5.3: Resilience scores for HA2.



Group HB1: Low Elevation Sedimentary Hills and Valleys



Description: Acidic sedimentary sandstones, siltstone and conglomerates at low elevations (800-1700') in hilly landscapes; forest vary from lowland spruce in the north to oak or pine-oak in the south.

Tracked species typical of this habitat:
Birds: Whip-poor-will, Canada Warbler, Black billed Cuckoo, Blackpoll Warbler, Red-headed Woodpecker, Long-eared Owl, Short-eared Owl.

Fish and Mussels: Eastern Pearlshell, Dwarf Wedgemussel, Pocketbook Mussel, Round Whitefish, Longtail Darter.

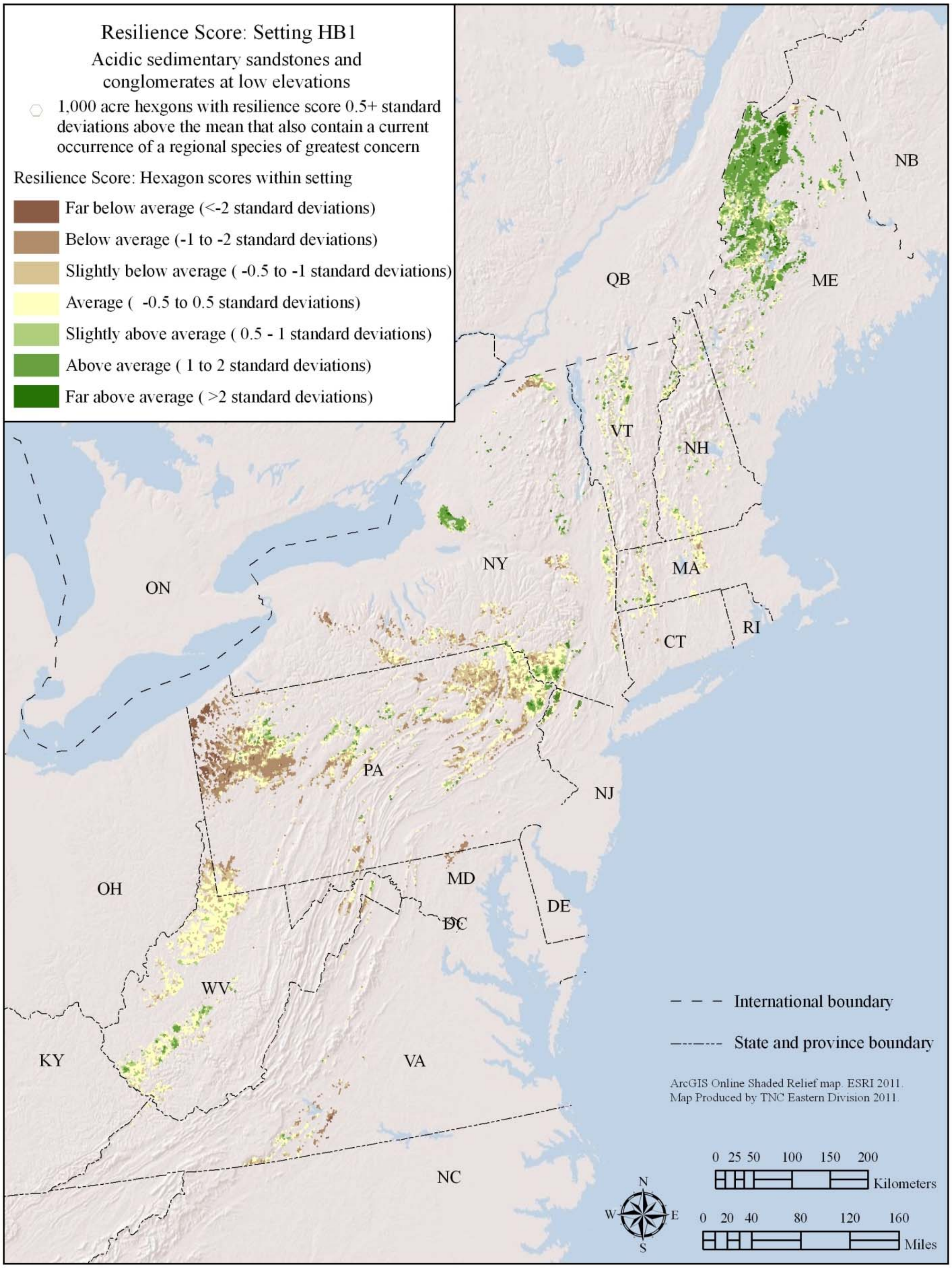
Herptiles: Eastern Box Turtle, Marbled Salamander.

Sub types: H2, H7: The two subtypes are similar in geology and elevation, but differ in their landforms and geographic distribution with H2 being flatter and wetter, and H7 being more mountainous with side-slopes, cliffs and summits.

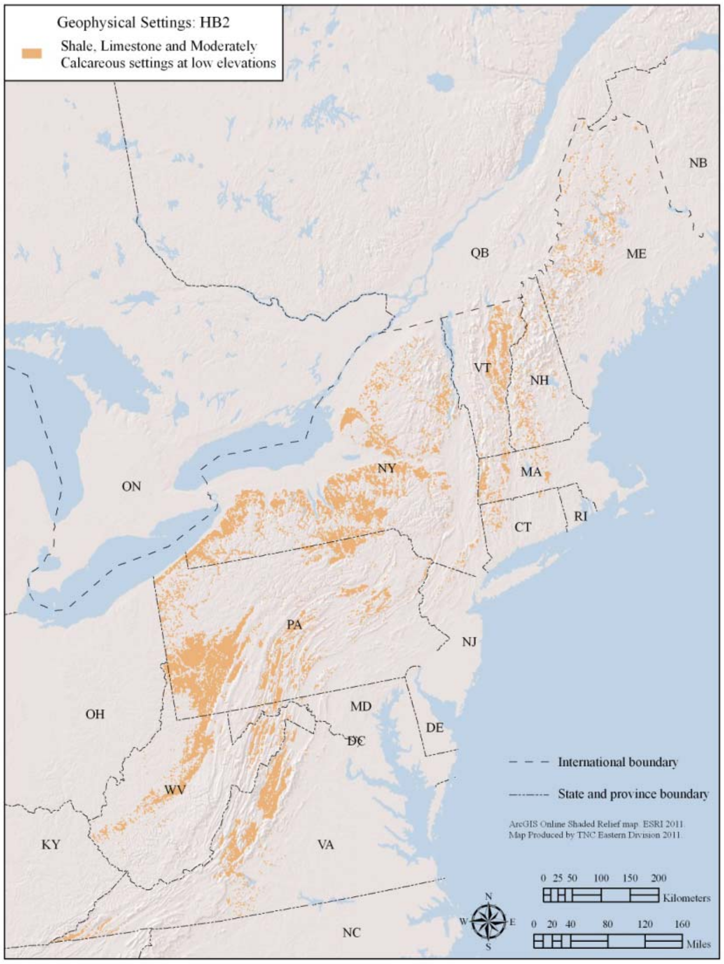
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coast	Very Low	Low	Mod-erate	High	Very High
HB1	H2	0.79	0.05	0.02	0.05	0.01	0.01	0.00	0.06	0.01		0.10	0.85	0.05		
HB1	H7	0.89	0.01	0.01	0.03	0.01	0.01		0.04	0.01		0.06	0.89	0.05		
HB1 Average		0.84	0.03	0.01	0.04	0.01	0.01	0.00	0.05	0.01		0.08	0.87	0.05		

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / foot	Hill / Valley	Dry Flat	Wet Flat	Water
HB1	H2	0.00	0.00	0.11	0.00	0.45	0.11	0.28	0.04
HB1	H7	0.03	0.04	0.38	0.04	0.33	0.04	0.10	0.04
HB1 Average		0.02	0.02	0.25	0.02	0.39	0.08	0.19	0.04

Map 5.4: Resilience scores for HB1.



Group HB2: Low Elevation Shale, Limestone and Moderately Calcareous Hills and Valleys



Description: Shale, Limestone and Moderately Calcareous settings at low elevations (800-1700') in hilly landscapes.

Tracked species typical of this habitat:
Birds: Upland Sandpiper, Sedge Wren, Henslow's Sparrow, Pied-billed Grebe, American Bittern.

Fish and Mussels: Longhead Darter, Longtail Salamander, Ohio Lamprey, Upland Sandpiper, Blackchin Shiner, Blue Ridge Sculpin, Channel Darter, Cherrystone Drop Snail, Triangle floater.

Herptiles: Jefferson Salamander.

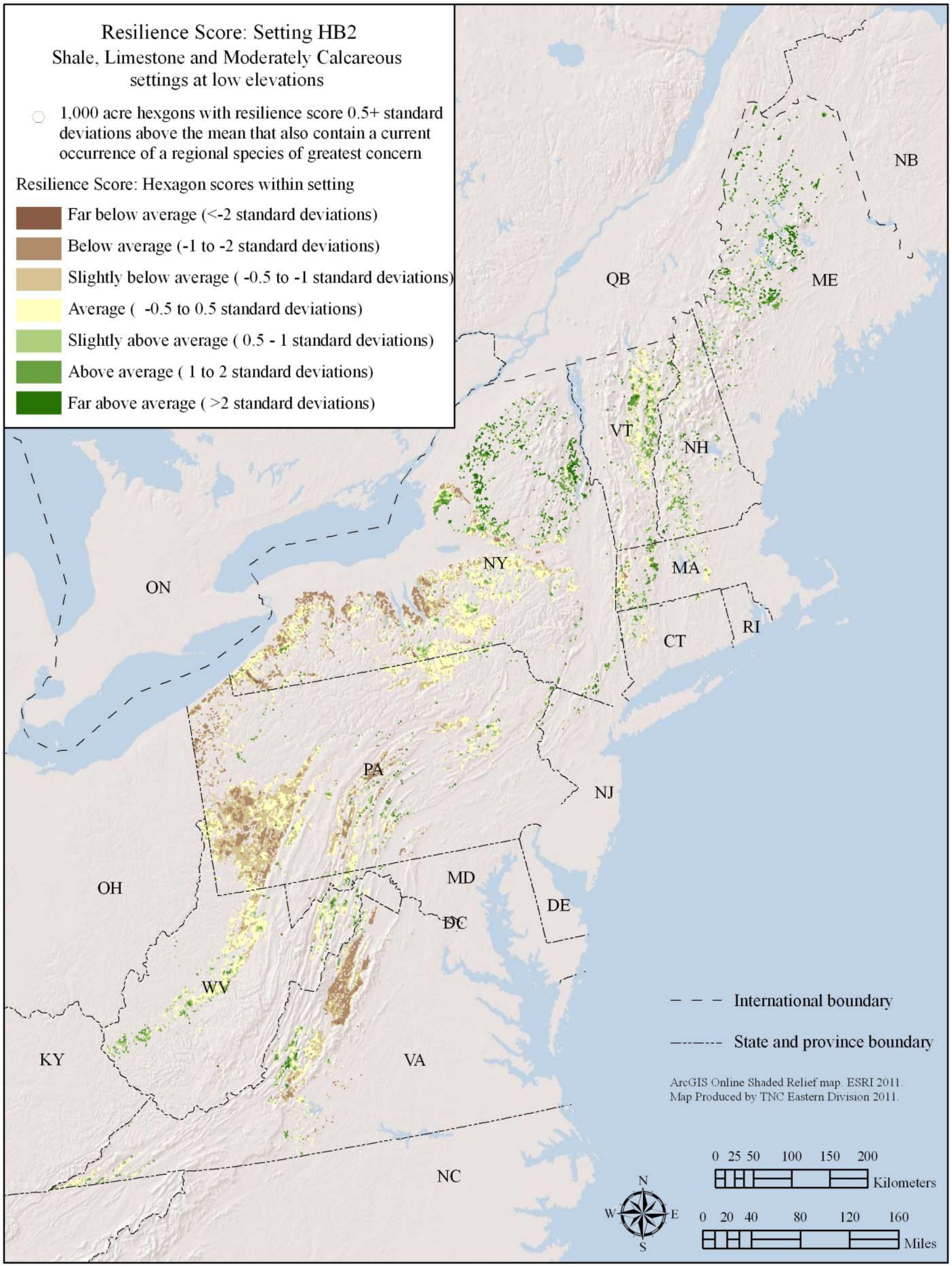
Mammals: Indiana Bat, Eastern Small-footed Bat, Allegheny Woodrat.

Sub types: H4, H59, H101, H49, H6. This group is a diverse mix of sedimentary environments excluding the common acidic sedimentary environs. H4 and H6 are mostly shales, H59 are limestones, H101 are moderately calcareous sedimentary rocks, typically shales and sandstones embedded in a calcareous matrix. H49 is equal parts shale, moderately calcareous and granitic bedrock.

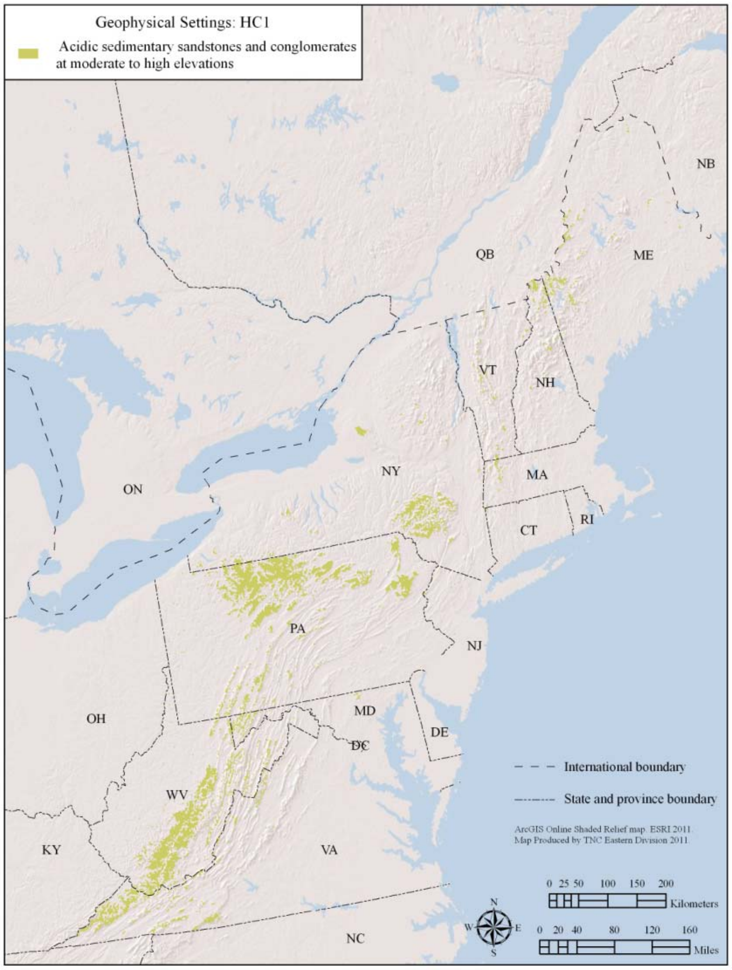
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coast	Very Low	Low	Mod-erate	High	Very High
HB2	H4	0.08	0.74	0.02	0.06	0.00			0.08	0.03		0.09	0.88	0.02		
HB2	H59	0.04	0.01	0.79	0.07	0.03	0.00		0.05			0.02	0.94	0.04	0.00	
HB2	H101	0.03	0.03	0.06	0.81	0.02	0.00		0.06	0.00		0.07	0.89	0.04		
HB2	H49	0.32	0.21	0.01	0.16	0.19	0.03	0.00	0.06	0.01		0.07	0.74	0.18	0.02	
HB2	H6	0.23	0.58	0.02	0.05	0.00	0.00		0.11	0.01		0.07	0.81	0.12	0.00	
HB2 Average		0.14	0.31	0.18	0.23	0.05	0.01	0.00	0.07	0.01		0.07	0.85	0.08	0.01	

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / foot	Hill / Valley	Dry Flat	Wet Flat	Water
HB2	H4	0.00	0.00	0.12	0.01	0.41	0.12	0.30	0.04
HB2	H59	0.01	0.01	0.21	0.01	0.36	0.08	0.24	0.06
HB2	H101	0.01	0.01	0.25	0.02	0.38	0.07	0.22	0.03
HB2	H49	0.01	0.01	0.10	0.01	0.18	0.04	0.09	0.56
HB2	H6	0.05	0.06	0.50	0.06	0.22	0.03	0.06	0.02
HB2 Average		0.02	0.02	0.24	0.02	0.31	0.07	0.18	0.14

Map 5.5: Resilience scores for HB2.



Group HC1: Moderate to High Acidic Sedimentary Mountains



Description: Acidic sedimentary sandstones and conglomerates at moderate to high elevations (1700-4000') in mountainous landscapes.

Tracked species typical of this habitat:

Birds: Black-throated Blue Warbler, Sharp-Shinned Hawk, Swainson's Thrush, Black-throated Green Warbler.

Fish and Mussels: Wavyrayed Lampmussel, Elktoe, Tonguetied Minnow, Bigmouth Chub, Candy Darter, Cheat Minnow, Angular Disc, Appalachia Darter, New River Shiner, Spruce Knob Three-tooth, Striped Whitelip, Kanawha Minnowhale.

Herptiles: Eastern Hellbender, Green Salamander, Black Mountain Salamander, Mountain Chorus Frog, Wehrle's Salamander, Broadhead Skink, Cow Knob Salamander.

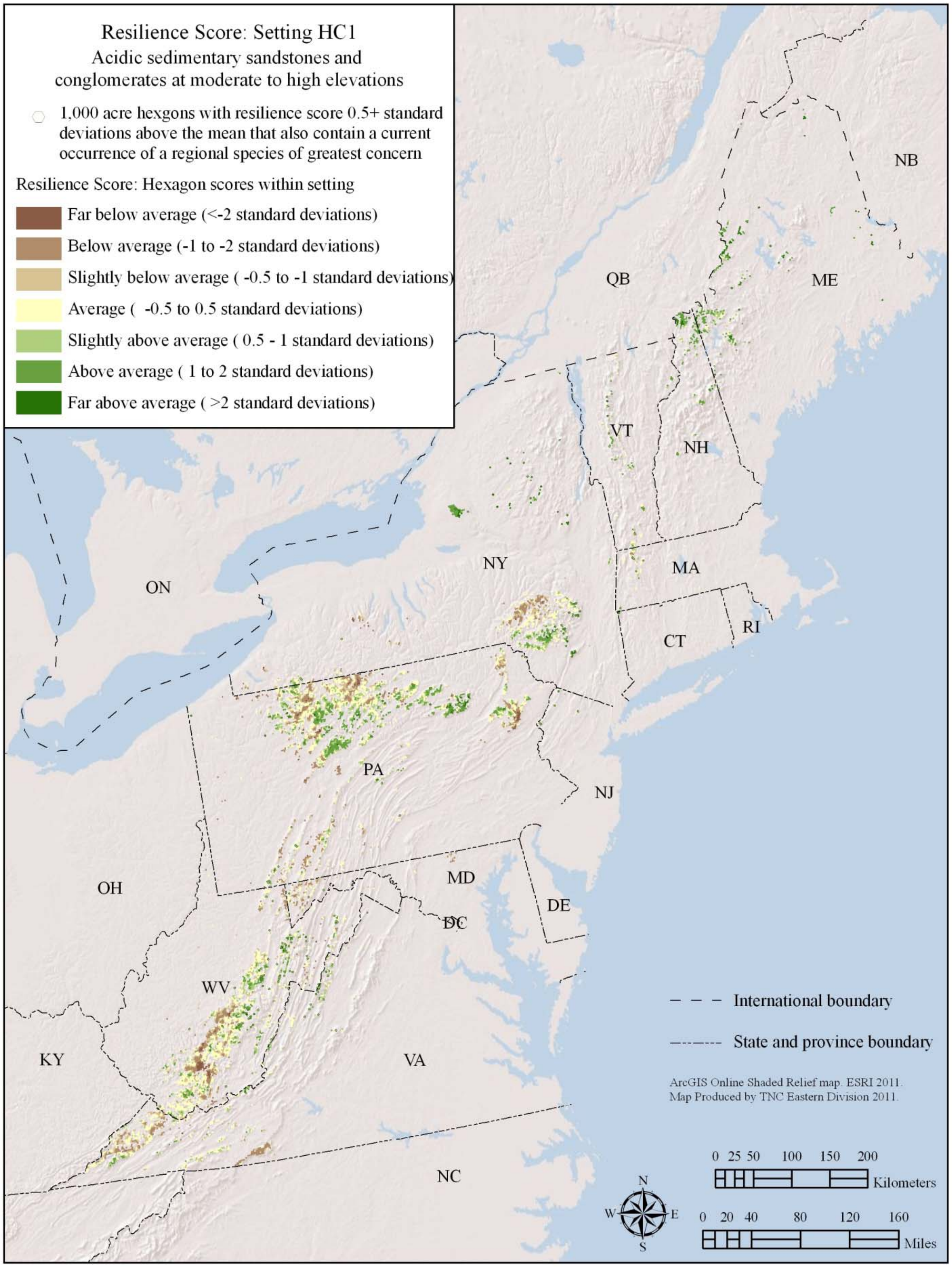
Mammals: Appalachian Cottontail, Silver-haired Bat, Southern Bog Lemming, Long-tailed Shrew.

Sub types: H97, H517, H16, H353, H530. Two groups (H16 and H530) are composed primarily of acidic sedimentary rock, while other groups have stronger components of shale and moderately calcareous substrates. Most groups have large elevation gradients but 97 and 517 are mostly lower while 353 and 530 is mostly higher. H97 is dominated by wet flat (74 percent).

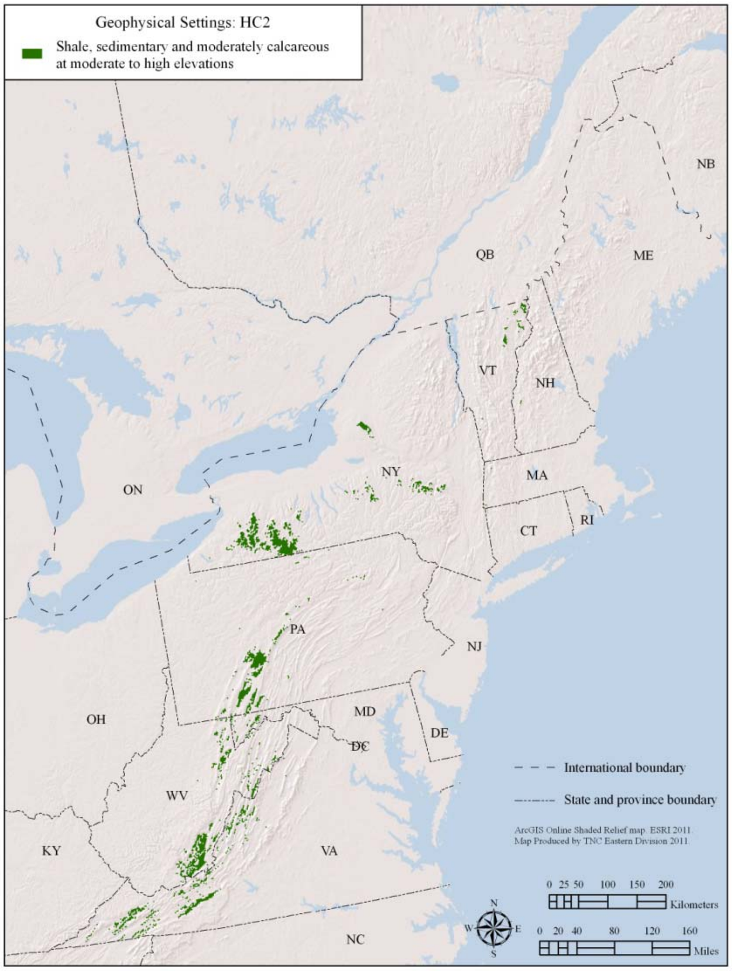
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coast	Very Low	Low	Mod-erate	High	Very High
HC1	H97	0.66	0.19	0.01	0.08	0.02	0.01		0.01	0.01		0.07	0.49	0.33	0.10	0.02
HC1	H517	0.46	0.17	0.06	0.26	0.00	0.01		0.04	0.00		0.05	0.35	0.25	0.24	0.10
HC1	H16	0.91	0.03	0.00	0.03	0.01	0.01	0.00	0.01			0.00	0.15	0.82	0.03	
HC1	H353	0.59	0.15	0.04	0.22	0.00			0.00				0.00	0.15	0.78	0.07
HC1	H530	0.74	0.13	0.01	0.07	0.01	0.03	0.01					0.01	0.16	0.72	0.11
HC1 Average		0.67	0.13	0.02	0.14	0.01	0.02	0.00	0.01	0.01		0.04	0.20	0.34	0.38	0.07

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / foot	Hill / Valley	Dry Flat	Wet Flat	Water
HC1	H97	0.00	0.00	0.01	0.00	0.12	0.08	0.74	0.06
HC1	H517			0.01	0.00	0.09	0.65	0.17	0.08
HC1	H16	0.02	0.03	0.27	0.03	0.33	0.10	0.17	0.05
HC1	H353	0.01	0.01	0.13	0.02	0.35	0.21	0.18	0.09
HC1	H530	0.06	0.12	0.55	0.08	0.12	0.01	0.04	0.01
HC1 Average		0.02	0.04	0.19	0.03	0.20	0.21	0.26	0.06

Map 5.6: Resilience scores for HC1.



Group HC2: Moderate Elevation Shale/Moderately Calcareous Hills



Description: Shale, sedimentary and moderately calcareous settings at moderate to high elevations.

Tracked species typical of this habitat:

Birds: Henslow's sparrow, Loggerhead Shrike.

Fish and Mussels: Stonecat, James Spinymussel.

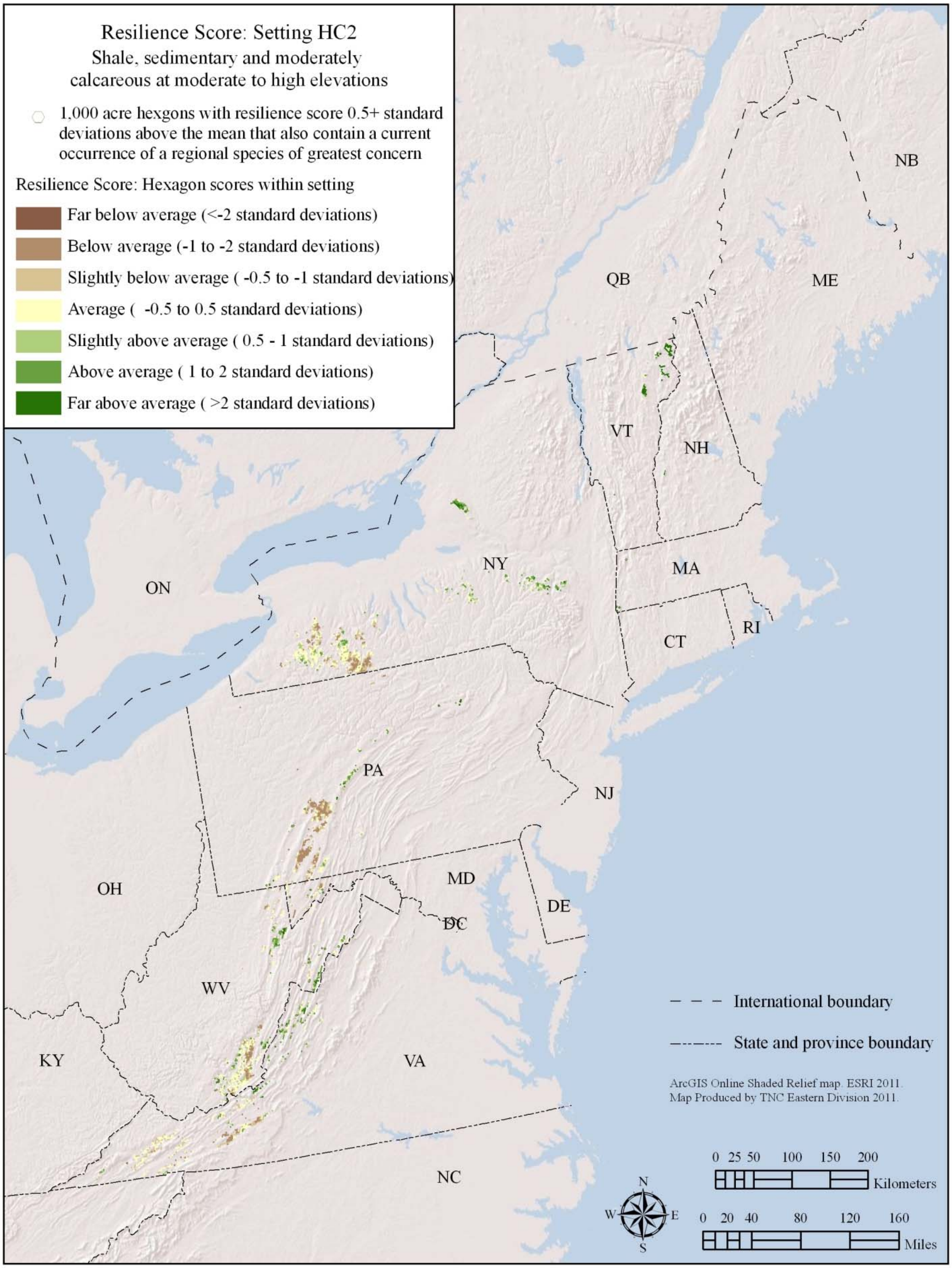
Mammals: Indiana bat, Eastern Small-footed Bat, Allegheny Woodrat.

Sub types: H254, H35. Group H254 is dominated by shale with small amounts of moderately calcareous bedrock while H35 is the reverse.

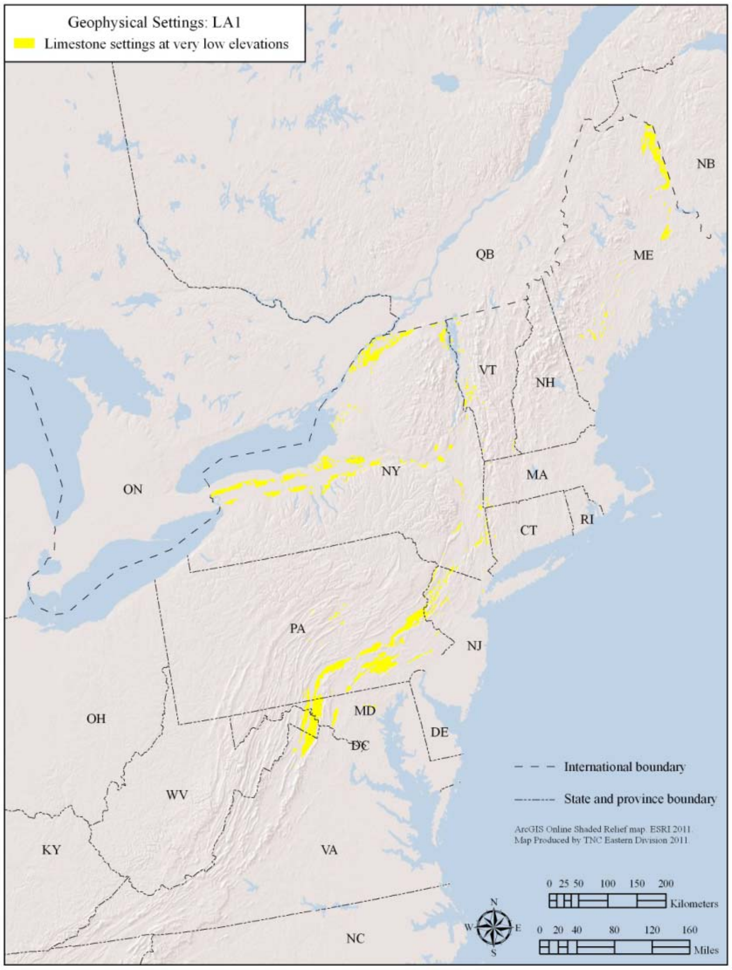
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coast	Very Low	Low	Mod-erate	High	Very High
HC2	H254	0.08	0.85	0.00	0.04				0.03				0.06	0.88	0.06	
HC2	H35	0.13	0.06	0.23	0.57				0.01				0.13	0.82	0.06	
HC2 Average		0.11	0.46	0.12	0.31				0.02				0.09	0.85	0.06	

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / foot	Hill / Valley	Dry Flat	Wet Flat	Water
HC2	H254	0.02	0.04	0.25	0.03	0.28	0.18	0.14	0.05
HC2	H35	0.03	0.05	0.39	0.05	0.29	0.09	0.07	0.03
HC2 Average		0.02	0.04	0.32	0.04	0.29	0.14	0.11	0.04

Map 5.7: Resilience scores for HC2.



Group LA1: Limestone settings at Very Low Elevations



Description: Limestone settings at very low elevations (below 800'), hilly landscape with wet flats.

Tracked species typical of this habitat:

Birds: Golden-winged Warbler, Field Sparrow, Prothonotary Warbler, Cerulean Warbler.

Fish and Mussels: Checkered Sculpin, Trout-perch, Stonecat, Longnose Sucker, Eastern Pearlshell.

Herptiles: Fowler's Toad, Bog turtle.

Invertbrates: Blue Ridge Springsnail.

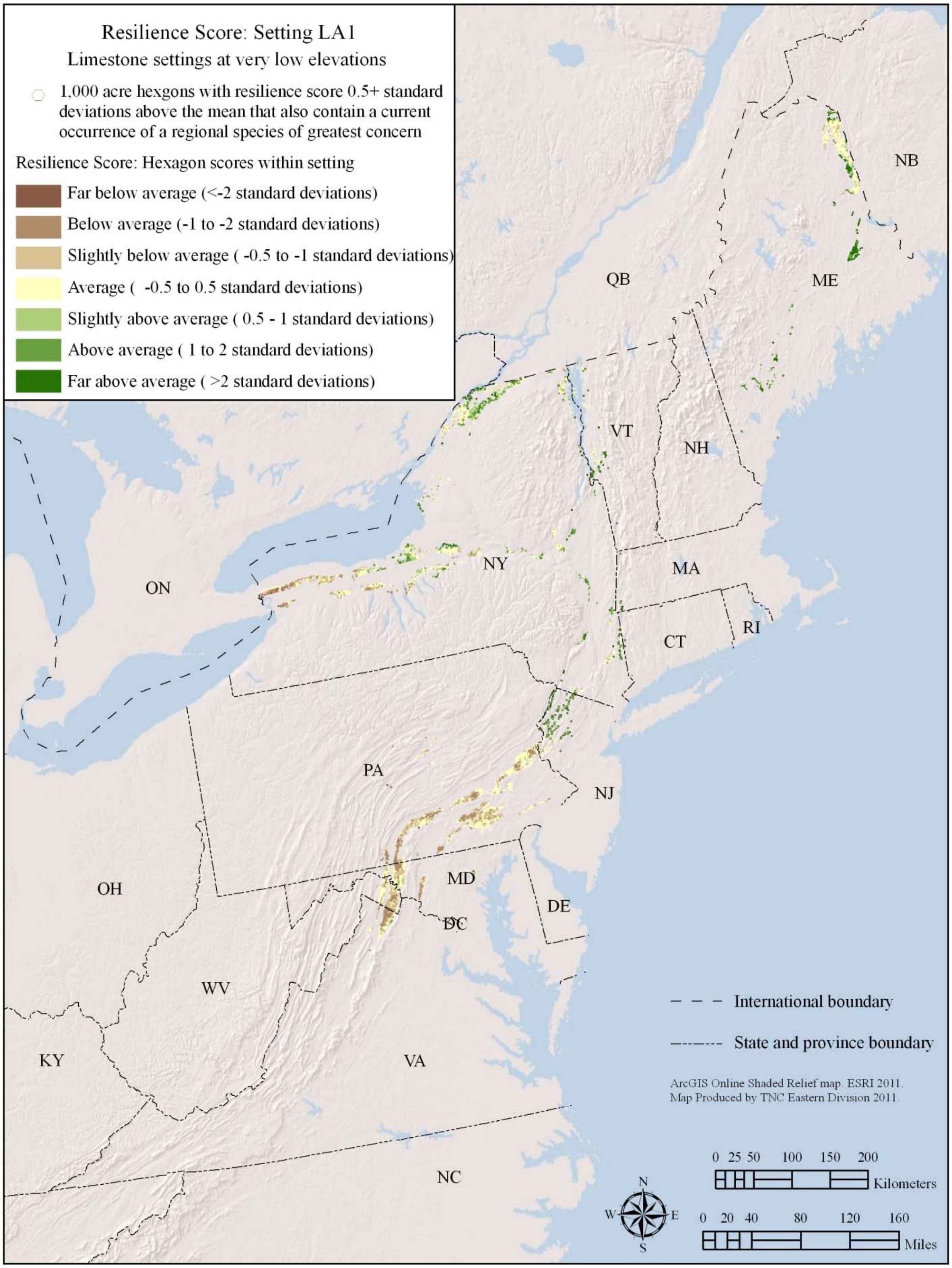
Mammals: Indiana bat, Eastern Red Bat.

Sub types: None

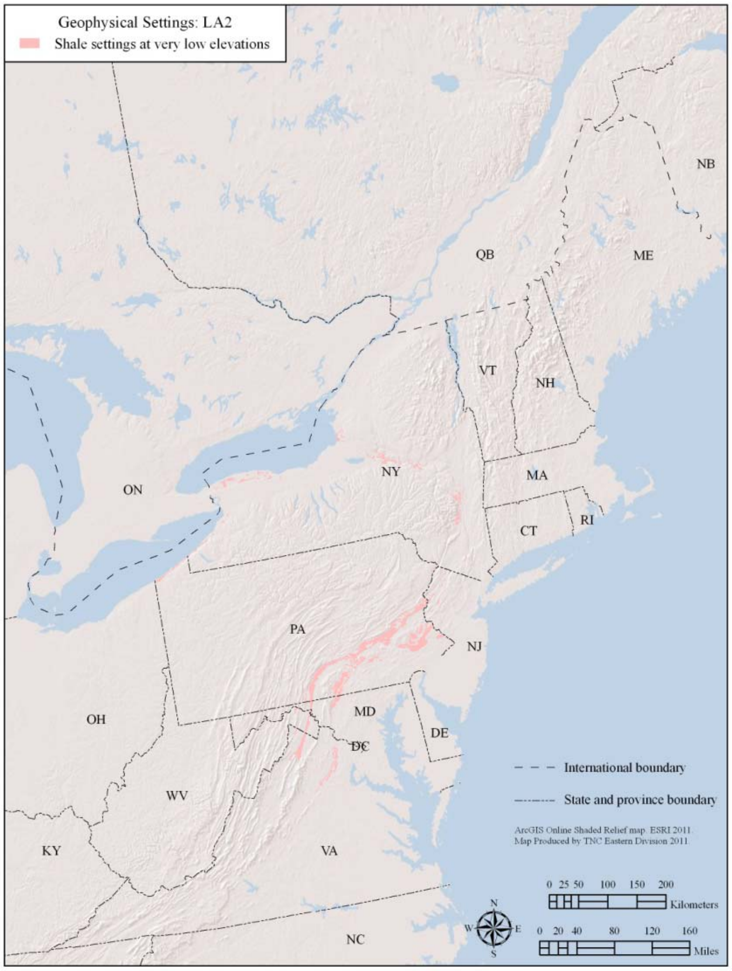
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coastal	Very Low	Low	Mod-erate	High	Very High
LA1	L1	0.08	0.02	0.64	0.02	0.06	0.02		0.13	0.03	0.00	0.95	0.05	0.00		
LA1 Average		0.08	0.02	0.64	0.02	0.06	0.02		0.13	0.03	0.00	0.95	0.05	0.00		

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / footslope	Hill / Valley	Dry Flat	Wet Flat	Water
LA1	L1	0.00	0.00	0.09	0.00	0.41	0.12	0.31	0.06
LA1 Average		0.00	0.00	0.09	0.00	0.41	0.12	0.31	0.06

Map 5.8: Resilience scores for LA1.



Group LA2: Shale settings at Very Low Elevation



Description: Shale settings at very low elevations (below 800') hilly landscapes.

Tracked species typical of this habitat:

Birds: Dickcissel, Barn Owl.

Fish and Mussels:, Comely Shiner, Pearl Dace, Slimy Sculpin, Swallowtail Shiner, Tessellated Darter, Green Floater, Brook Floater.

Herptiles: Upland Chorus Frog, Eastern Hognose Snake, Jefferson Salamander, Timber Rattlesnake, Northern Map Turtle, Marbled Salamander ,Blanding's Turtle.

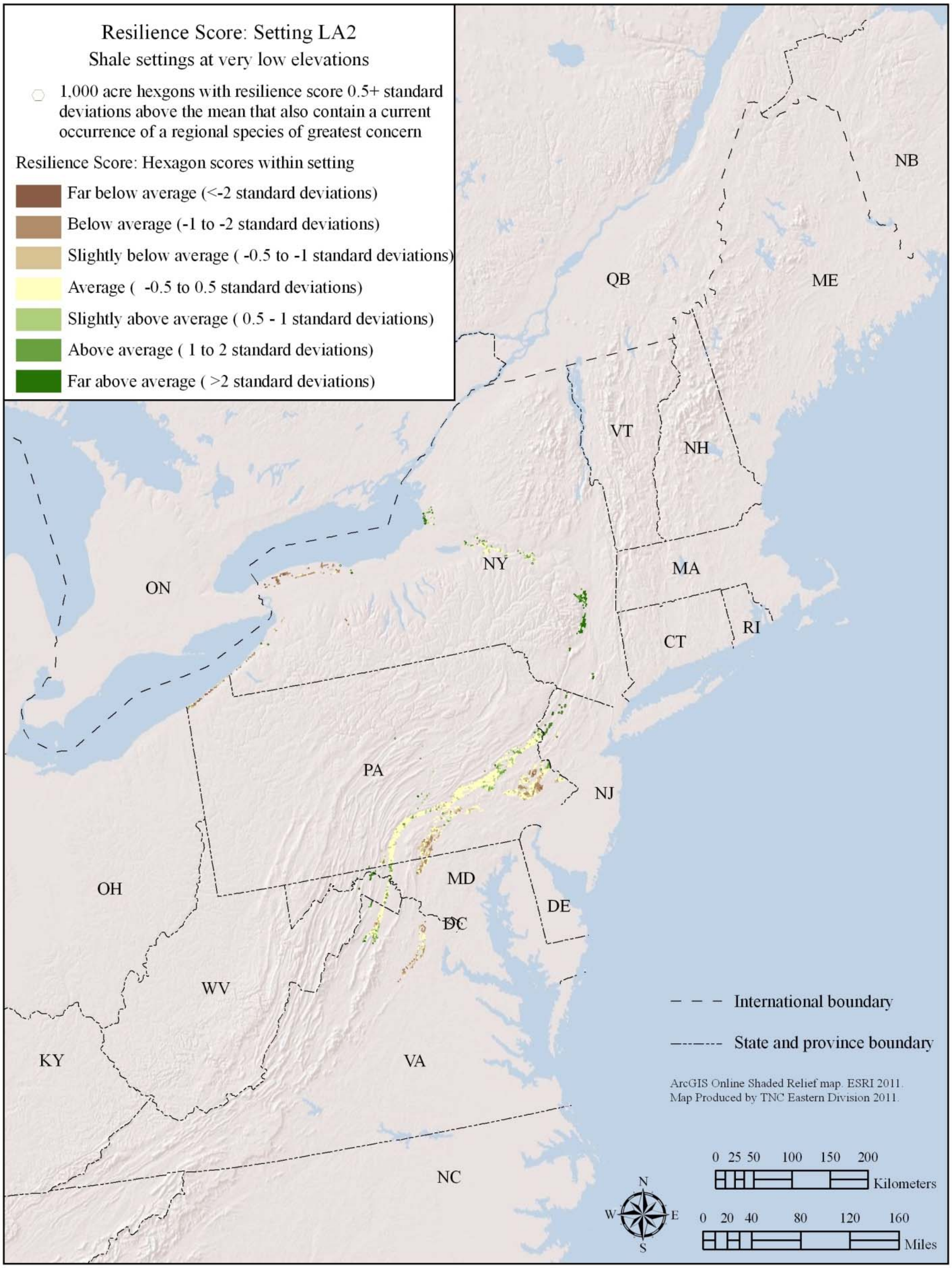
Mammals: Allegheny Woodrat.

Sub types: None

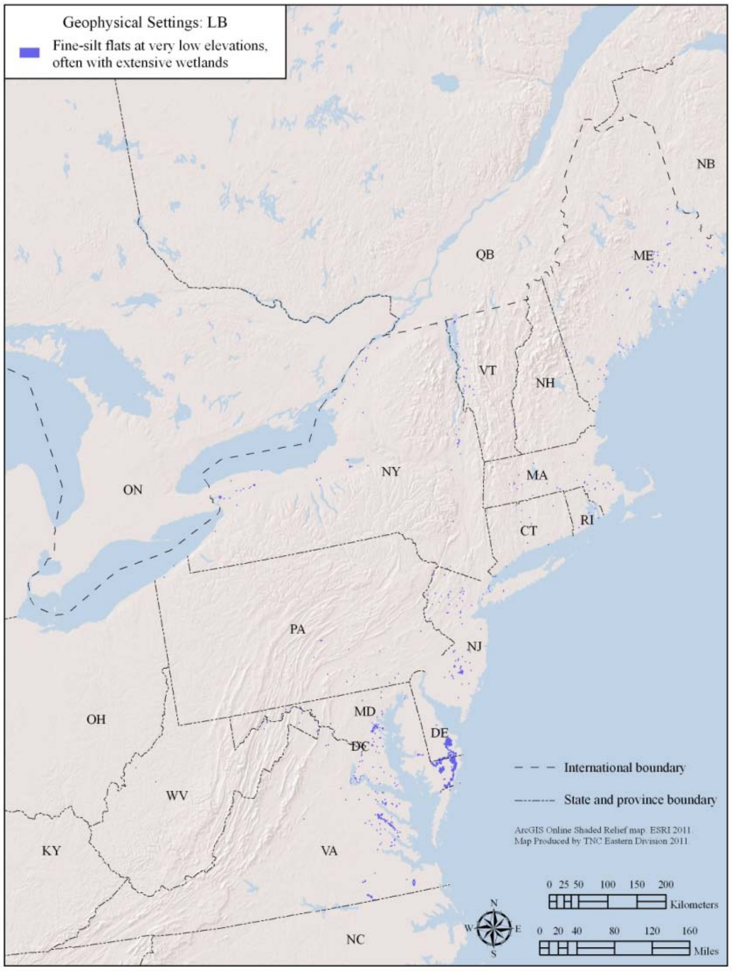
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coastal	Very Low	Low	Mod-erate	High	Very High
LA2	L64	0.07	0.71	0.12	0.01	0.01	0.03		0.04	0.02		0.99	0.01	0.00		
LA2 Average		0.07	0.71	0.12	0.01	0.01	0.03		0.04	0.02		0.99	0.01	0.00		

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / footslope	Hill / Valley	Dry Flat	Wet Flat	Water
LA2	L64	0.01	0.01	0.22	0.02	0.37	0.10	0.24	0.03
LA2 Average		0.01	0.01	0.22	0.02	0.37	0.10	0.24	0.03

Map 6.9: Resilience scores for LA2.



Group LB: Fine-Silt flats at Very Low Elevation



Description: Fine-silt flats at very low elevations (below 800'), often with extensive wetlands.

Tracked species typical of this habitat:

Birds: Least Bittern, Sora Rail, Pied-billed Grebe, Sedge Wren, Upland Sandpiper, Great Blue Heron.

Fish and Mussels:, Cherrystone Drop Snail Brook Floater, Dwarf Wedgemussel, Green Floater, Yellow Lampmussel.

Herptiles: Wood Turtle.

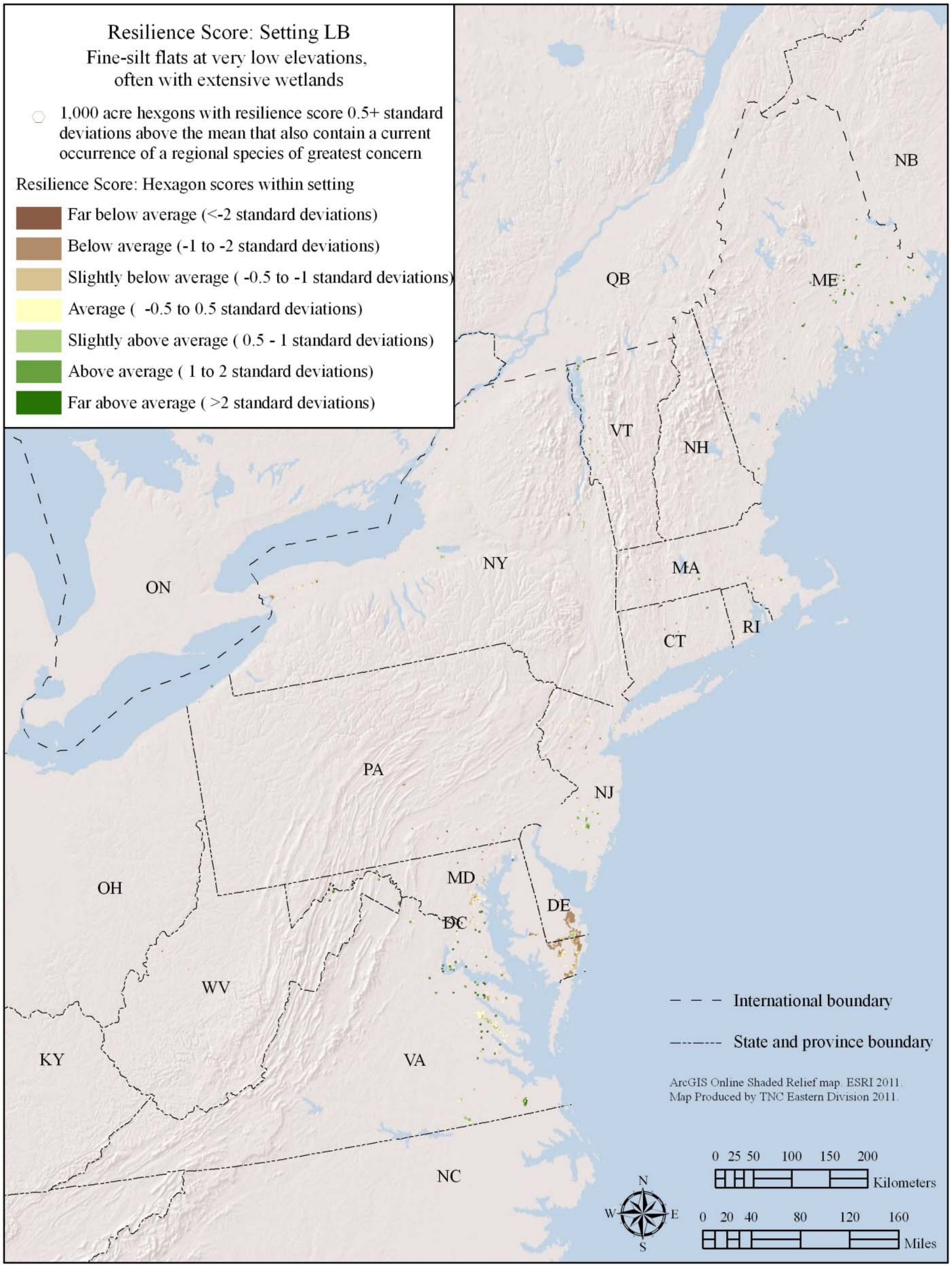
Mammals: Eastern Red Bat.

Sub types: L39 and L1712. L 39 has a high percentage of wet flats. L1712 is mostly dry flat.

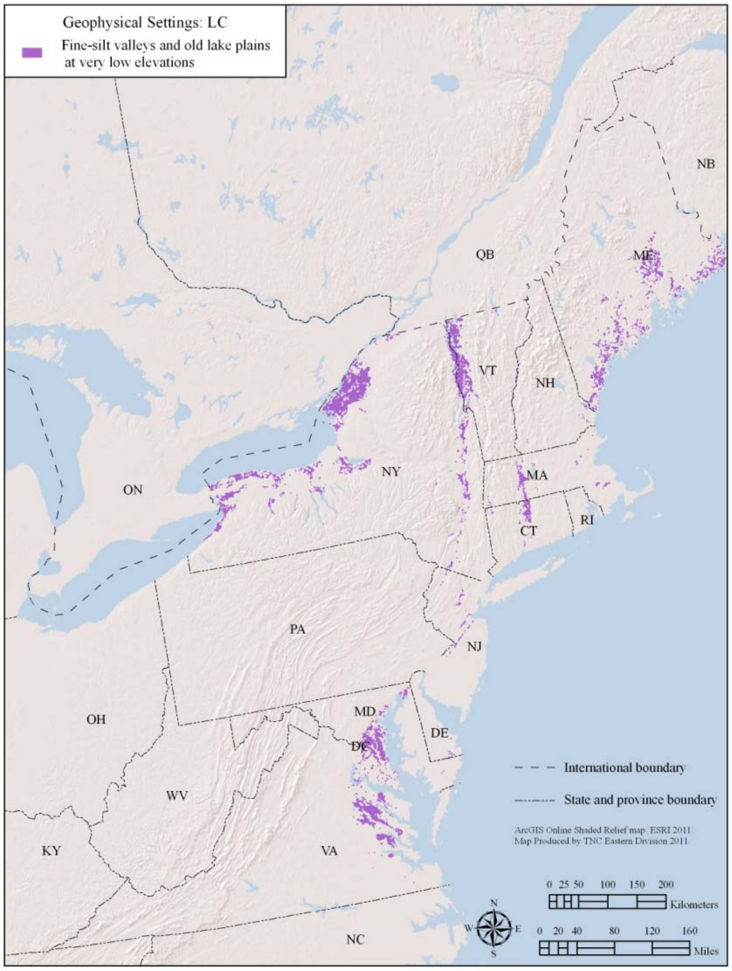
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coastal	Very Low	Low	Mod-erate	High	Very High
LB	L39	0.25	0.03	0.05	0.13	0.04	0.05		0.15	0.29	0.09	0.87	0.04			
LB	L1712	0.14	0.02	0.03	0.06	0.01	0.08	0.00	0.15	0.46	0.19	0.79	0.02			
LB Average		0.20	0.02	0.04	0.10	0.02	0.06	0.00	0.15	0.38	0.14	0.83	0.03			

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / footslope	Hill / Valley	Dry Flat	Wet Flat	Water
LB	L39	0.00		0.01	0.00	0.11	0.05	0.77	0.05
LB	L1712	0.00		0.02	0.01	0.11	0.64	0.15	0.08
LB Average		0.00		0.01	0.00	0.11	0.34	0.46	0.07

Map 5.10: Resilience scores for LB.



Group LC: Fine-silt Valleys and Lake Plains



Description: Fine-silt valleys and old lake plains at low elevations (below 800'), Forested or with open agricultural grasslands.

Tracked species typical of this habitat:

Birds: Henslow's Sparrow, Sora Rail, Great Black-backed Gull.

Fish and Mussels: Creek heelsplitter, Cylindrical Papershell, Wavyrayed Lampmussel, Longnose Sucker, Stripeback Darter, Dwarf Wedgemussel, Eastern Silvery Minnow, Pocketbook Mussel, Rainbow, Blackchin Shiner.

Herptiles: Northern Map Turtle, Common Mudpuppy.

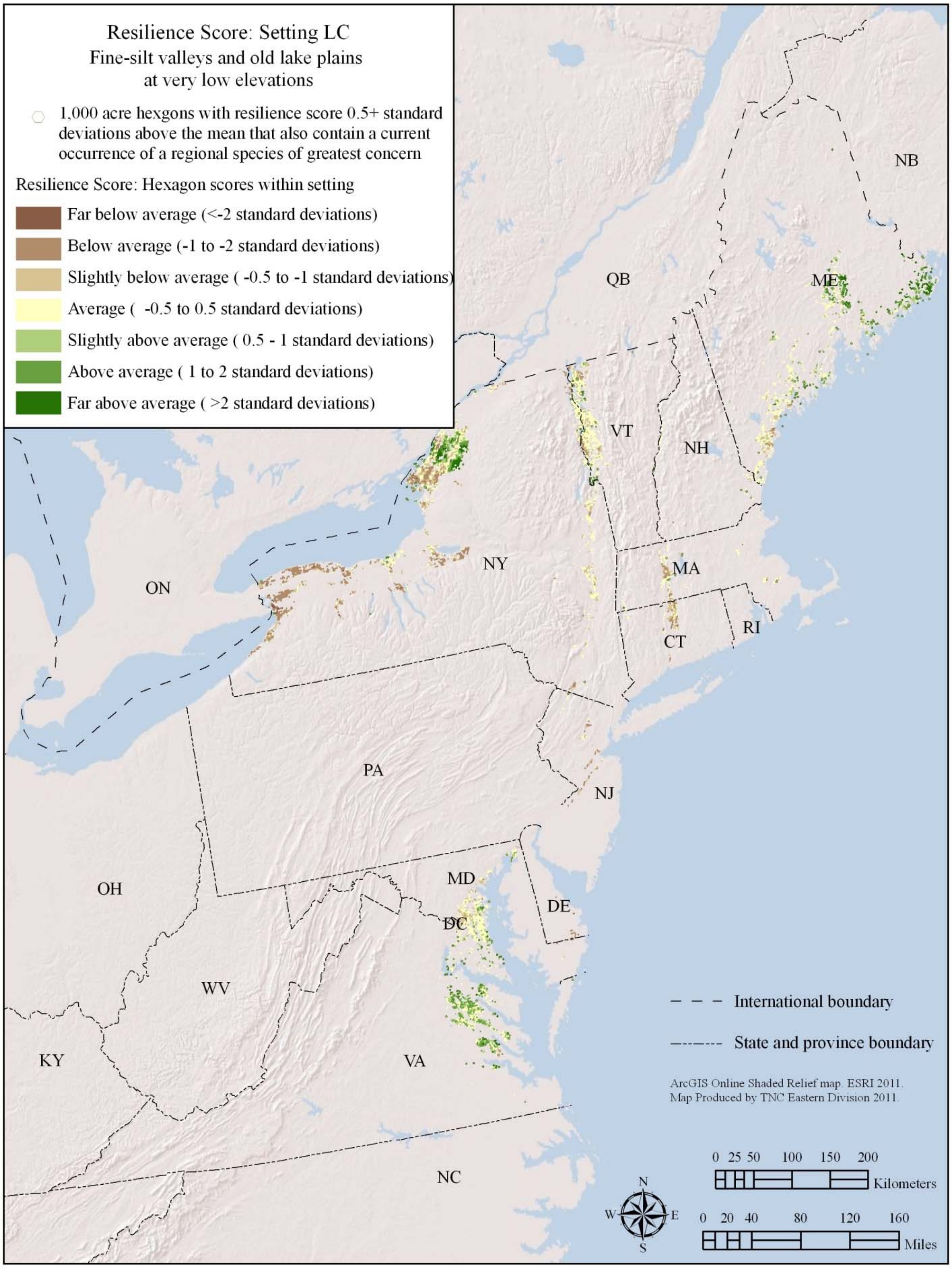
Mammals: Eastern Red Bat.

Sub types: L51 and L91. Both are over 75% fine sediment but L51 has rolling hills and flats while L91 is more side-slopes, and steep slopes.

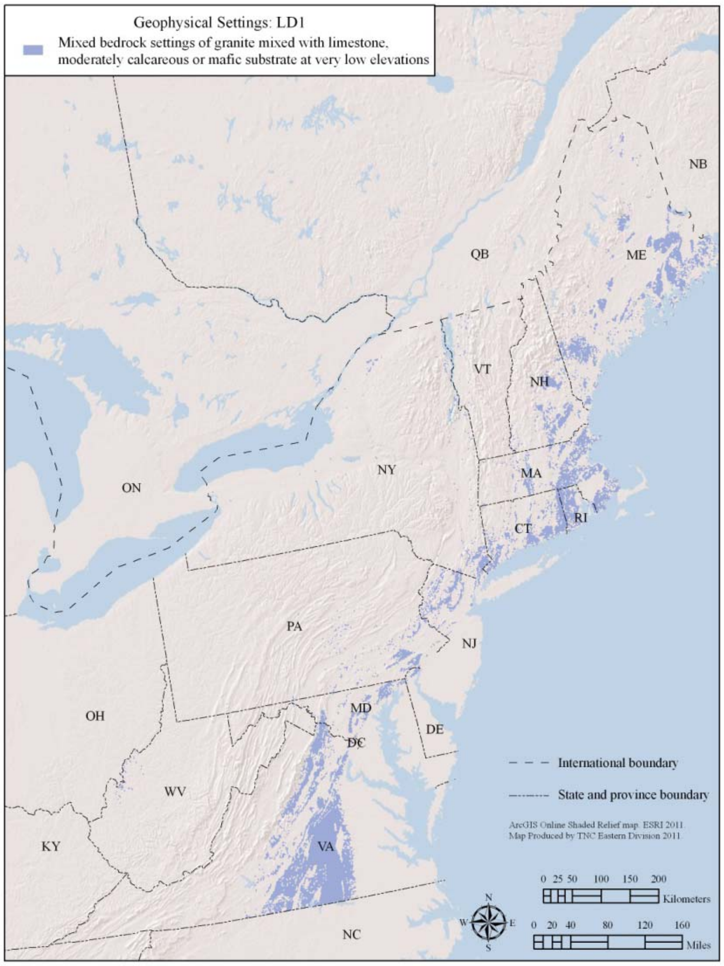
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coastal	Very Low	Low	Mod-erate	High	Very High
LC	L51	0.04	0.00	0.04	0.03	0.02	0.03	0.00	0.05	0.79	0.04	0.95	0.00			
LC	L91	0.06	0.00	0.03	0.03	0.02	0.01		0.06	0.75	0.13	0.86	0.01			
LC Average		0.05	0.00	0.04	0.03	0.02	0.02	0.00	0.05	0.77	0.09	0.91	0.01			

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / footslope	Hill / Valley	Dry Flat	Wet Flat	Water
LC	L51	0.00	0.00	0.12	0.01	0.42	0.10	0.25	0.11
LC	L91	0.05	0.09	0.50	0.06	0.17	0.02	0.07	0.04
LC Average		0.03	0.04	0.31	0.03	0.30	0.06	0.16	0.07

Map 5.11 Resilience scores for LC.



Group LD1: Mixed Granitic and Mafic Bedrock at Very Low Elevation



Description: Mixed bedrock settings of granite mixed with limestone, moderately calcareous or rich mafic substrates.

Tracked species typical of this habitat:

Birds: Golden-winged Warbler, Prothonotary Warbler, Common Loon, Whip-poor-will, Veery, Sora Rail, Hooded Warbler, Common Moorhen.

Fish and Mussels:, Eastern Pearlshell, American Brook Lamprey, Bridle Shiner, Brook Floater, Dwarf Wedgemussel, Triangle Floater, Yellow Lance, Green Floater, Banded Sunfish.

Herptiles: Eastern Hognose Snake, Blue-spotted Salamander, Jefferson Salamander, Timber Rattlesnake, Marbled Salamander, Blanding's Turtle, Copperhead, Bog Turtle.

Mammals: Eastern Red Bat, Indiana Bat, Allegheny Woodrat.

Sub types: L2, L28 and L6. L2 has a high percentage of mafic bedrock. L28 is a mix of granite and mafic, L6 has a high proportion of calcareous and moderately calcareous settings and is less flat.

Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coastal	Very Low	Low	Mod-erate	High	Very High
LD1	L2	0.10	0.00	0.01	0.02	0.07	0.64	0.00	0.15	0.02	0.03	0.94	0.03	0.00		
LD1	L28	0.02	0.00	0.00	0.01	0.67	0.06	0.00	0.21	0.02	0.03	0.96	0.01			
LD1	L6	0.05	0.01	0.20	0.12	0.47	0.04	0.00	0.08	0.02	0.05	0.89	0.05			
LD1 Average		0.06	0.00	0.07	0.05	0.40	0.25	0.00	0.15	0.02	0.04	0.93	0.03	0.00		

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / footslope	Hill / Valley	Dry Flat	Wet Flat	Water
LD1	L2	0.01	0.01	0.15	0.01	0.40	0.09	0.27	0.06
LD1	L28	0.00	0.00	0.12	0.00	0.44	0.10	0.28	0.05
LD1	L6	0.03	0.04	0.45	0.04	0.27	0.03	0.10	0.04
LD1 Average		0.02	0.02	0.24	0.02	0.37	0.07	0.22	0.05

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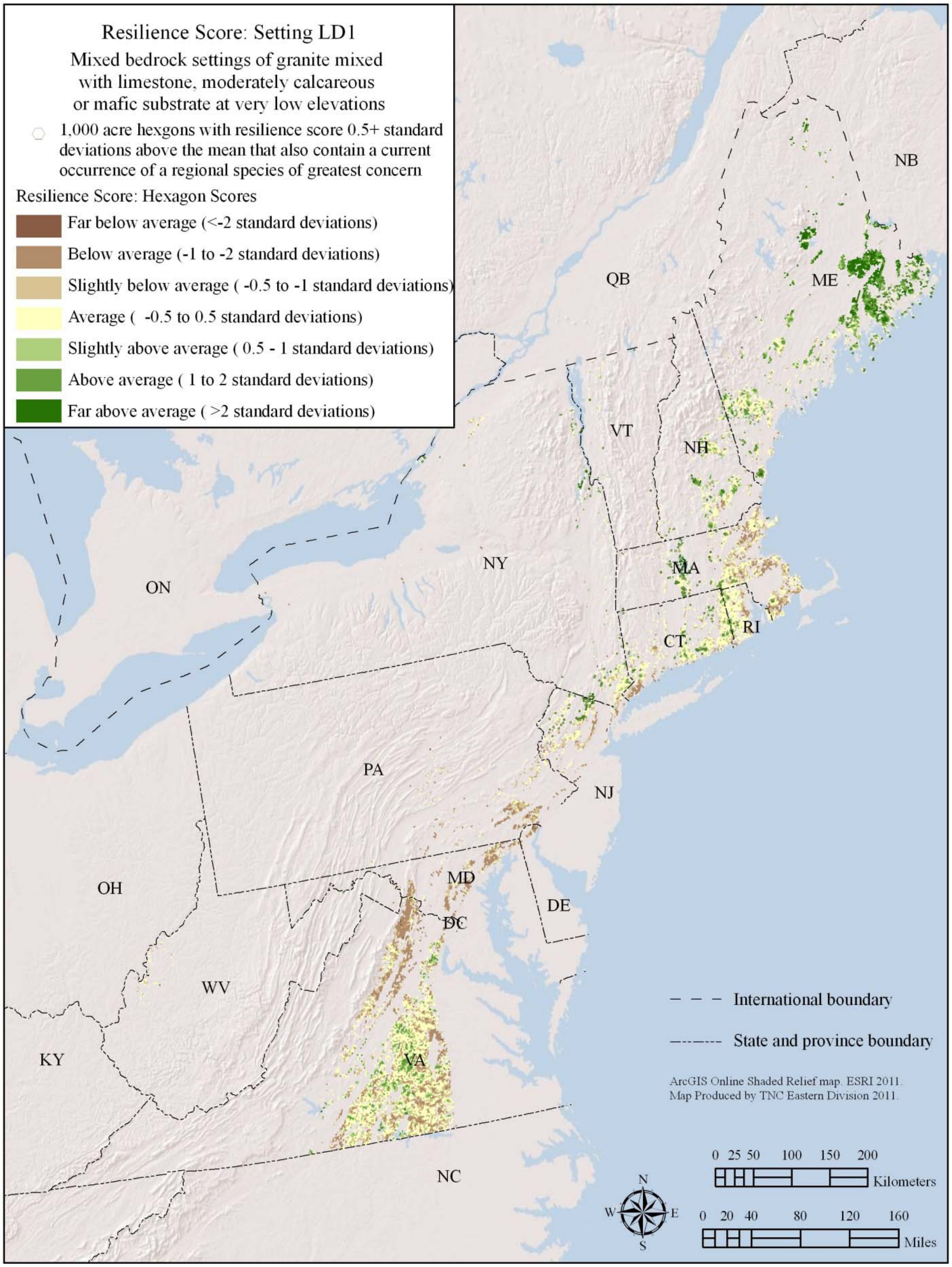
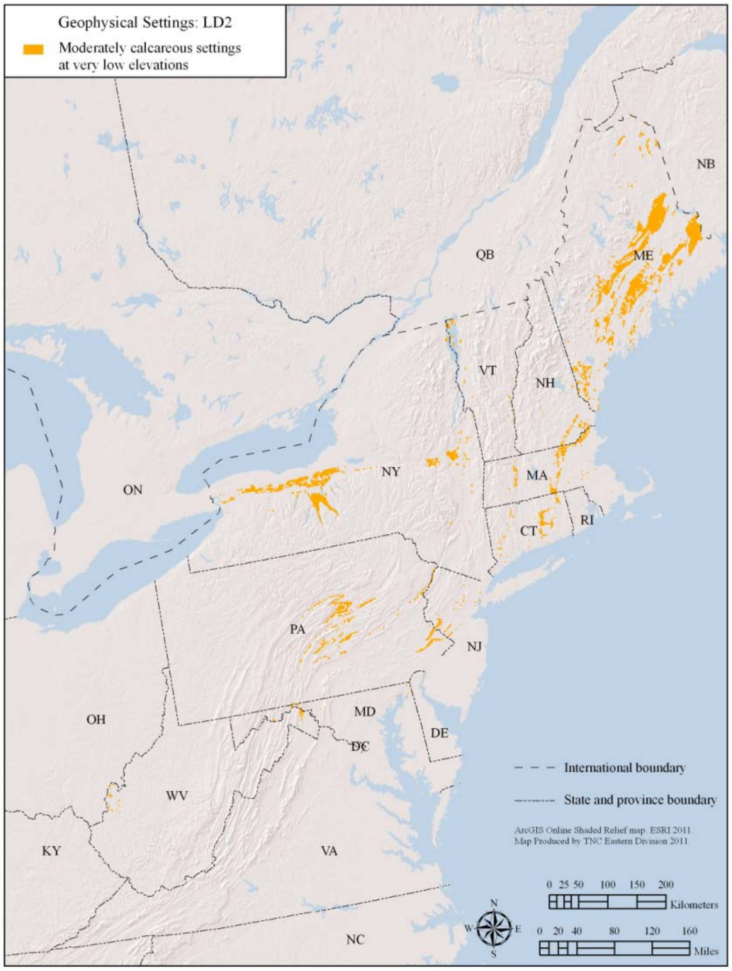
Map 5.12 Resilience scores for LD1.



Group LD2: Moderately Calcareous settings at Very Low Elevation



Description: Mixed bedrock settings dominated by moderately calcareous substrates.

Tracked species typical of this habitat:

Birds: Whip-poor-will, Cooper's Hawk, Grasshopper Sparrow, Pied-billed Grebe, Red-headed Woodpecker, Upland Sandpiper, Black Tern, Great Blue Heron, Brown Thrasher, Least Bittern

Fish and Mussels: Triangle Floater, Blackchin Shiner, Shortnose Sturgeon, Eastern Pond Mussel, Tidewater Mucket, Yellow Lampmussel,

Herptiles: Blanding's Turtle, Bog Turtle, Spotted Turtle, Wood Turtle, Eastern Box Turtle.

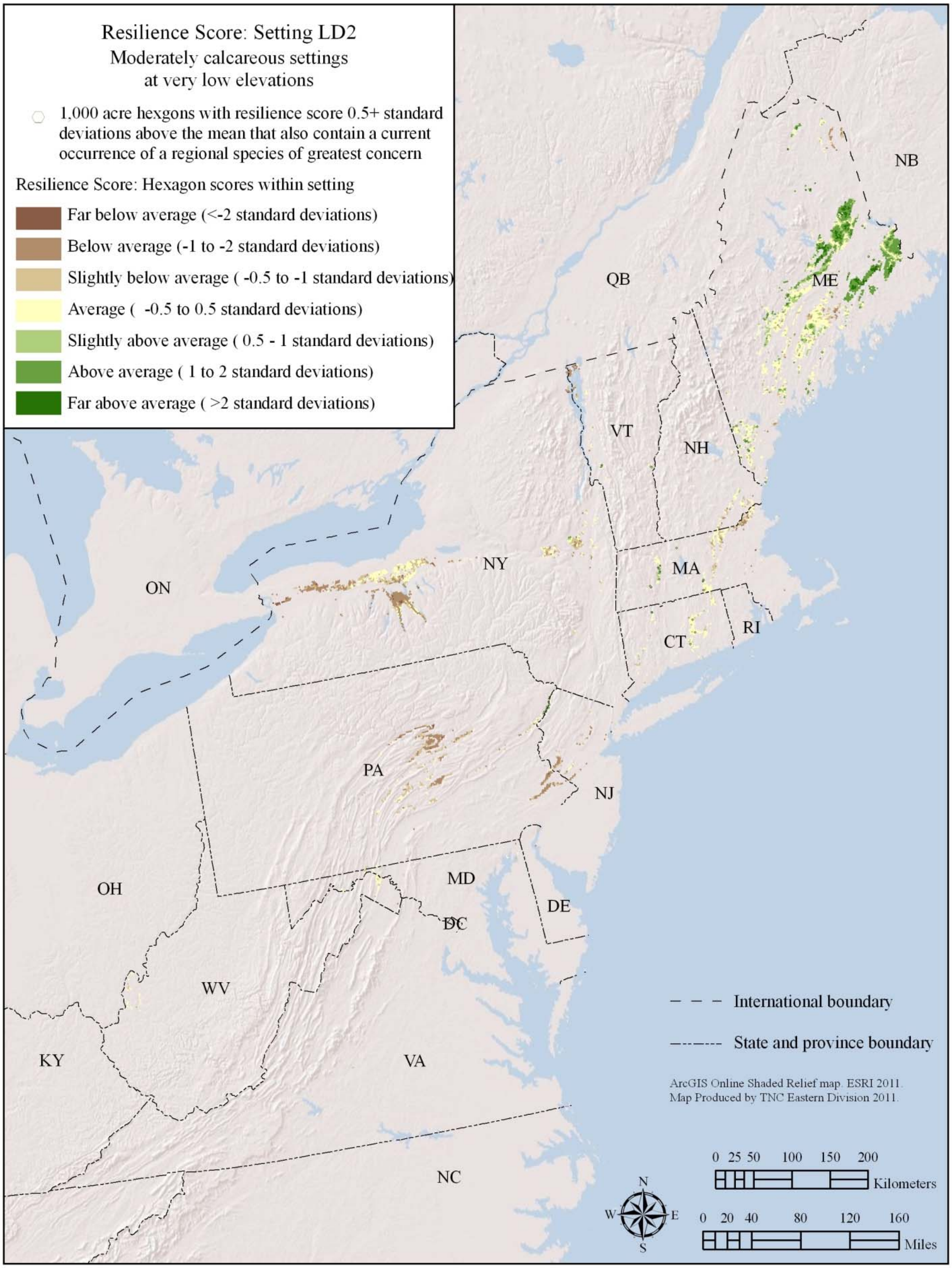
Mammals: New England Cottontail.

Sub types: L57 and L9. L57 has moderate amounts of granite mafic as well as open water. L9 is mostly mixed with coarse sediments.

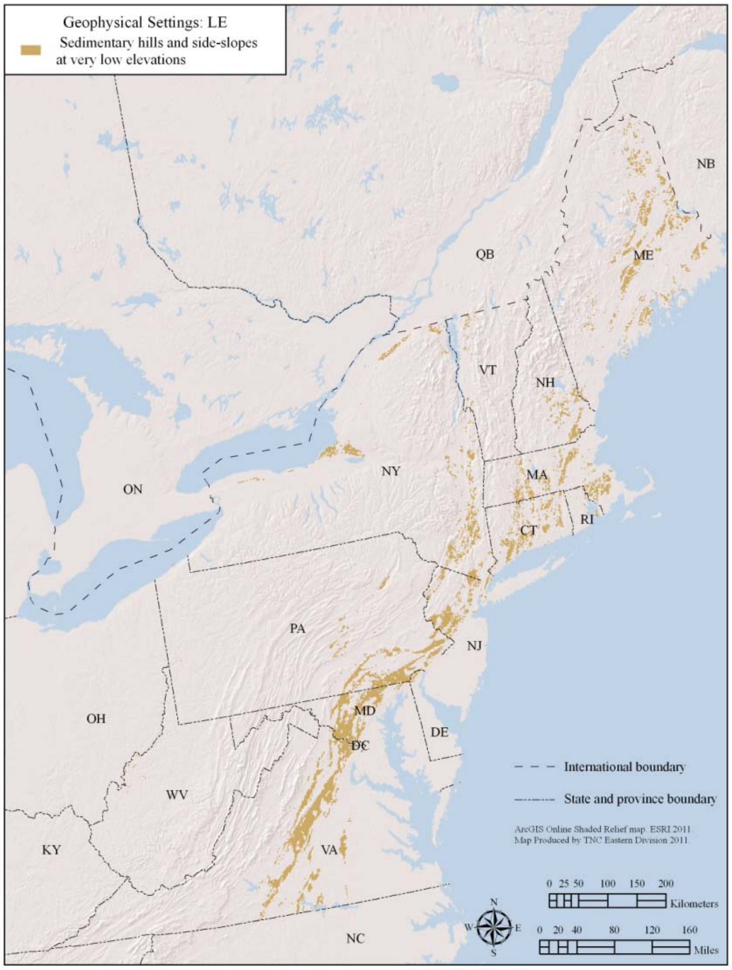
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coastal	Very Low	Low	Mod-erate	High	Very High
LD2	L57	0.05		0.01	0.40	0.32	0.03		0.14	0.03	0.12	0.88	0.00			
LD2	L9	0.06	0.01	0.04	0.69	0.01	0.01		0.12	0.05	0.02	0.95	0.04			
LD2 Average		0.06	0.01	0.02	0.55	0.17	0.02		0.13	0.04	0.07	0.91	0.02			

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / footslope	Hill / Valley	Dry Flat	Wet Flat	Water
LD2	L57	0.00	0.00	0.03	0.00	0.14	0.05	0.12	0.66
LD2	L9	0.00	0.00	0.11	0.00	0.47	0.11	0.28	0.03
LD2 Average		0.00	0.00	0.07	0.00	0.30	0.08	0.20	0.35

Map 5.13: Resilience scores for LD2.



Group LE: Sedimentary Hills and Side-slopes at Very Low Elevation



Description: Sedimentary hills and side-slopes at low elevation (below 800').

Tracked species typical of this habitat:

Birds: Prothonotary Warbler, Cerulean Warbler, Upland Sandpiper, Eastern Meadowlark, Common Nighthawk.

Fish and Mussels: Bridle Shiner, Brook Floater, Yellow Lampmussel.

Herptiles: Fowler's Toad, Blue-spotted Salamander, Jefferson Salamander, Wood Turtle.

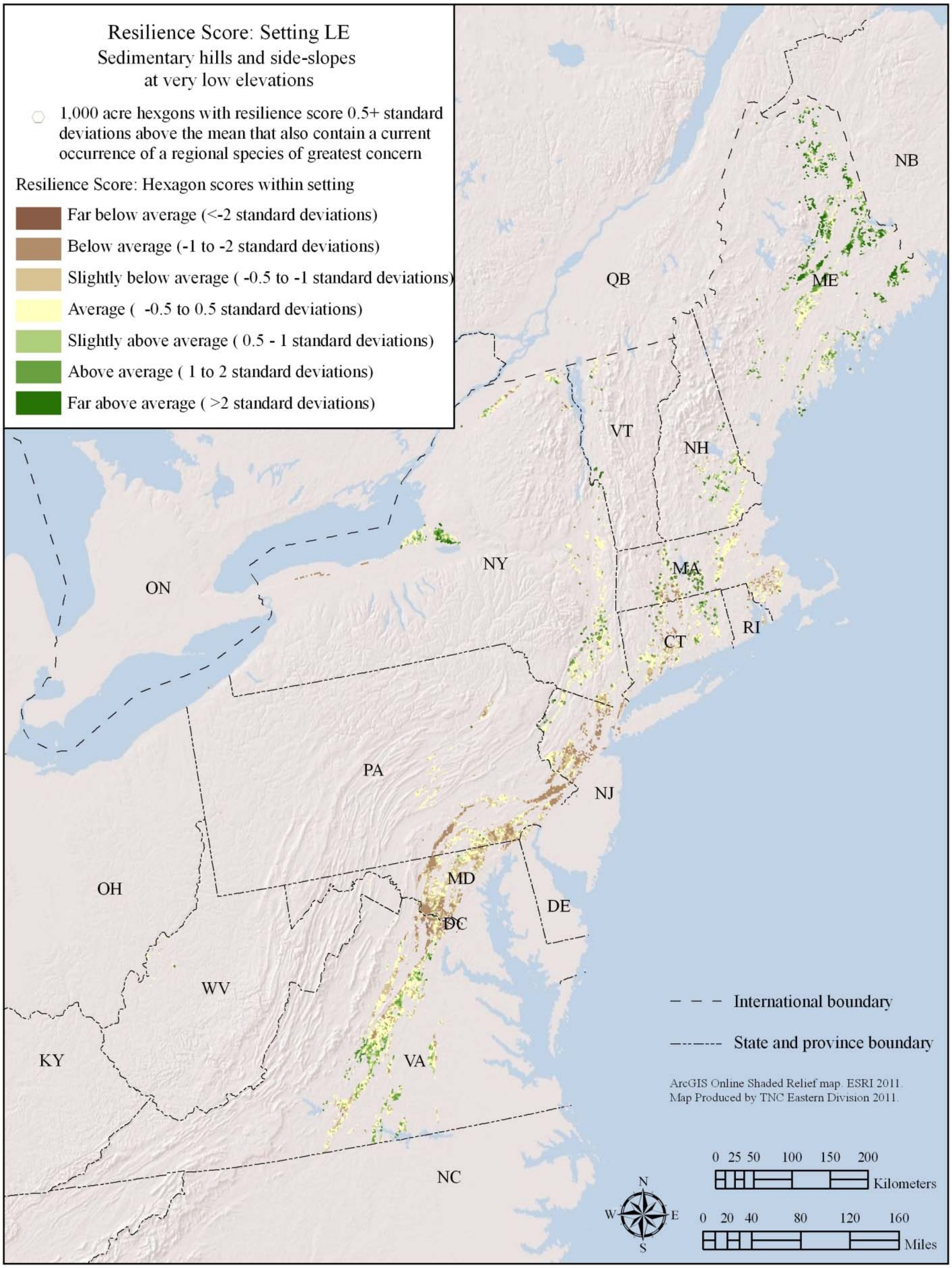
Mammals: Eastern Red Bat, New England Cottontail.

Sub types: L4 and L5. These two subtypes are almost identical in geology and elevation , they differ in the L4 is a hill and valley landscape with almost a third in wet flats. L5 has more slopes, summits and cliffs.

Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coastal	Very Low	Low	Mod-erate	High	Very High
LE	L4	0.71	0.00	0.00	0.02	0.03	0.02	0.00	0.18	0.03	0.01	0.97	0.02			
LE	L5	0.79	0.01	0.02	0.02	0.01	0.02	0.00	0.12	0.01	0.01	0.95	0.04			
LE Average		0.75	0.01	0.01	0.02	0.02	0.02	0.00	0.15	0.02	0.01	0.96	0.03			

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / footslope	Hill / Valley	Dry Flat	Wet Flat	Water
LE	L4	0.00	0.00	0.11	0.00	0.46	0.10	0.29	0.03
LE	L5	0.04	0.04	0.43	0.05	0.22	0.03	0.09	0.10
LE Average		0.02	0.02	0.27	0.02	0.34	0.07	0.19	0.06

Map 5.14: Resilience scores for LE.



Group LF: Coarse Sand and Outwash at Very Low Elevation

Description: Coarse sand and outwash at very low elevation gentle hills and flats, often supporting oak and pine. Pitch pine and scrub oak barrens are found here.

Tracked species typical of this habitat:

Birds: Brown Thrasher, Chuck-will's-widow, Red-headed Woodpecker, Sharp-Shinned Hawk, American Bittern, Vesper Sparrow, Upland Sandpiper, Eastern Meadowlark, Great Blue Heron. Northern Harrier, Osprey, Common Tern, Yellow-crowned Night-heron, Piping Plover.

Fish and Mussels: Glassy Darter, Tidewater Mucket, Yellow Lampmussel.

Herptiles: Wood Turtle, Carpenter Frog, Tiger Salamander, Corn Snake, Eastern Spadefoot Toad, Eastern Box Turtle. Spotted Turtle, Eastern Box Turtle.

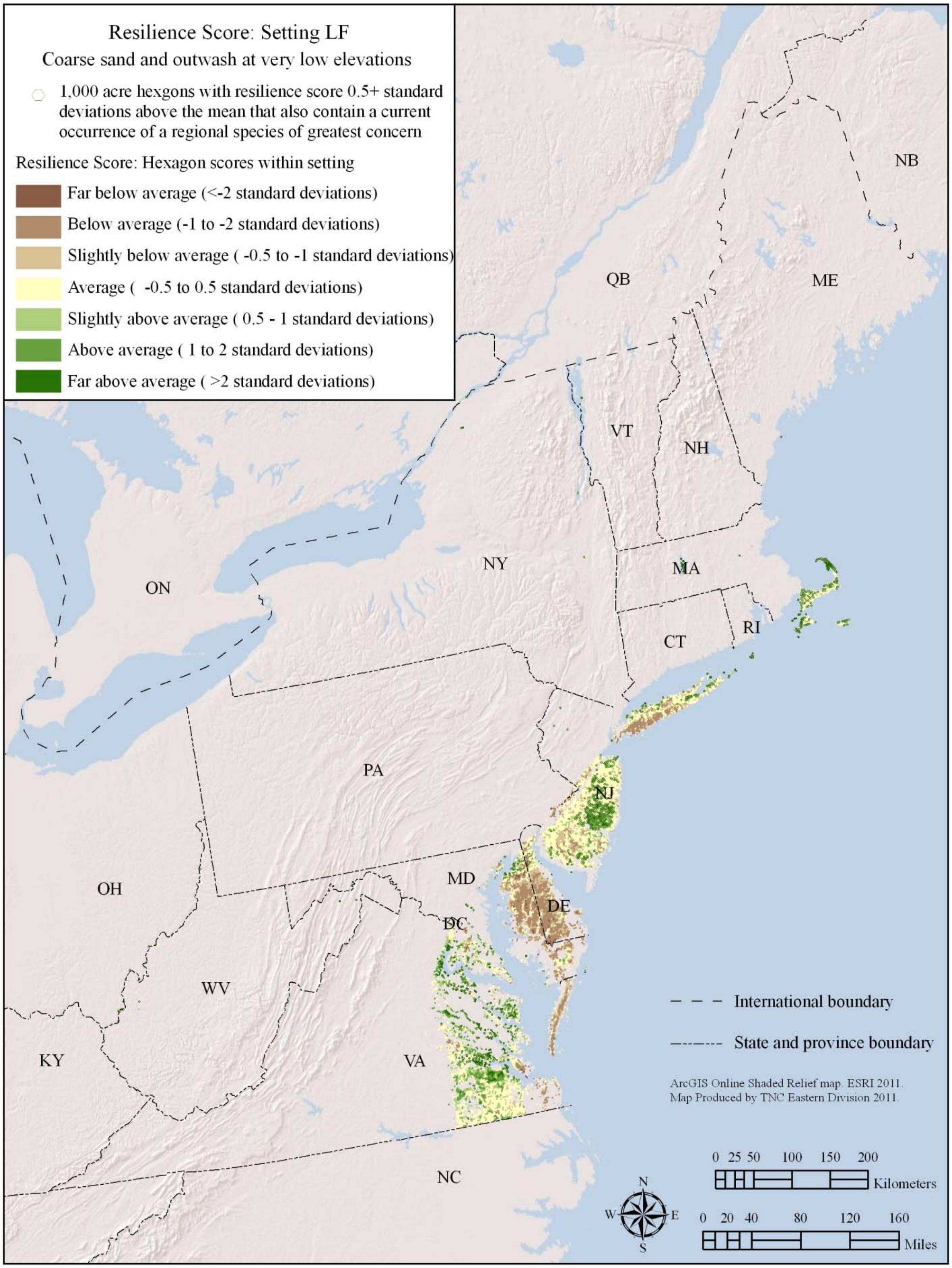
Mammals: Southern Bog Lemming.

Sub types: L135 and L176. L176 is lower in elevation and is highly sloped (coastal bluffs).

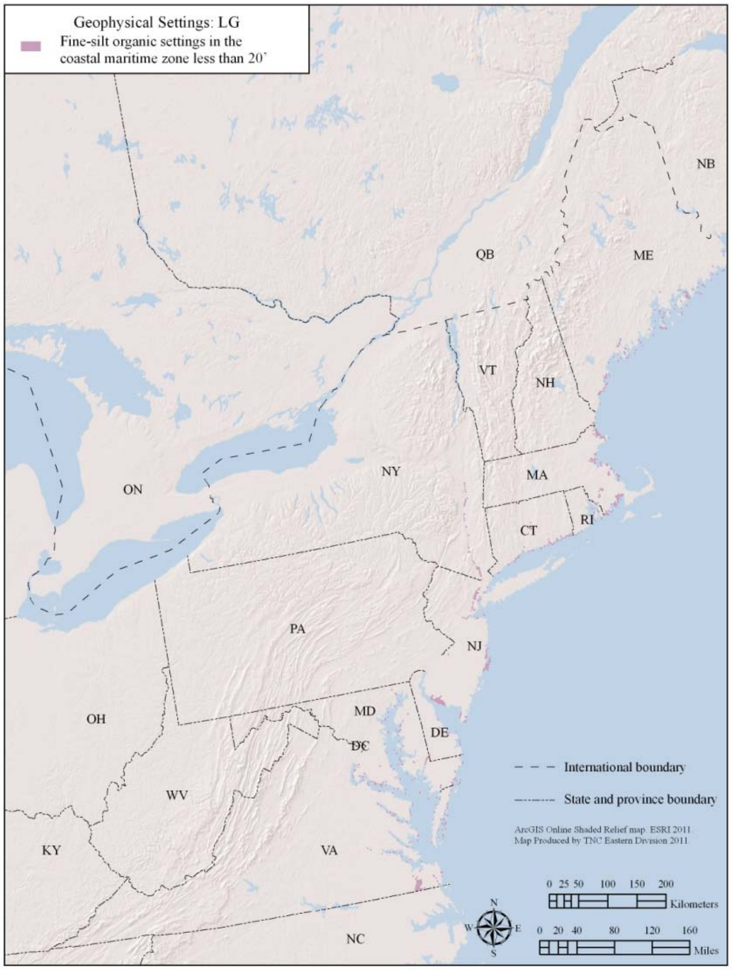
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coastal	Very Low	Low	Mod-erate	High	Very High
LF	L135	0.00	0.00	0.00	0.00	0.00	0.00		0.97	0.02	0.05	0.95	0.00			
LF	L176	0.02	0.01	0.00	0.02	0.00	0.00		0.80	0.11	0.41	0.59	0.01			
LF Average		0.01	0.01	0.00	0.01	0.00	0.00		0.88	0.06	0.23	0.77	0.00			

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / footslope	Hill / Valley	Dry Flat	Wet Flat	Water
LF	L135	0.01	0.01	0.14	0.01	0.34	0.13	0.30	0.06
LF	L176	0.05	0.13	0.44	0.07	0.19	0.03	0.07	0.03
LF Average		0.03	0.07	0.29	0.04	0.27	0.08	0.19	0.04

Map 5.15: Resilience scores for LF.



Group LG: Fine-Silt Settings in the Coastal Zone



Description: Fine-silt organic settings in the coastal maritime zone less than 20' elevation. Some areas include granite bedrock.

Tracked species typical of this habitat:

Birds: Saltmarsh Sharp-tailed Sparrow, Willet, Black-crowned Night-heron, Common Tern, Yellow-crowned Night-Heron, Common Tern, Least Tern, Great Egret, Snowy Egret, American Oystercatcher, Black Rail, Glossy Ibis, Little Blue Heron, Red Knot.

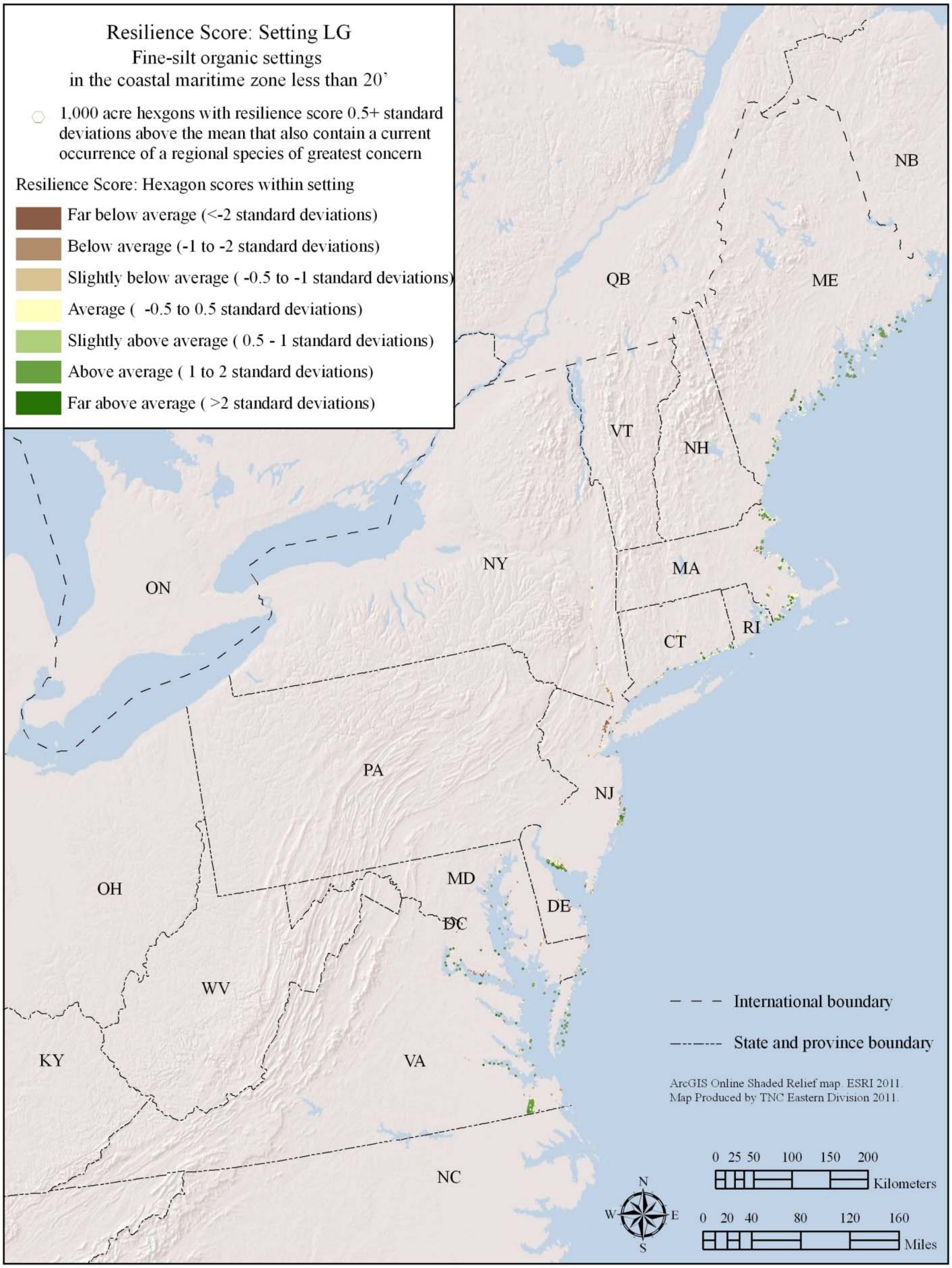
Fish and Mussels:
Herptiles:
Mammals:.

Sub types: L115, L71 and L3241. L115 is mostly granite with coarse sand and silt. L71 is dominated by fine silt. L3241 is partially ocean.

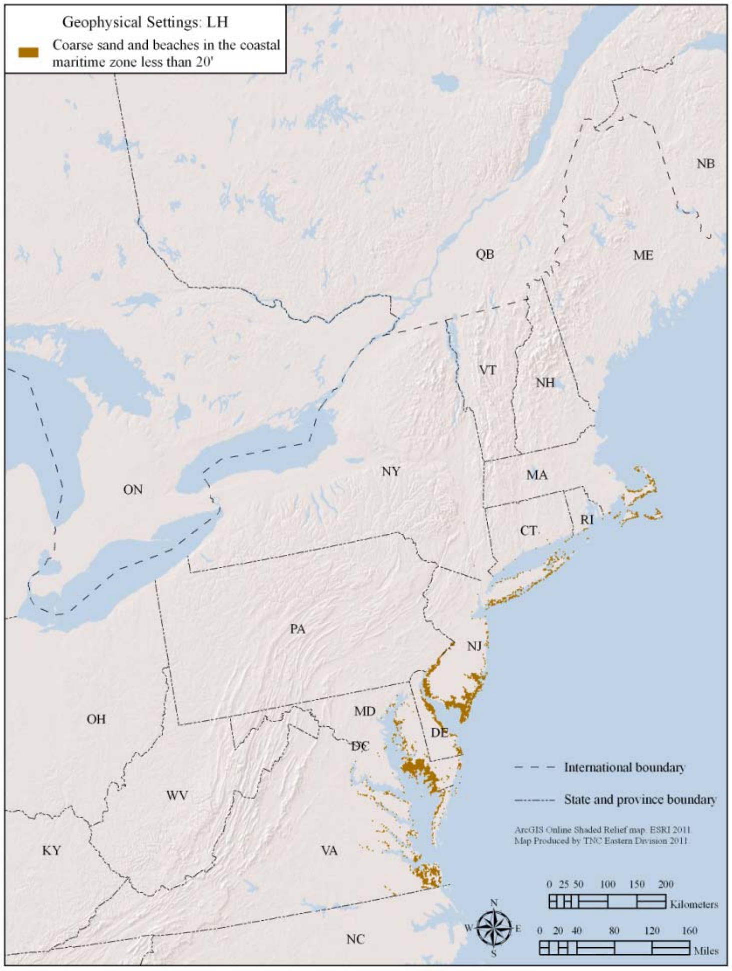
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coastal	Very Low	Low	Mod-erate	High	Very High
LG	L115	0.27		0.00	0.02	0.37	0.09		0.18	0.06	0.69	0.31				
LG	L71	0.03		0.00	0.00	0.01	0.01		0.04	0.90	0.86	0.14				
LG	L3241								0.37	0.15	0.95	0.05				
LG Average		0.15		0.00	0.01	0.19	0.05		0.19	0.37	0.83	0.17				

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / footslope	Hill / Valley	Dry Flat	Wet Flat	Water
LG	L115	0.01	0.00	0.12	0.01	0.40	0.09	0.34	0.04
LG	L71	0.01	0.01	0.10	0.01	0.33	0.15	0.29	0.11
LG	L3241								
LG Average		0.01	0.01	0.11	0.01	0.36	0.12	0.31	0.07

Map 5.16: Resilience scores for LG.



Group LH: Coarse Sand and Beaches in the Coastal Zone



Description: Coarse sand and beaches in the coastal maritime zone less than 20' elevation.

Tracked species typical of this habitat:

Birds: Least Tern, Piping Plover, Great Egret, Snowy Egret, American Oystercatcher, Arctic Tern, Black Rail, Black Skimmer, Glossy Ibis, Gull-billed Tern, Little Blue Heron, Red Knot, Roseate Tern, Seaside Sparrow, Tricolored Heron, Cattle Egret, Forster's Tern

Fish and Mussels:

Herptiles: Marbled Salamander

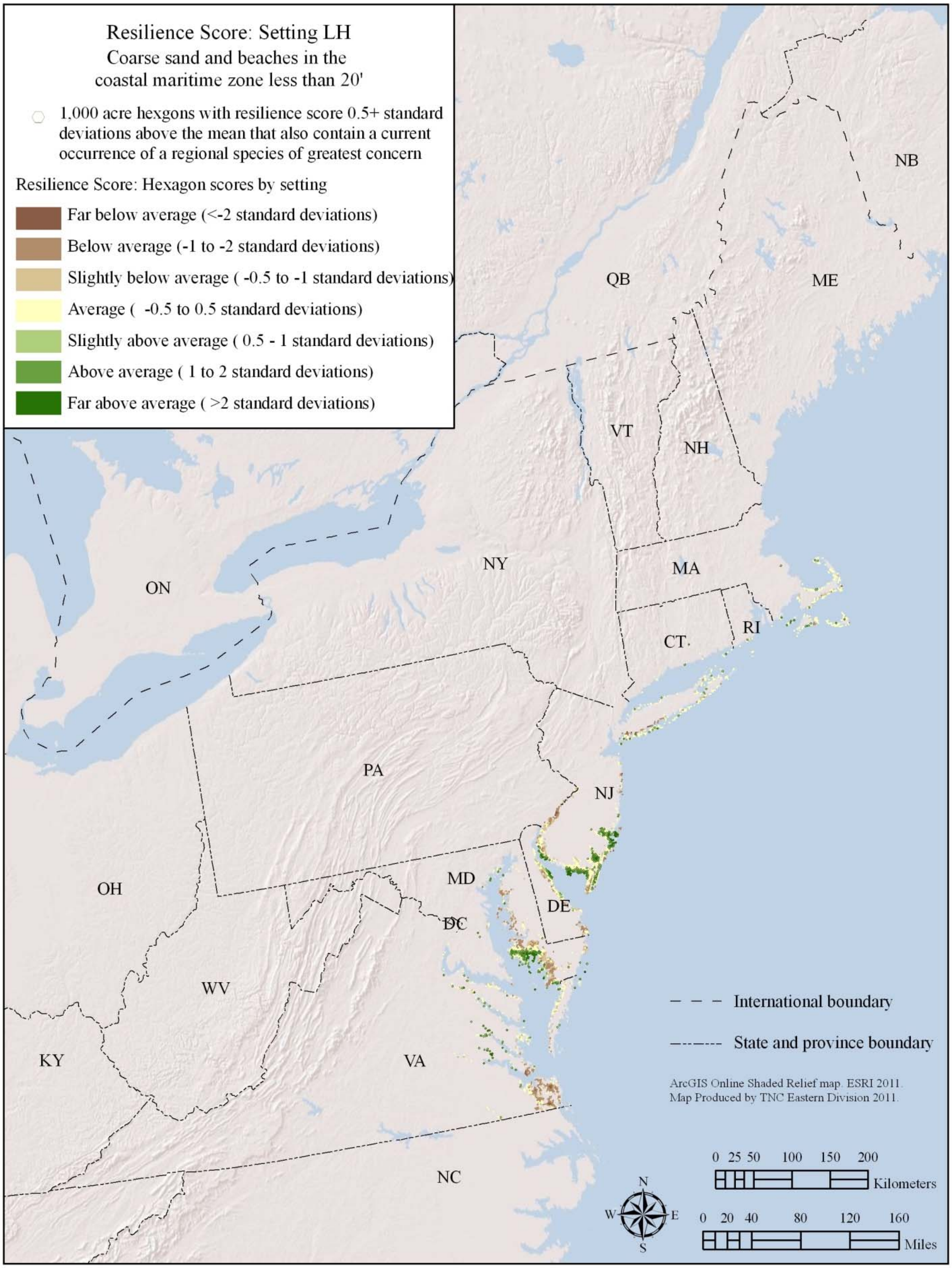
Mammals:

Sub types: L87 and L133. L87 is very flat while L133 has highly sloped coastal bluffs.

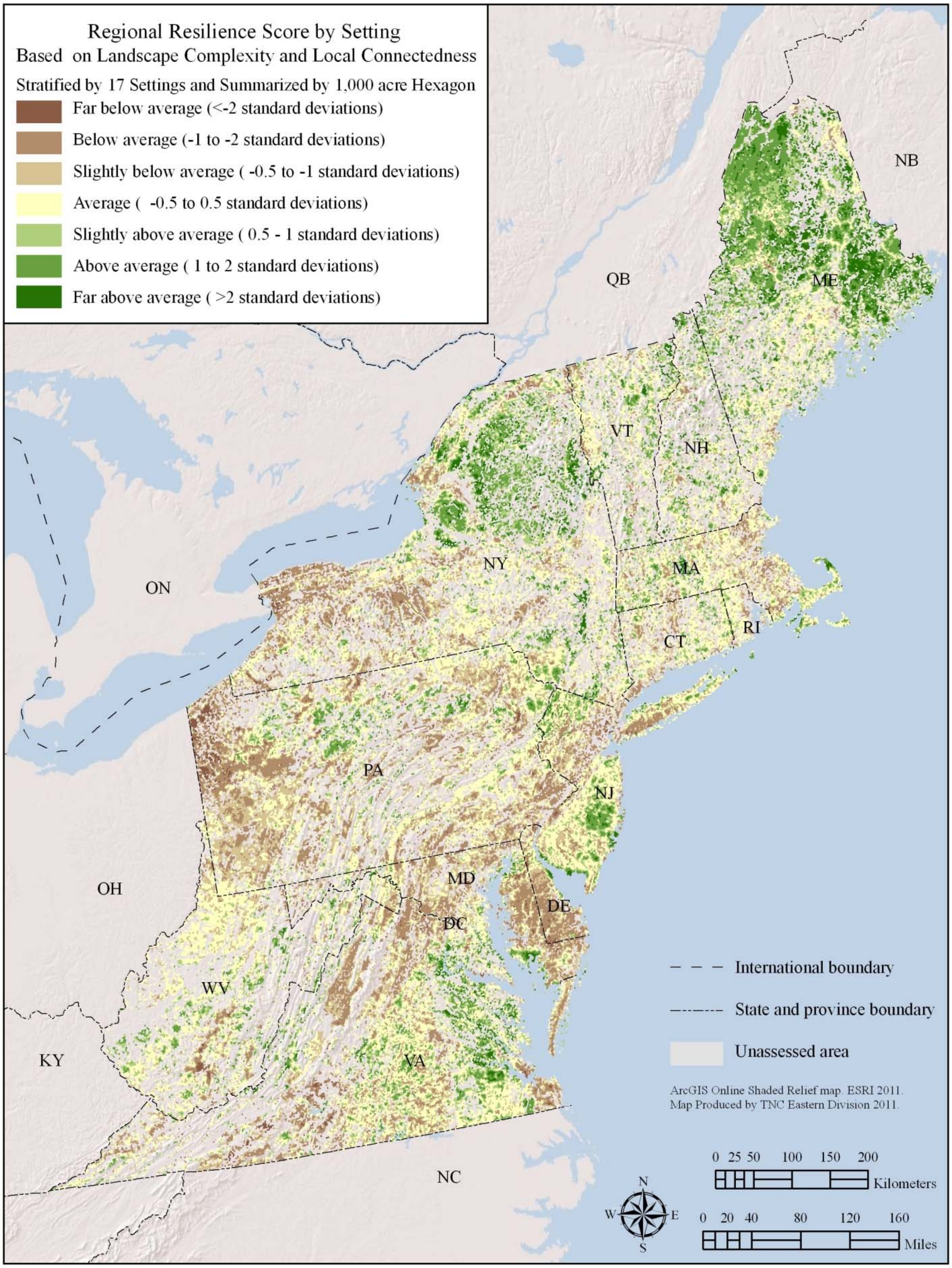
Group 15	Group 40	Acidic Sedi-mentary	Acidic Shale	Rich Calc-areous	Mod. Calc-areous	Acidic Granitic	Mafic	Ultra-mafic	Coarse sand	Fine silt	Coastal	Very Low	Low	Mod-erate	High	Very High
LH	L87	0.00		0.00	0.00	0.00	0.00	0.00	0.95	0.03	0.87	0.13				
LH	L133	0.01	0.00		0.00	0.00	0.01		0.94	0.03	0.93	0.07				
LH Average		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.03	0.90	0.10				

Group 15	Group 40	Summit / Ridge	Cliff / Steep	Side-slope	Cove / footslope	Hill / Valley	Dry Flat	Wet Flat	Water
LH	L87	0.00	0.00	0.04	0.01	0.27	0.16	0.39	0.13
LH	L133	0.04	0.06	0.53	0.07	0.20	0.02	0.06	0.03
LH Average		0.02	0.03	0.28	0.04	0.23	0.09	0.23	0.08

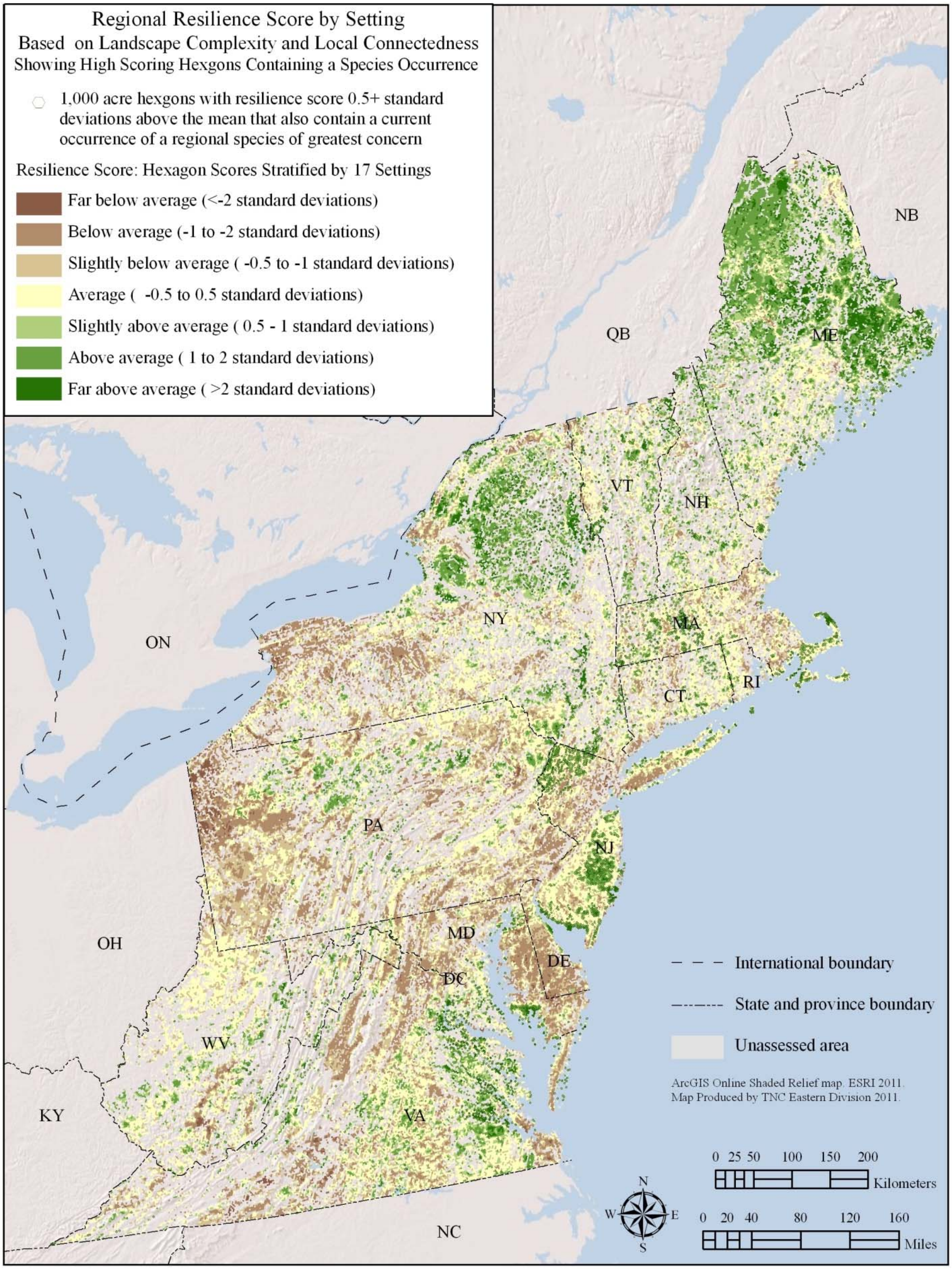
Map 5.17: Resilience scores for LH.



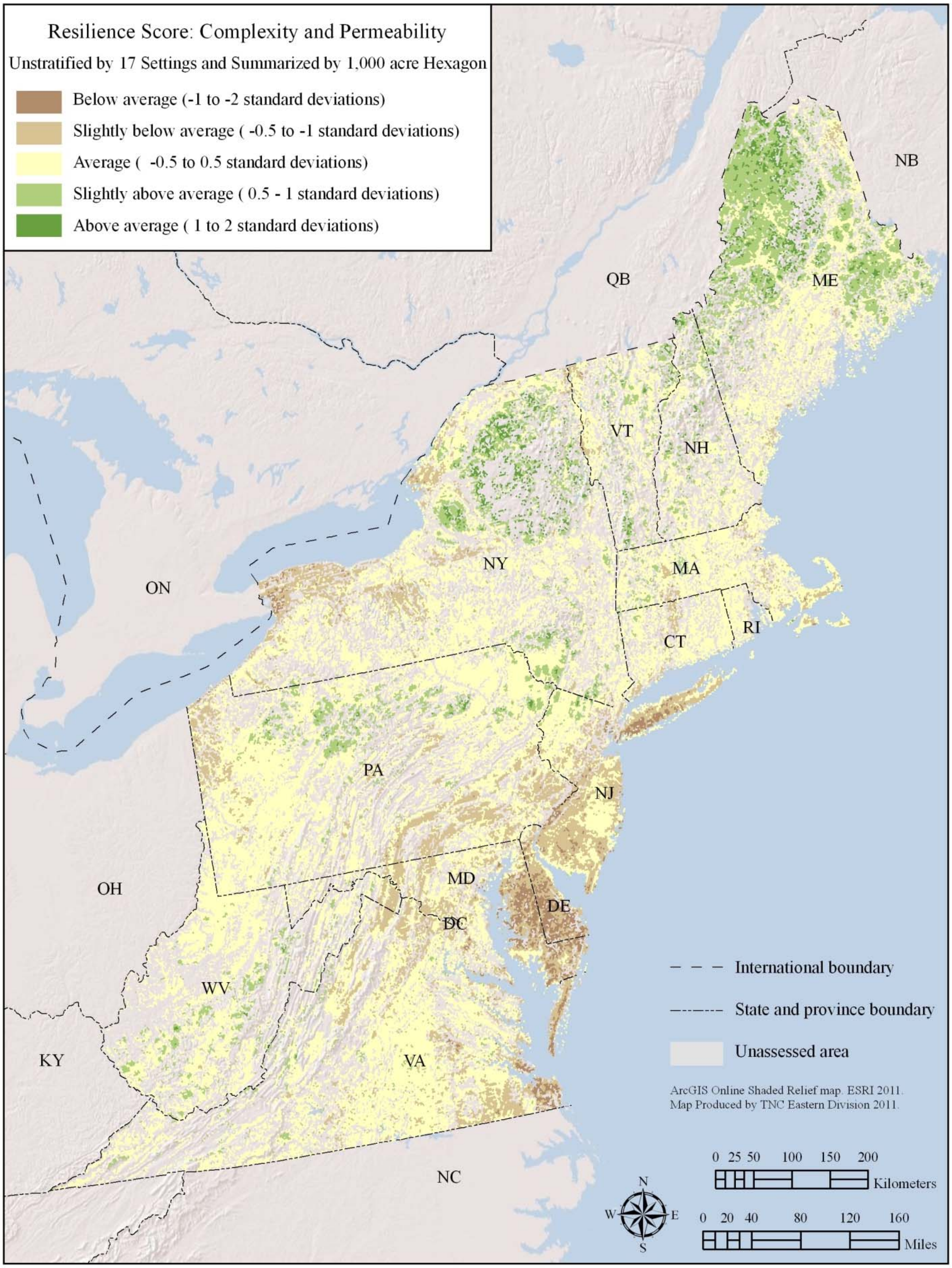
Map 5.18: Resilience scores by geophysical setting.



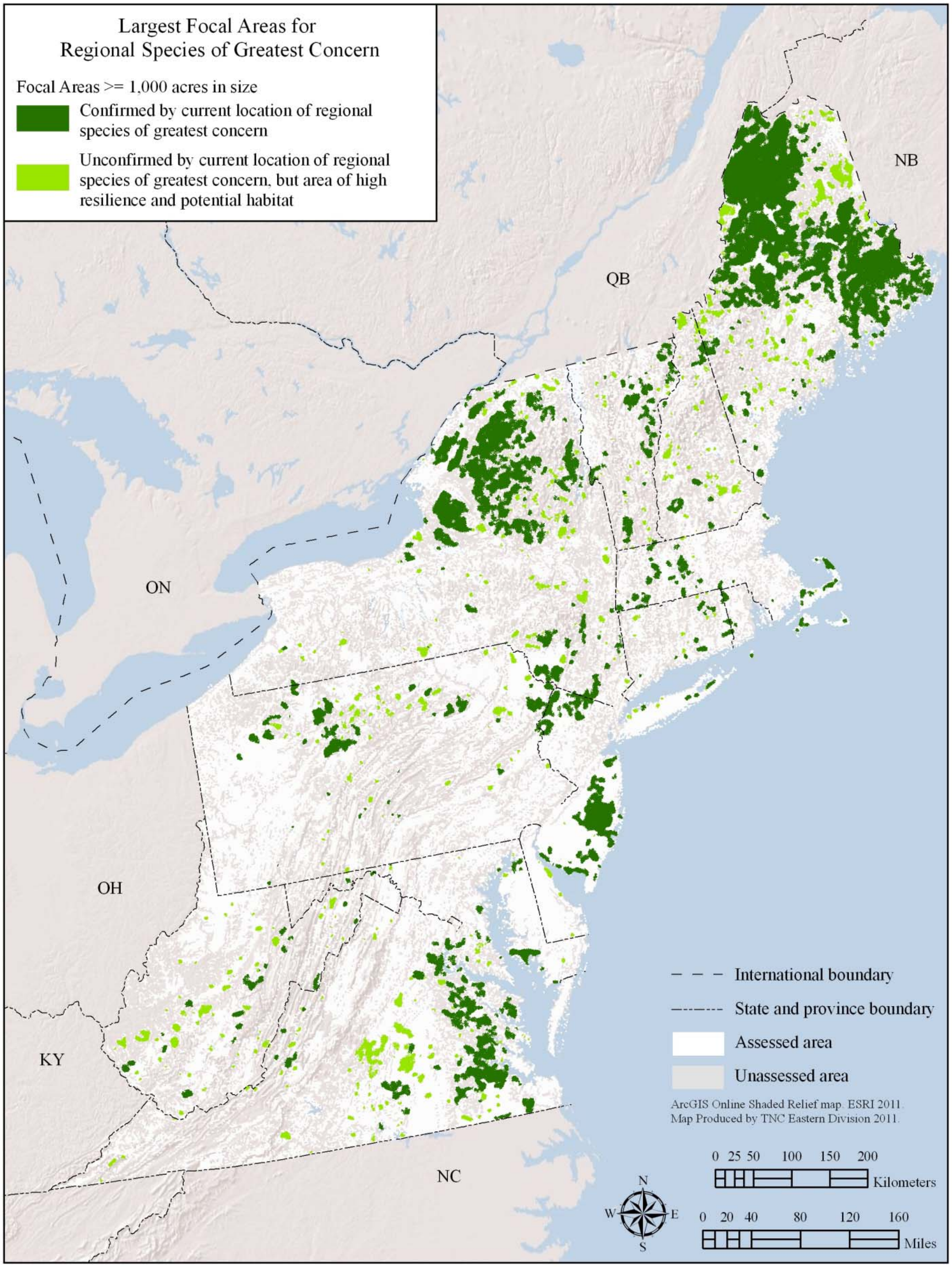
Map 5.19: Resilience scores by geophysical setting showing confirmed species areas.



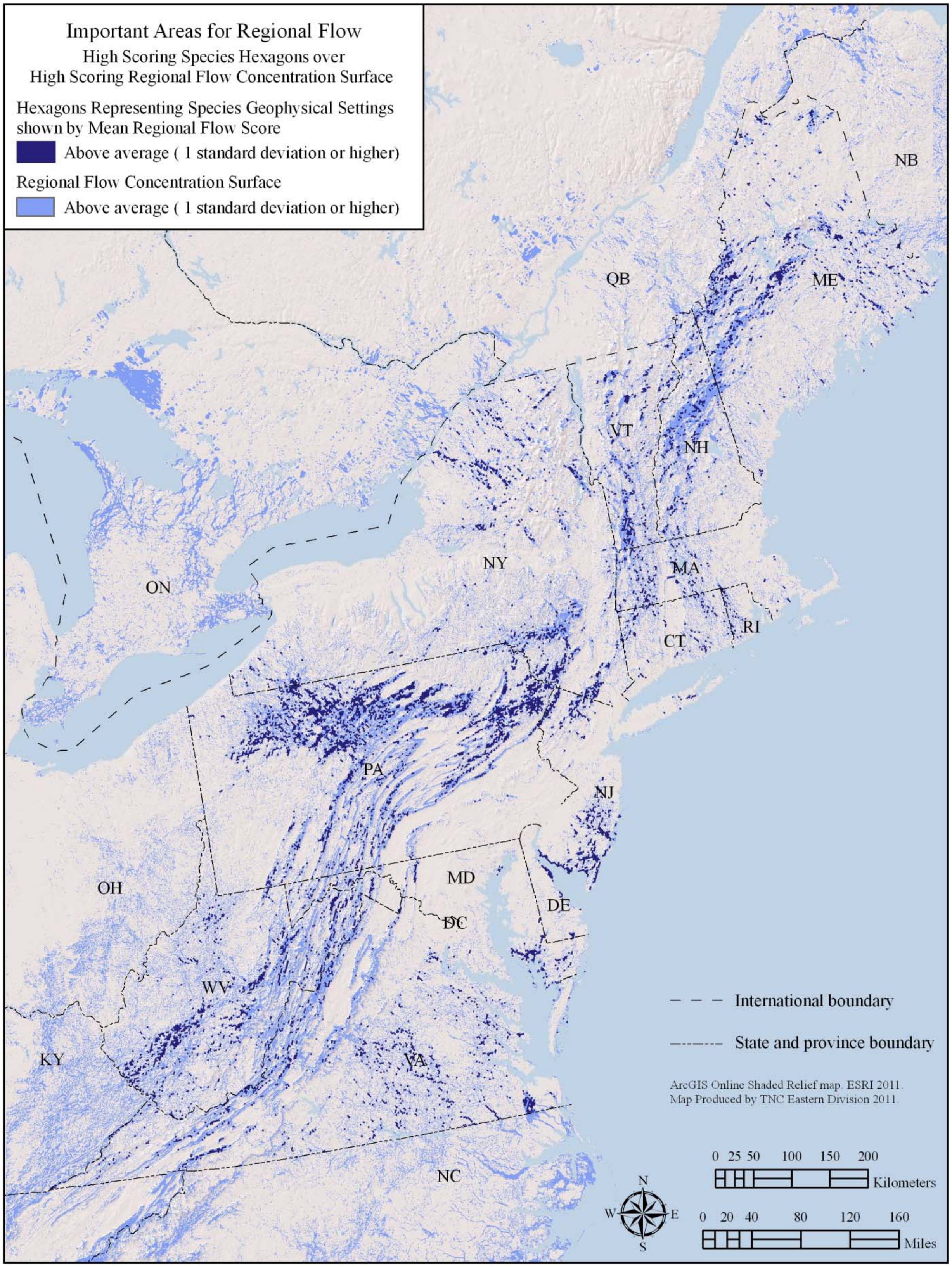
Map 5.20: Unstratified resilience scores for the Region.



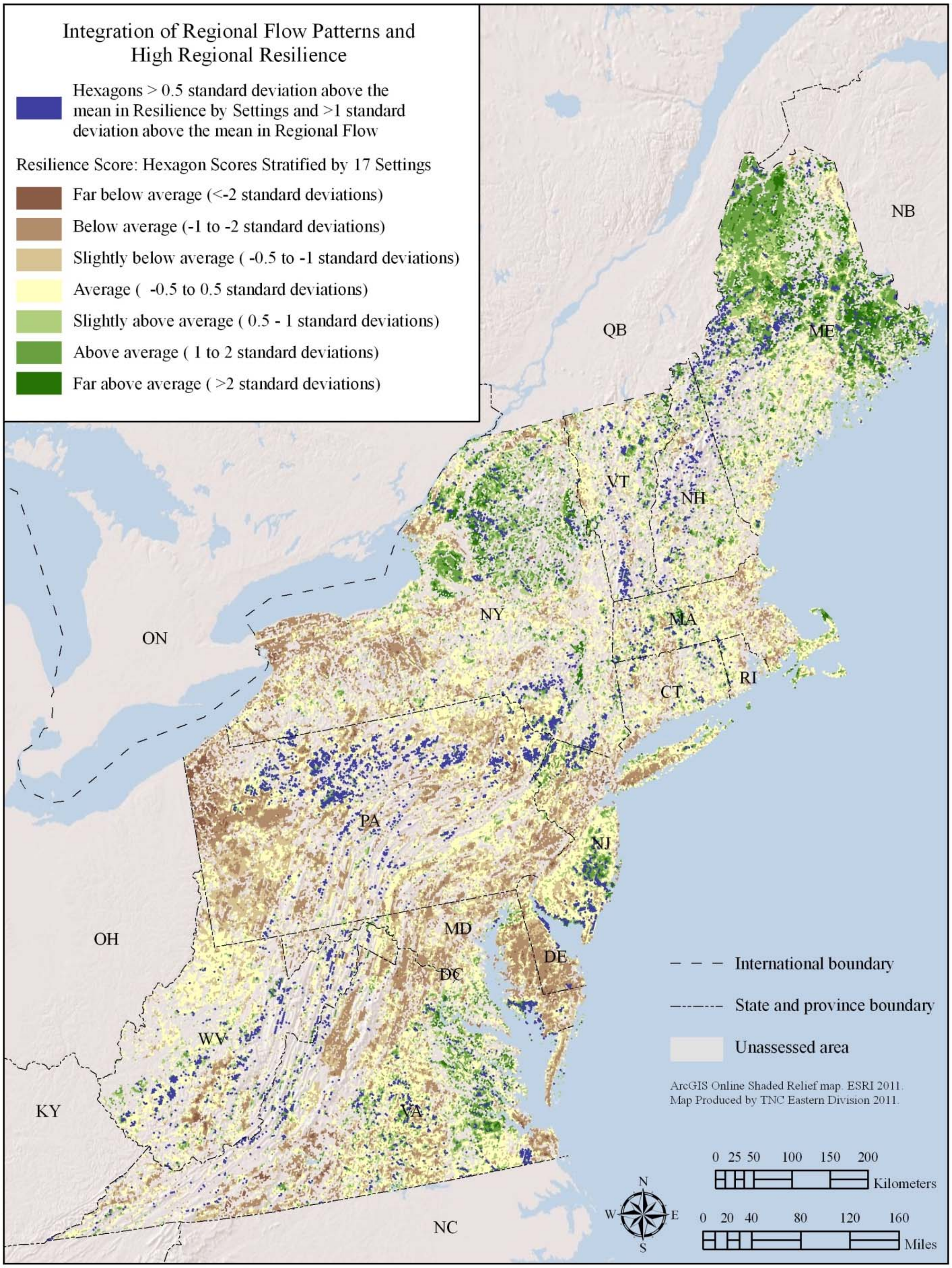
Map 5.21: Largest and most resilient focal areas for SGCN species and settings.



Map 5.22: Key permeability areas based on regional flow concentration patterns.



Map 5.23: Highest scoring sites for resilience and regional flow concentrations.



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Species Summary Tables

How to Read the Tables : Example for First Species in Top Row

Cow Knob Salamander *Plethodon Punctatus*
Locations: 20 **Data Adequacy:** Sufficient (S)

Averages	**Value**	**Relation to Region***
# Landforms	5.4	-0.38 below mean
Elevation range	205 m	1.51 above mean
Wetland Density /100ac 0.0 %	-0.92 below mean	
Connectedness	68%	1.91 above mean
Estimated Resilience score		0.57 above mean

Tables A-E

					Resilience: Average Z-scores					Components: Average Values					Flow Values		Condition Values				
Taxa Group	Common Name	*Standard Name*	Number of Hexagon Locations	Data Adequacy	Ave Resilience (Z)	Landform Variety (Z)	Elevation Range (Z)	Wetland Density (Z)	Connectedness (Z)	Landform Variety (count)	Elevation range (meters)	Wetland C (%)	Wetland M (%)	Connectedness (%)	Flow Concentrations	Flow Conentrations (Z)	Road Density (m per 1000 acres)	Developed (%)	Agriculture (%)	Max connected streams	Mean connected streams
Amphibian	Cow Knob Salamander	*Plethodon punctatus*	20	S	0.57	-0.38	1.51	-0.92	1.19	5.4	205.3	0.0	0.0	68.0	18.5	1.74	6.9	2.4	0.3	224.0	218.7
Amphibian	Black Mountain Salamander	*Desmognathus welteri*	11	A	0.40	0.58	1.05	-0.92	0.48	7.1	128.8	0.0	0.0	46.4	12.7	0.38	11.3	5.1	5.6	737.4	737.4
Amphibian	Green Salamander	*Aneides aeneus*	46	A	0.30	0.44	0.96	-0.83	0.35	6.9	124.6	0.3	0.3	42.4	13.7	0.61	11.5	4.9	3.7	406.6	403.1
Amphibian	Mountain Chorus Frog	*Pseudacris brachyphona*	4	P	0.24	0.47	0.65	-0.67	0.25	6.9	89.9	0.8	0.7	39.5	12.8	0.40	13.4	5.6	2.6	82.0	82.0
Amphibian	Wehrle's Salamander	*Plethodon wehrlei*	6	NU	0.12	0.47	0.90	-0.88	0.00	6.9	112.5	0.1	0.1	31.9	16.1	1.19	11.9	3.7	8.4	189.7	186.8
Amphibian	Jefferson Salamander	*Ambystoma jeffersonianu*	184	A	0.10	0.57	0.41	0.19	-0.23	7.1	72.4	7.2	7.2	24.8	11.7	0.13	20.0	9.5	10.8	133.0	118.4
Amphibian	Eastern Hellbender	*Cryptobranchus alleganie*	49	S	0.07	0.53	0.75	-0.60	-0.17	7.0	108.0	2.4	2.2	26.6	11.4	0.08	23.7	11.1	11.8	853.9	837.6
Amphibian	Upland//Southeastern Chorus	*Pseudacris feriarum*	8	P	0.04	0.27	0.70	-0.81	-0.02	6.6	105.8	0.4	0.4	31.1	13.2	0.49	16.1	6.5	19.8	1246.9	1246.9

Condition: Roads 6.9 /1000 m. Develop 2%, Ag. 0.3 %, Streams 218 mi

Spread of Resilience Scores: 0 below, 20 above = 100% above mean
Amount in large focal areas: 17 out, 3 in = 17% in focal areas

Tables F-H

			Sites: Hexagons by Setting (Map 5.18, 5.19)									Sites: Hexagons Unstratified (Map 5.20)							Largest Focal Areas (Map 5.21)			
Taxa Group	Species	Data Adequacy	Total Hexagons with Species	1-	0-	0+	1+	2+	3+	(blank)	Total Above Ave	% Above Average BY SETTING	Total Hexagons with Species	1-	0-	0+	1+	(blank)	Total above average	% Above Average: UNSTRATIFED	Total Hexagons with Species	OUT	IN	% Within Large Focal Areas
Amphibian	Cow Knob Salamander	S	20			16	4				20	100%	20			20			20	100%	20	17	3	17%
Amphibian	Mountain Chorus Frog	P	4			4					4	100%	4			4			4	100%	4	4	0	0%
Amphibian	Black Mountain Salamander	A	11		1	9	1				10	91%	11		1	10			10	91%	11	9	2	18%
Amphibian	Green Salamander	A	46		6	35	4	1			40	87%	46		6	39	1		40	87%	46	43	3	6%
Amphibian	Jefferson Salamander	A	184		50	102	28	4			134	73%	184		73	111			111	60%	184	155	29	16%
Amphibian	Longtail Salamander	NU	21		7	13		1			14	67%	21		8	13			13	62%	21	19	2	8%
Amphibian	Marbled Salamander	P	147		55	81	11				92	63%	147		78	69			69	47%	147	124	23	16%
Amphibian	Upland//Southeastern Chorus Frog	P	8		3	5					5	63%	8		3	5			5	63%	8	8	0	0%
Amphibian	Eastern Hellbender	S	49		19	27	3				30	61%	49		20	29			29	59%	49	45	4	8%

* Units are Standard Deviations above or below a mean of "0"

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Table A-E. Summary of Species and Resilience information. These tables give the common and standard name for all species used in this analysis as well as the average scores, based on all known locations, for the resilience and conditions factors.

Table A: Amphibians and Reptiles: sorted by the average resilience score of all locations.

					Resilience: Average Z-scores					Components: Average Values					Flow Values		Condition Values				
Taxa Group	Common Name	*Standard Name*	Number of Hexagon Locations	Data Adequacy	Ave Resilience (Z)	Landform Variety (Z)	Elevation Range (Z)	Wetland Density (Z)	Connectedness (Z)	(count)	Elevation range (meters)	Wetland C (%)	Wetland M (%)	Connectedness (%)	Flow Concentrations	Flow Conentrations (Z)	Road Density (m per 1000 acres)	Developed (%)	Agriculture (%)	Max connected streams	Mean connected streams
Amphibian	Cow Knob Salamander	*Plethodon punctatus*	20	S	0.57	-0.38	1.51	-0.92	1.19	5.4	205.3	0.0	0.0	68.0	18.5	1.74	6.9	2.4	0.3	224.0	218.7
Amphibian	Black Mountain Salamander	*Desmognathus welteri*	11	A	0.40	0.58	1.05	-0.92	0.48	7.1	128.8	0.0	0.0	46.4	12.7	0.38	11.3	5.1	5.6	737.4	737.4
Amphibian	Green Salamander	*Aneides aeneus*	46	A	0.30	0.44	0.96	-0.83	0.35	6.9	124.6	0.3	0.3	42.4	13.7	0.61	11.5	4.9	3.7	406.6	403.1
Amphibian	Mountain Chorus Frog	*Pseudacris brachyphona*	4	P	0.24	0.47	0.65	-0.67	0.25	6.9	89.9	0.8	0.7	39.5	12.8	0.40	13.4	5.6	2.6	82.0	82.0
Amphibian	Wehrle's Salamander	*Plethodon wehrlei*	6	NU	0.12	0.47	0.90	-0.88	0.00	6.9	112.5	0.1	0.1	31.9	16.1	1.19	11.9	3.7	8.4	189.7	186.8
Amphibian	Jefferson Salamander	*Ambystoma jeffersonianu*	184	A	0.10	0.57	0.41	0.19	-0.23	7.1	72.4	7.2	7.2	24.8	11.7	0.13	20.0	9.5	10.8	133.0	118.4
Amphibian	Eastern Hellbender	*Cryptobranchus alleganie*	49	S	0.07	0.53	0.75	-0.60	-0.17	7.0	108.0	2.4	2.2	26.6	11.4	0.08	23.7	11.1	11.8	853.9	837.6
Amphibian	Upland//Southeastern Chorus	*Pseudacris feriarum*	8	P	0.04	0.27	0.70	-0.81	-0.02	6.6	105.8	0.4	0.4	31.1	13.2	0.49	16.1	6.5	19.8	1246.9	1246.9
Amphibian	Longtail Salamander	*Eurycea longicauda*	21	NU	0.04	0.49	0.49	0.13	-0.31	7.0	89.4	9.7	8.9	22.1	11.0	-0.01	23.4	8.9	8.4	364.1	355.7
Amphibian	Marbled Salamander	*Ambystoma opacum*	147	P	-0.04	0.36	-0.18	0.76	-0.40	6.7	40.4	12.6	12.6	19.4	11.5	0.10	26.9	16.3	4.8	29.4	23.6
Amphibian	Fowler's Toad	*Bufo fowleri*	16	P	-0.06	0.50	-0.01	0.49	-0.49	7.0	55.4	11.0	11.1	16.6	11.0	-0.03	42.6	28.9	3.6	425.2	383.8
Amphibian	Common Mudpuppy	*Necturus maculosus*	9	P	-0.18	0.51	0.21	-0.30	-0.59	7.0	69.8	4.4	4.8	13.7	9.5	-0.38	21.3	9.0	28.1	844.6	844.6
Amphibian	Blue-spotted Salamander	*Ambystoma laterale*	315	A	-0.20	0.15	-0.45	1.07	-0.62	6.3	30.3	19.5	19.0	12.6	9.5	-0.39	33.3	24.6	10.3	55.3	50.9
Amphibian	Eastern Spadefoot Toad	*Scaphiopus holbrookii*	90	A	-0.23	-0.13	-1.05	1.14	-0.64	5.8	19.1	20.4	21.6	12.1	9.7	-0.33	35.3	19.7	3.5	43.5	41.9
Amphibian	Northern Leopard Frog	*Rana pipiens*	19	P	-0.24	0.11	-0.45	0.97	-0.70	6.2	30.7	18.0	17.2	10.2	9.0	-0.50	34.4	29.2	11.6	60.7	60.0
Amphibian	Eastern/Tiger Salamander	*Ambystoma tigrinum*	77	S	-0.59	-0.41	-1.16	0.16	-0.75	5.3	13.4	8.9	8.9	8.6	10.5	-0.14	34.9	26.7	5.1	40.9	20.7
Amphibian	Carpenter Frog	*Rana virgatipes*	20	A	-0.90	-1.81	-2.28	1.58	-0.71	2.7	3.2	29.4	28.8	9.9	10.2	-0.21	13.5	6.1	4.3	77.2	74.5
Amphibian Total			1042		-0.10	0.19	-0.17	0.52	-0.41	6.4	51.8	12.8	12.7	19.3	10.9	-0.05	27.4	17.4	8.2	156.0	147.8
Reptile	Timber/Canebrake Rattlesnak	*Crotalus horridus*	223	A	0.39	0.74	0.83	-0.15	0.24	7.4	112.9	3.9	4.1	39.2	14.5	0.80	15.6	6.9	3.4	356.1	350.0
Reptile	Smooth Green Snake	*Opheodrys vernalis*	4	NU	0.26	0.53	0.43	0.03	0.15	7.1	68.5	3.8	3.7	36.4	13.8	0.64	10.7	3.1	1.8	32.8	32.8
Reptile	Broadhead Skink	*Plestiodon laticeps*	3	P	0.14	0.68	0.97	-0.55	-0.16	7.3	128.1	1.4	1.1	26.9	12.9	0.42	23.0	13.3	1.9	767.7	767.7
Reptile	Rough Green Snake	*Opheodrys aestivus*	1	NU	0.08	0.45	1.45	-0.92	-0.19	6.9	222.6	0.0	0.0	25.8	14.1	0.72	16.3	0.8	0.3	448.0	448.0
Reptile	Wood Turtle	*Glyptemys insculpta*	1183	S	-0.02	0.32	-0.06	0.70	-0.37	6.6	46.1	12.7	12.3	20.6	11.0	-0.02	27.0	16.5	7.9	195.3	179.9
Reptile	Eastern Hognose Snake	*Heterodon platirhinos*	40	P	-0.07	0.38	0.05	0.49	-0.47	6.7	48.0	9.6	9.4	17.5	10.7	-0.09	27.0	20.8	5.1	107.4	103.5
Reptile	Copperhead	*Agkistrodon contortrix*	15	NU	-0.08	0.77	0.26	0.25	-0.67	7.5	63.6	6.5	6.8	11.1	11.8	0.17	43.3	30.2	2.6	94.9	78.0
Reptile	Redbelly/Red-bellied Cooter/	*Pseudemys rubriventris*	1	NU	-0.11	0.85	0.40	-0.39	-0.65	7.6	62.6	1.9	1.4	11.9	9.7	-0.33	26.4	18.2	7.1	227.0	227.0
Reptile	Blanding's Turtle	*Emydoidea blandingii*	310	S	-0.11	0.14	-0.50	1.09	-0.45	6.3	26.5	18.1	17.4	18.1	10.0	-0.25	27.4	18.3	7.2	32.5	27.7
Reptile	Spotted Turtle	*Clemmys guttata*	834	A	-0.19	0.03	-0.60	1.13	-0.54	6.1	24.9	19.2	18.9	15.2	10.0	-0.26	32.6	23.1	5.6	34.1	30.0
Reptile	Bog Turtle	*Glyptemys muhlenbergii*	364	S	-0.19	0.47	-0.01	0.40	-0.72	6.9	45.8	10.8	10.4	9.9	9.5	-0.37	25.3	11.9	19.4	186.6	163.8
Reptile	Northern Map Turtle	*Graptemys geographica*	13	A	-0.20	0.26	-0.34	0.38	-0.53	6.5	48.6	7.8	7.8	15.4	10.3	-0.19	27.4	15.5	7.3	714.5	549.0
Reptile	Eastern Box Turtle	*Terrapene carolina*	707	NU	-0.27	-0.04	-0.73	0.92	-0.64	6.0	22.8	17.0	17.1	12.2	9.8	-0.31	40.0	27.6	3.2	16.7	14.2
Reptile	Queen Snake	*Regina septemvittata*	3	NU	-0.45	-0.52	-1.16	1.44	-0.72	5.1	11.3	38.7	33.7	9.7	9.5	-0.37	28.3	20.7	9.7	217.7	217.6
Reptile	Corn Snake	*Pantherophis guttatus*	17	P	-0.48	-0.91	-1.49	1.12	-0.42	4.4	11.1	23.7	25.0	18.8	12.1	0.25	24.9	24.1	0.7	259.9	257.8
Reptile Total			3718		-0.11	0.21	-0.29	0.79	-0.46	6.4	39.3	14.7	14.4	17.6	10.5	-0.13	30.0	19.3	7.2	121.6	111.6

Table B: Mammals: sorted by the average resilience score of all locations.

Taxa Group	Common Name	Standard Name	Number of Hexagon Locations	Data Adequacy	Resilience: Average Z-scores: Ave Resilience (Z)	Landform Variety (Z)	Elevation Range (Z)	Wetland Density (Z)	Connectedness (Z)	Components: Average Values: Landform Variety (count)	Elevation range (meters)	Wetland C (%)	Wetland M (%)	Connectedness (%)	Flow Values: Flow Concentrations	Flow Conentrations (Z)	Condition Values: Road Density (m per 1000 acres)	Developed (%)	Agriculture (%)	Max connected streams	Mean connected streams
Mammal	Silver-haired Bat	*Lasionycteris noctivagans*	27	NU	0.30	0.54	0.52	-0.73	0.39	7.0	80.5	0.9	0.8	43.7	14.2	0.73	15.9	6.4	2.1	707.4	703.5
Mammal	Long-tailed or Rock Shrew	*Sorex dispar*	37	A	0.29	0.11	1.00	-0.81	0.48	6.2	131.7	0.3	0.4	46.4	15.1	0.95	10.2	3.7	4.0	479.4	400.2
Mammal	Appalachian Cottontail	*Sylvilagus obscurus*	15	S	0.28	0.12	0.93	-0.86	0.48	6.3	120.3	0.1	0.2	46.6	15.0	0.92	9.7	3.7	4.0	520.7	517.1
Mammal	Allegheny Woodrat	*Neotoma magister*	344	A	0.28	0.18	1.09	-0.78	0.38	6.4	140.9	0.6	0.7	43.4	16.0	1.16	12.8	4.9	3.3	792.0	756.5
Mammal	Fisher	*Martes pennanti*	5	NU	0.24	0.70	0.48	0.23	-0.05	7.4	70.3	6.0	5.7	30.2	13.7	0.61	21.8	7.2	3.6	609.2	606.9
Mammal	Southern Bog Lemming	*Synaptomys cooperi*	35	P	0.21	0.00	0.15	0.19	0.34	6.0	84.2	14.3	13.4	42.1	13.4	0.56	13.2	5.1	1.4	345.5	265.7
Mammal	Eastern Small-footed Bat	*Myotis leibii*	195	S	0.16	0.49	0.76	-0.49	0.01	7.0	107.3	2.5	2.5	32.0	12.7	0.37	17.0	7.3	10.6	625.3	599.7
Mammal	Bobcat	*Lynx rufus*	133	NU	0.15	0.53	0.11	0.84	-0.20	7.0	58.5	15.9	15.6	25.5	13.3	0.53	24.8	11.3	5.0	279.9	247.9
Mammal	Indiana Bat	*Myotis sodalis*	122	S	0.08	0.36	0.50	-0.08	-0.13	6.7	96.5	7.5	7.3	27.8	12.0	0.22	15.6	7.6	15.7	559.1	532.0
Mammal	Smoky Shrew	*Sorex fumeus*	9	NU	-0.02	0.37	0.37	-0.15	-0.29	6.7	65.1	5.3	4.8	23.0	12.3	0.29	17.1	8.8	4.6	148.3	124.1
Mammal	Eastern Red Bat	*Lasiurus borealis*	6	NU	-0.04	0.14	-0.44	0.81	-0.25	6.3	29.9	16.7	15.9	24.0	13.0	0.46	28.5	17.7	1.1	75.8	75.8
Mammal	Least Weasel	*Mustela nivalis*	8	A	-0.15	0.42	0.49	-0.58	-0.49	6.8	76.3	1.6	1.3	16.8	12.5	0.33	20.7	12.0	13.5	1019.5	941.9
Mammal	Hoary Bat	*Lasiurus cinereus*	6	NU	-0.17	0.20	-0.18	0.32	-0.47	6.4	37.5	5.8	7.2	17.2	10.3	-0.19	40.2	26.0	2.4	6.7	6.5
Mammal	New England Cottontail	*Sylvilagus transitionalis*	72	P	-0.19	0.05	-0.46	0.90	-0.53	6.1	33.6	15.9	16.0	15.4	9.9	-0.28	25.8	17.6	10.7	49.5	47.6
Mammal	Least Shrew	*Cryptotis parva*	7	P	-0.34	-0.06	-0.41	0.08	-0.56	5.9	30.9	11.9	10.7	14.5	8.9	-0.51	24.5	10.6	21.2	91.0	89.3
Mammal Total			1021		0.17	0.30	0.63	-0.24	0.08	6.6	103.2	5.6	5.5	34.2	13.8	0.63	16.9	7.7	7.1	562.0	531.0

Table C: Birds (1.0 to -0.10): sorted by the average resilience score of all locations.

Taxa Group	Common Name	Standard Name	Number of Hexagon Locations	Data Adequacy	Resilience: Average Z-scores: Ave Resilience (Z)	Landform Variety (Z)	Elevation Range (Z)	Wetland Density (Z)	Connectedness (Z)	Components: Average Values: Landform Variety (count)	Elevation range (meters)	Wetland C (%)	Wetland M (%)	Connectedness (%)	Flow Values: Flow Concentrations	Flow Conentrations (Z)	Condition Values: Road Density (m per 1000 acres)	Developed (%)	Agriculture (%)	Max connected streams	Mean connected streams
Bird	Spruce Grouse	*Falcipennis canadensis*	32	S	0.83	-0.08	-0.44	1.62	1.41	5.9	38.8	37.8	35.6	74.9	13.5	0.56	6.4	0.6	0.3	82.1	79.9
Bird	Bicknell's Thrush	*Catharus bicknelli*	62	S	0.80	-0.51	1.51	-0.77	1.67	5.1	208.2	0.4	0.6	82.9	15.5	1.05	1.1	0.2	0.0	42.4	40.5
Bird	American Three-toed Woodpe	*Picoides dorsalis*	10	S	0.80	0.29	0.21	0.93	1.17	6.6	67.4	16.4	17.8	67.4	13.2	0.49	5.7	0.6	0.3	117.8	115.9
Bird	Common Loon	*Gavia immer*	365	A	0.76	0.54	-0.02	0.72	1.08	7.0	53.0	12.6	12.9	64.9	11.9	0.20	7.8	2.0	0.9	72.6	67.9
Bird	Rusty Blackbird	*Euphagus carolinus*	27	P	0.73	0.05	-0.04	0.75	1.26	6.1	44.6	11.2	10.7	70.4	12.6	0.35	3.8	0.5	0.4	426.9	426.3
Bird	Golden Eagle	*Aquila chrysaetos*	14	P	0.71	0.24	1.00	-0.25	1.11	6.5	135.3	3.7	4.8	65.8	14.6	0.83	2.8	1.3	1.2	89.4	88.5
Bird	Swainson's Thrush	*Catharus ustulatus*	16	NU	0.60	0.67	0.52	-0.42	0.83	7.3	74.2	2.4	2.1	57.3	16.0	1.17	10.2	1.6	0.7	496.3	456.9
Bird	Yellow Rail	*Coturnicops noveboracen*	8	P	0.58	-0.74	-1.16	1.76	1.28	4.7	16.7	44.3	41.7	66.8	12.7	0.37	2.5	0.7	0.0	184.0	184.0
Bird	Olive-sided Flycatcher	*Contopus cooperi*	1	NU	0.57	1.02	0.54	0.76	0.32	7.9	70.4	9.8	8.8	41.4	13.2	0.50	8.4	2.9	3.8	4.0	3.3
Bird	Bay-breasted Warbler	*Dendroica castanea*	5	P	0.56	-0.17	-0.07	0.80	1.03	5.7	57.6	17.4	16.9	63.4	12.7	0.38	8.3	1.3	0.0	120.4	120.4
Bird	Blackpoll Warbler	*Dendroica striata*	6	P	0.54	-0.27	1.09	-0.52	1.07	5.6	165.9	2.9	2.5	64.5	16.6	1.31	7.8	1.9	0.9	697.5	696.8
Bird	Cape May Warbler	*Dendroica tigrina*	5	P	0.51	0.35	0.59	0.43	0.57	6.7	90.4	10.1	10.0	49.2	12.1	0.24	10.7	5.0	5.0	105.6	105.6
Bird	Northern Goshawk	*Accipiter gentilis*	56	P	0.36	0.47	0.34	0.23	0.33	6.9	71.9	11.0	10.2	41.9	14.6	0.83	14.6	6.0	4.8	426.7	401.9
Bird	Canada Warbler	*Wilsonia canadensis*	15	NU	0.30	0.74	0.17	0.93	-0.04	7.4	58.7	14.4	14.1	30.5	14.0	0.69	17.4	6.4	3.0	151.6	151.0
Bird	Cerulean Warbler	*Dendroica cerulea*	52	P	0.27	0.85	0.31	0.65	-0.13	7.6	66.8	10.8	11.0	27.7	13.4	0.55	17.6	7.0	3.8	463.6	454.5
Bird	Blackburnian Warbler	*Dendroica fusca*	19	P	0.20	0.36	0.04	0.56	0.06	6.7	63.1	12.6	12.4	33.7	13.7	0.62	20.5	9.2	2.3	492.6	365.5
Bird	Black-throated Green Warbler	*Dendroica virens*	27	NU	0.17	0.41	-0.12	0.98	-0.07	6.8	48.2	16.9	17.2	29.5	13.5	0.57	23.5	12.9	2.2	197.8	187.5
Bird	Golden-winged Warbler	*Vermivora chrysoptera*	57	A	0.16	0.64	0.08	0.88	-0.24	7.2	51.0	16.5	16.0	24.3	12.4	0.32	24.3	14.4	4.8	237.3	221.6
Bird	Black-throated Blue Warbler	*Dendroica caerulescens*	15	NU	0.12	0.39	-0.27	1.07	-0.15	6.8	44.5	18.6	17.6	27.1	13.5	0.56	29.9	19.4	3.0	117.2	116.2
Bird	Veery	*Catharus fuscescens*	276	NU	0.10	0.56	0.16	0.75	-0.31	7.1	56.3	13.6	13.3	22.4	12.4	0.30	26.6	12.0	4.5	259.3	224.5
Bird	Red-shouldered Hawk	*Buteo lineatus*	145	NU	0.05	0.18	-0.33	1.12	-0.18	6.4	39.2	21.8	21.1	26.1	12.8	0.40	30.2	17.5	2.0	154.8	138.6
Bird	Whip-poor-will	*Caprimulgus vociferus*	48	NU	0.02	0.23	-0.07	0.45	-0.18	6.5	51.1	10.9	11.1	26.1	12.1	0.24	19.2	8.3	5.6	58.7	51.8
Bird	American Bittern	*Botaurus lentiginosus*	174	A	0.02	0.21	-0.28	1.05	-0.29	6.4	40.5	19.9	18.7	23.0	11.2	0.02	23.2	13.2	7.7	105.8	77.2
Bird	Atlantic Puffin	*Fratercula arctica*	4	P	0.00	-1.48	-3.14	-0.92	0.00	3.4	0.7	0.0	0.0	0.0	9.0	-0.49	0.0	0.0	0.0	0.0	0.0
Bird	Brown Pelican	*Pelecanus occidentalis*	1	P	0.00	-2.32	-2.86	2.31	-0.08	1.8	1.0	72.8	61.5	0.0	11.5	0.10	0.0	0.0	0.0	0.0	0.0
Bird	Great Cormorant	*Phalacrocorax carbo*	9	NU	0.00	-1.48	-2.26	0.93	0.00	3.3	7.3	12.6	11.8	0.0	9.1	-0.48	0.0	0.0	0.0	0.0	0.0
Bird	Razorbill	*Alca torda*	6	P	0.00	-1.65	-3.12	-0.61	0.00	3.0	1.0	0.0	3.1	0.0	9.0	-0.50	0.0	0.0	0.0	0.0	0.0
Bird	Great Blue Heron	*Ardea herodias*	428	A	-0.01	0.26	-0.01	0.35	-0.23	6.5	53.6	11.0	10.3	24.6	11.6	0.12	22.1	11.0	8.5	397.3	381.9
Bird	Hooded Warbler	*Wilsonia citrina*	46	NU	-0.02	-0.12	-0.59	1.09	-0.14	5.8	41.2	23.9	23.9	27.4	13.5	0.58	20.9	9.9	1.9	193.8	173.9
Bird	Harlequin Duck	*Histrionicus histrionicus*	28	P	-0.02	-0.67	-2.21	0.54	-0.15	4.8	7.6	9.2	10.6	17.4	8.7	-0.58	12.7	4.2	1.1	0.8	0.8
Bird	Black Tern	*Chlidonias niger*	47	S	-0.02	-0.53	-1.43	1.40	0.29	5.1	12.2	33.2	30.9	40.6	10.4	-0.17	10.0	3.2	8.0	150.2	140.4
Bird	Acadian Flycatcher	*Empidonax virescens*	13	P	-0.04	-0.22	-0.66	1.18	-0.10	5.6	33.3	23.6	24.3	28.8	14.1	0.70	18.7	9.9	2.4	21.4	20.1
Bird	Peregrine Falcon	*Falco peregrinus*	284	S	-0.06	-0.17	-0.36	0.02	-0.12	5.7	71.2	9.9	10.0	27.4	10.8	-0.06	55.8	31.3	1.5	267.8	258.9
Bird	Sharp-Shinned Hawk	*Accipiter striatus*	45	P	-0.09	0.12	-0.22	0.63	-0.34	6.3	45.8	15.5	15.1	21.5	11.3	0.06	28.2	19.4	5.3	94.7	93.1
Bird	Pied-billed Grebe	*Podilymbus podiceps*	217	A	-0.09	0.01	-0.61	1.00	-0.29	6.1	32.0	21.4	20.0	22.9	10.5	-0.14	22.1	11.3	9.9	211.7	201.2
Bird	Bald Eagle	*Haliaeetus leucocephalus*	2270	S	-0.10	-0.42	-1.06	0.90	-0.02	5.3	27.2	21.9	21.4	30.7	11.1	0.00	15.4	7.8	4.8	512.1	491.5
Bird	Black-and-White Warbler	*Mniotilta varia*	13	NU	-0.10	-0.60	-1.22	1.52	0.02	4.9	20.3	34.2	33.6	32.3	15.0	0.92	16.0	7.9	0.2	51.0	27.5

Table C: Birds (-0.1 to -0.5): sorted by the average resilience score of all locations.

					Resilience: Average Z-scores					Components: Average Values					Flow Values		Condition Values				
Taxa Group	Common Name	Standard Name	Number of Hexagon Locations	Data Adequacy	Ave Resilience (Z)	Landform Variety (Z)	Elevation Range (Z)	Wetland Density (Z)	Connectedness (Z)	Landform Variety (count)	Elevation range (meters)	Wetland C (%)	Wetland M (%)	Connectedness (%)	Flow Concentrations	Flow Concentrations (Z)	Road Density (m per 1000 acres)	Developed (%)	Agriculture (%)	Max connected streams	Mean connected streams
Bird	Gull-billed Tern	*Gelochelidon nilotica*	28	S	-0.12	-2.16	-2.89	2.17	0.14	2.1	0.9	74.6	72.7	26.2	11.2	0.03	21.3	7.8	0.0	0.2	0.2
Bird	Least Bittern	*Ixobrychus exilis*	242	S	-0.12	-0.09	-0.85	1.28	-0.31	5.9	26.5	28.0	25.6	22.0	10.2	-0.21	26.0	15.3	7.6	177.5	169.1
Bird	Black-billed Cuckoo	*Coccyzus erythropthalmu*	47	NU	-0.13	-0.33	-0.82	1.14	-0.18	5.4	30.1	22.4	22.9	26.3	12.9	0.43	20.8	9.4	5.4	153.1	140.5
Bird	Arctic Tern	*Sterna paradisaea*	35	S	-0.13	-1.12	-2.45	0.87	-0.21	4.0	4.3	18.3	19.1	16.6	9.4	-0.40	6.0	1.9	0.1	1.3	1.3
Bird	Kentucky Warbler	*Oporornis formosus*	27	P	-0.14	0.08	-0.30	0.70	-0.42	6.2	47.1	15.6	15.7	18.8	11.8	0.16	23.5	14.0	6.7	90.4	62.2
Bird	Broad-winged Hawk	*Buteo platypterus*	29	NU	-0.15	-0.10	-0.41	0.72	-0.32	5.9	38.7	18.4	18.1	21.9	11.7	0.14	24.5	13.7	4.2	73.6	72.3
Bird	Osprey	*Pandion haliaetus*	238	P	-0.15	-0.30	-0.97	0.95	-0.23	5.5	27.7	25.0	24.2	24.6	10.7	-0.09	26.2	13.5	6.9	267.9	255.4
Bird	Saltmarsh Sharp-tailed Sparro	*Ammodramus caudacutu*	43	P	-0.15	-0.39	-1.28	1.69	-0.34	5.3	13.5	37.6	35.2	20.6	9.9	-0.28	28.6	21.4	2.4	30.4	29.1
Bird	Roseate Tern	*Sterna dougallii*	110	S	-0.15	-1.10	-2.41	1.15	-0.32	4.0	4.6	22.0	21.9	19.3	9.5	-0.38	18.7	5.9	0.1	1.1	1.1
Bird	Willet	*Tringa semipalmata*	13	NU	-0.16	-0.54	-1.47	1.68	-0.35	5.0	11.1	39.9	37.2	21.1	9.9	-0.29	30.5	23.8	1.1	79.0	78.6
Bird	Piping Plover	*Charadrius melodus*	404	S	-0.17	-0.79	-2.17	1.25	-0.44	4.6	6.1	23.8	25.0	17.9	9.5	-0.37	27.6	11.4	0.8	3.4	3.2
Bird	Common Tern	*Sterna hirundo*	358	A	-0.18	-1.16	-2.26	1.36	-0.12	3.9	5.1	36.9	35.5	28.0	10.4	-0.17	25.7	11.0	0.7	33.2	32.2
Bird	Wood Thrush	*Hylocichla mustelina*	1010	NU	-0.19	-0.02	-0.44	0.97	-0.50	6.0	38.5	18.7	18.7	16.3	11.5	0.11	28.7	15.7	6.6	188.6	166.8
Bird	Common Moorhen	*Gallinula chloropus*	65	A	-0.19	-0.10	-0.64	1.12	-0.49	5.9	30.5	24.3	23.0	16.2	9.3	-0.42	24.9	16.8	10.2	197.8	191.3
Bird	Northern Parula	*Parula americana*	46	P	-0.19	-0.20	-0.76	1.08	-0.38	5.7	28.4	20.8	20.3	20.1	11.5	0.09	28.7	18.4	3.8	116.9	112.4
Bird	Sedge Wren	*Cistothorus platensis*	101	S	-0.19	-0.35	-0.82	1.05	-0.27	5.4	25.3	25.4	23.9	23.3	10.7	-0.10	17.5	9.5	15.4	141.8	133.5
Bird	Sora Rail	*Porzana carolina*	65	S	-0.20	0.16	-0.33	0.73	-0.59	6.4	38.4	17.4	16.4	13.7	10.0	-0.25	30.3	19.2	13.3	378.9	305.3
Bird	Red Knot	*Calidris canutus*	57	P	-0.22	-1.59	-2.60	2.03	0.44	3.1	2.2	66.7	67.7	45.3	11.9	0.19	26.3	13.1	0.1	44.3	43.8
Bird	Cattle Egret	*Bubulcus ibis*	34	A	-0.22	-1.45	-2.41	1.36	0.26	3.4	3.2	47.1	44.8	39.6	11.0	-0.03	24.3	13.6	1.1	3.7	3.3
Bird	Black Skimmer	*Rynchops niger*	86	A	-0.23	-1.74	-2.71	1.77	-0.10	2.8	1.8	53.4	52.3	25.7	10.5	-0.13	20.5	8.5	0.0	1.1	1.0
Bird	Least Tern	*Sternula antillarum*	376	S	-0.23	-0.87	-2.15	1.21	-0.47	4.4	5.9	23.5	24.1	17.2	9.4	-0.40	29.4	14.8	1.2	11.5	11.1
Bird	Forster's Tern	*Sterna forsteri*	30	P	-0.25	-1.77	-2.61	2.29	-0.01	2.8	1.7	80.5	75.2	31.4	13.4	0.54	25.3	7.6	0.0	0.9	0.6
Bird	Yellow-breasted Chat	*Icteria virens*	25	NU	-0.25	-0.06	-0.64	1.21	-0.62	5.9	32.3	23.5	23.5	12.9	11.1	-0.01	22.6	13.4	7.7	163.6	157.3
Bird	Northern Harrier	*Circus cyaneus*	301	S	-0.26	-0.52	-1.29	0.99	-0.34	5.1	17.6	24.4	23.6	21.1	10.4	-0.15	23.8	11.9	10.4	144.3	139.8
Bird	Prothonotary Warbler	*Protonotaria citrea*	18	P	-0.26	-0.30	-0.83	0.70	-0.31	5.5	35.4	20.8	20.4	22.3	10.9	-0.06	25.2	13.2	5.5	299.3	242.0
Bird	Cooper's Hawk	*Accipiter cooperii*	237	P	-0.26	-0.20	-0.62	0.95	-0.52	5.7	32.6	19.0	19.1	15.9	11.2	0.04	33.9	21.4	6.2	185.4	169.0
Bird	Long-eared Owl	*Asio otus*	42	A	-0.27	-0.11	-0.54	0.76	-0.59	5.8	33.3	19.9	19.0	13.6	10.8	-0.07	29.7	18.9	11.3	215.0	210.1
Bird	Glossy Ibis	*Plegadis falcinellus*	74	A	-0.28	-1.57	-2.46	2.00	-0.07	3.2	2.6	65.9	60.7	28.4	11.2	0.04	31.1	13.5	0.5	1.8	1.7
Bird	Tricolored Heron	*Egretta tricolor*	41	P	-0.28	-1.77	-2.58	2.20	-0.01	2.8	1.7	75.3	70.9	29.6	12.0	0.22	27.0	9.0	0.0	0.3	0.1
Bird	Snowy Egret	*Egretta thula*	87	A	-0.29	-1.50	-2.45	1.93	-0.07	3.3	3.1	62.5	57.8	28.3	11.2	0.03	30.6	13.8	0.1	1.7	1.6
Bird	King Rail	*Rallus elegans*	58	A	-0.29	-0.40	-1.09	1.43	-0.57	5.3	19.6	34.4	32.9	14.2	10.1	-0.24	28.1	18.2	9.9	127.1	107.4
Bird	Seaside Sparrow	*Ammodramus maritimus*	25	P	-0.30	-1.24	-2.08	1.83	-0.22	3.8	5.6	49.1	47.3	25.0	10.2	-0.22	33.0	25.4	0.6	18.4	18.3
Bird	Dickcissel	*Spiza americana*	16	P	-0.30	0.48	0.03	-0.41	-0.75	6.9	45.8	2.0	2.0	8.7	8.5	-0.61	23.4	10.4	26.6	280.6	280.6
Bird	Marsh Wren	*Cistothorus palustris*	32	P	-0.32	-0.12	-0.69	0.73	-0.61	5.8	33.2	16.5	16.0	13.1	9.2	-0.44	32.1	21.3	10.9	839.2	835.6
Bird	Royal Tern	*Thalasseus maximus*	3	P	-0.32	-2.13	-2.76	1.38	-0.52	2.1	1.3	31.1	29.8	1.3	9.3	-0.43	16.7	14.7	0.0	0.0	0.0
Bird	Henslow's Sparrow	*Ammodramus henslowii*	52	S	-0.32	-0.09	-0.57	0.41	-0.56	5.9	32.3	11.2	11.4	14.5	9.8	-0.31	19.2	10.2	21.4	94.6	67.7
Bird	Little Blue Heron	*Egretta caerulea*	66	A	-0.33	-1.55	-2.46	1.94	-0.19	3.2	2.7	62.7	58.1	24.8	11.3	0.06	33.8	14.3	0.5	1.7	1.6
Bird	Black Rail	*Laterallus jamaicensis*	26	A	-0.33	-1.71	-2.40	2.14	0.22	2.9	4.6	65.8	64.8	38.5	13.3	0.53	18.1	12.1	1.1	101.5	96.8
Bird	Red-headed Woodpecker	*Melanerpes erythrocepha*	142	P	-0.35	-0.39	-0.92	1.03	-0.54	5.3	23.1	19.9	20.3	15.3	11.0	-0.03	31.2	20.5	7.1	207.8	183.0
Bird	Brown Thrasher	*Toxostoma rufum*	228	NU	-0.36	-0.59	-1.12	1.22	-0.44	4.9	19.3	26.1	26.1	18.2	11.3	0.06	28.7	17.4	5.1	91.6	83.8
Bird	Chuck-will's-widow	*Caprimulgus carolinensis*	4	P	-0.37	-0.73	-1.58	1.35	-0.47	4.7	8.6	23.7	25.1	17.4	11.0	-0.03	24.0	16.2	0.6	8.3	8.3
Bird	Black-crowned Night-heron	*Nycticorax nycticorax*	103	A	-0.37	-1.00	-1.92	1.40	-0.27	4.2	10.0	46.6	42.7	22.6	10.5	-0.15	39.9	21.3	3.4	121.6	115.8
Bird	Great Egret	*Ardea alba*	89	A	-0.37	-1.38	-2.36	1.62	-0.26	3.5	3.9	50.4	47.3	23.0	10.6	-0.10	35.8	19.5	0.2	94.9	93.8
Bird	Bobolink	*Dolichonyx oryzivorus*	92	P	-0.37	-0.14	-0.55	0.68	-0.71	5.8	31.6	14.2	14.4	10.1	10.1	-0.24	29.7	19.3	15.4	212.2	202.2
Bird	Common Nighthawk	*Chordeiles minor*	12	P	-0.38	-0.30	-0.72	0.49	-0.55	5.5	30.9	12.8	12.5	15.0	10.0	-0.26	61.7	40.8	0.0	35.9	32.8
Bird	Upland Sandpiper	*Bartramia longicauda*	271	S	-0.38	-0.16	-0.69	0.53	-0.65	5.8	23.2	11.2	11.4	11.8	8.5	-0.60	19.6	16.6	21.8	195.0	185.0
Bird	American Oystercatcher	*Haematopus palliatus*	49	P	-0.38	-1.19	-2.17	1.48	-0.38	3.8	5.4	36.6	34.4	20.1	10.0	-0.27	32.8	17.0	0.6	18.1	17.3
Bird	Grasshopper Sparrow	*Ammodramus savannaru*	183	A	-0.39	-0.19	-0.78	0.68	-0.68	5.7	24.7	13.6	13.7	11.1	9.3	-0.42	29.5	24.9	10.9	141.3	121.9
Bird	Blue-winged Warbler	*Vermivora pinus*	2	NU	-0.40	0.65	-0.06	-0.54	-0.96	7.3	36.3	1.0	1.4	2.3	8.2	-0.69	48.1	41.9	19.2	540.5	540.5
Bird	Barn Owl	*Tyto alba*	145	A	-0.40	0.06	-0.52	-0.06	-0.75	6.2	33.9	8.6	8.3	8.7	8.8	-0.53	31.2	17.1	22.2	608.0	597.1
Bird	Gray-Cheeked Thrush	*Catharus minimus*	1	P	-0.40	-0.85	-1.43	1.93	-0.50	4.5	8.5	55.1	51.8	16.4	11.5	0.11	12.2	6.8	0.0	27.0	13.8
Bird	Great Black-backed Gull	*Larus marinus*	1	NU	-0.40	-1.67	-2.51	-0.58	0.77	3.0	3.7	0.4	2.0	55.3	8.2	-0.67	5.0	1.9	3.8	0.0	0.0
Bird	Northen Bobwhite	*Colinus virginianus*	4	NU	-0.41	0.26	0.00	-0.58	-0.80	6.5	40.7	1.2	1.4	7.4	8.7	-0.57	29.7	15.6	18.6	202.3	151.2
Bird	Field Sparrow	*Spizella pusilla*	6	NU	-0.41	-0.83	-1.17	1.14	-0.40	4.5	15.2	17.3	18.9	19.6	11.3	0.05	19.0	10.0	4.7	41.3	34.6
Bird	Eastern Meadowlark	*Sturnella magna*	73	NU	-0.41	-0.13	-0.60	0.71	-0.79	5.8	28.1	12.4	12.6	7.5	9.4	-0.39	28.2	21.2	13.9	145.0	117.0
Bird	Short-eared Owl	*Asio flammeus*	103	S	-0.44	-0.55	-1.29	0.71	-0.60	5.0	15.2	16.9	16.7	13.0	8.9	-0.52	21.7	11.0	18.8	111.0	108.6
Bird	Vesper Sparrow	*Pooecetes gramineus*	113	P	-0.45	-0.20	-0.79	0.67	-0.81	5.7	23.4	12.8	13.6	7.1	9.1	-0.46	27.5	19.5	10.0	186.8	176.5
Bird	Loggerhead Shrike	*Lanius ludovicianus*	23	S	-0.46	-0.11	-0.48	-0.15	-0.72	5.8	32.7	5.6	5.6	9.7	9.1	-0.46	18.6	8.9	38.0	562.4	561.9
Bird	Horned Lark	*Eremophila alpestris*	10	NU	-0.49	-0.50	-1.14	0.85	-0.77	5.1	19.8	19.0	18.9	8.1	9.1	-0.47	33.7	36.5	8.0	43.2	20.9
Bird	Yellow-crowned Night-heron	*Nyctanassa violacea*	88	A	-0.53	-0.87	-1.76	1.07	-0.59	4.4	9.7	35.0	33.6	13.2	9.8	-0.29	61.8	40.5	1.9	114.3	112.8
Bird Total			11135		-0.12	-0.31	-0.93	0.93	-0.22	5.5	30.6	22.2	21.7	24.8	10.9	-0.04	24.1	13.1	6.1	238.2	224.5

Table D: Fish: sorted by the average resilience score of all locations.

					Resilience: Average Z-scores					Components: Average Values					Flow Values		Condition Values				
Taxa Group	**Common Name**	*Standard Name*	**Number of Hexagon Locations**	**Data Adequacy**	Ave Resilience (Z)	Landform Variety (Z)	Elevation Range (Z)	Wetland Density (Z)	Connectedness (Z)	Landform Variety (count)	Elevation range (meters)	Wetland C (%)	Wetland M (%)	Connectedness (%)	Flow Concentrations	Flow Conentrations (Z)	Road Density (m per 1000 acres)	Developed (%)	Agriculture (%)	Max connected streams	Mean connected streams
Fish	Round Whitefish	*Prosopium cylindraceum*	15	A	0.81	0.47	0.22	0.57	1.20	6.9	78.6	10.4	10.6	68.5	11.6	0.13	8.3	2.6	1.0	95.1	95.0
Fish	Appalachia Darter	*Percina gymnocephala*	3	A	0.65	0.25	0.99	-0.67	1.10	6.5	115.6	0.7	0.7	65.4	15.7	1.08	8.0	1.7	1.6	912.0	912.0
Fish	Cheat Minnow	*Pararhinichthys bowersi*	7	A	0.33	0.50	1.01	-0.50	0.28	7.0	121.9	2.2	1.7	40.3	13.4	0.54	12.3	7.0	5.2	619.0	619.0
Fish	Mountain Redbelly Dace	*Phoxinus oreas*	22	A	0.33	0.11	1.14	-0.72	0.49	6.3	140.6	0.6	0.6	46.9	14.0	0.69	11.2	4.5	2.8	854.5	853.0
Fish	New River Shiner	*Notropis scabriceps*	4	A	0.31	0.33	1.19	-0.63	0.31	6.7	144.2	1.2	1.1	41.2	14.1	0.70	16.7	7.1	3.6	970.3	970.3
Fish	Candy Darter	*Etheostoma osburni*	15	A	0.26	0.21	1.12	-0.65	0.30	6.4	138.1	0.9	0.8	41.0	13.7	0.62	17.6	7.6	4.4	993.1	993.1
Fish	Spotted Darter	*Etheostoma maculatum*	3	A	0.23	0.08	0.62	-0.17	0.32	6.2	116.2	8.1	8.1	41.5	13.2	0.51	7.1	2.9	5.9	511.7	511.7
Fish	Tonguetied Minnow	*Exoglossum laurae*	10	A	0.22	0.38	0.81	-0.40	0.15	6.8	106.7	3.3	2.8	36.3	13.6	0.58	17.2	5.2	2.5	596.9	596.2
Fish	Bigmouth Chub	*Nocomis platyrhynchus*	23	A	0.22	0.37	1.20	-0.79	0.15	6.7	150.9	0.4	0.4	36.3	12.6	0.36	19.1	8.3	4.7	895.7	865.6
Fish	Torrent Sucker	*Thoburnia rhothoeca*	2	A	0.21	0.08	1.48	-0.83	0.22	6.2	207.6	0.3	0.2	38.6	14.2	0.74	8.4	6.2	10.5	2966.0	2966.0
Fish	Least Brook Lamprey	*Lampetra aepyptera*	2	NU	0.16	0.18	1.17	-0.92	0.17	6.4	136.2	0.0	0.0	36.8	14.6	0.83	13.9	5.5	3.6	1228.0	1228.0
Fish	Swamp Darter	*Etheostoma fusiforme*	8	NU	0.15	0.12	-0.57	1.26	0.06	6.3	25.4	21.1	19.7	33.6	13.9	0.68	12.8	6.5	1.5	24.3	22.1
Fish	Potomac Sculpin	*Cottus girardi*	2	P	0.08	0.33	1.08	-0.91	-0.05	6.6	136.4	0.0	0.0	30.2	12.5	0.33	16.9	9.1	6.1	1514.0	1514.0
Fish	River Redhorse	*Moxostoma carinatum*	15	P	0.05	0.95	0.78	-0.71	-0.39	7.8	98.6	0.7	1.0	19.8	9.7	-0.34	20.3	7.4	26.1	2017.4	1992.0
Fish	Bluebreast Darter	*Etheostoma camurum*	23	A	0.05	0.76	0.89	-0.70	-0.33	7.4	115.7	1.8	1.6	21.6	10.3	-0.18	21.9	9.1	16.2	1259.6	1259.6
Fish	Kanawha Minnow	*Phenacobius teretulus*	6	A	0.04	0.71	0.59	-0.65	-0.26	7.4	84.2	0.8	0.7	23.9	10.9	-0.04	18.7	7.4	23.5	736.2	628.7
Fish	Longnose Sucker	*Catostomus catostomus*	88	P	0.02	0.30	0.63	-0.22	-0.22	6.6	93.0	4.0	4.0	25.1	11.6	0.12	21.7	12.1	12.5	76.9	71.1
Fish	Blue Ridge Sculpin	*Cottus caeruleomentum*	1	NU	0.01	0.86	0.73	-0.92	-0.37	7.6	88.8	0.0	0.0	20.3	10.6	-0.11	12.8	5.3	30.9	2966.0	2966.0
Fish	Sauger	*Sander canadensis*	6	NU	0.00	0.88	0.67	-0.90	-0.39	7.7	86.8	0.1	0.0	19.8	9.2	-0.46	21.7	10.1	19.4	2625.0	2625.0
Fish	American Eel	*Anguilla rostrata*	2	NU	-0.02	1.05	0.60	-0.61	-0.55	8.0	78.8	0.7	0.8	14.8	11.0	-0.02	20.4	12.9	15.9	993.5	888.8
Fish	Bridle Shiner	*Notropis bifrenatus*	102	NU	-0.03	0.34	-0.22	0.81	-0.38	6.7	40.0	14.2	13.8	20.1	10.4	-0.17	26.0	15.2	8.6	42.8	38.4
Fish	Blackchin Shiner	*Notropis heterodon*	24	A	-0.04	0.17	-0.70	0.86	-0.10	6.4	32.9	15.5	16.1	28.8	9.5	-0.38	17.0	7.6	15.5	251.0	239.3
Fish	Stonecat	*Noturus flavus*	14	P	-0.07	0.77	0.70	-0.49	-0.58	7.5	93.1	1.7	1.7	14.0	9.9	-0.28	19.4	8.2	27.0	1234.9	1234.9
Fish	Banded Sunfish	*Enneacanthus obesus*	27	NU	-0.09	0.12	-0.37	1.09	-0.42	6.3	29.6	17.0	16.8	18.8	11.2	0.02	24.9	14.9	8.1	33.6	13.9
Fish	Longhead Darter	*Percina macrocephala*	8	A	-0.11	0.48	0.57	-0.84	-0.39	6.9	100.5	0.2	0.4	19.7	9.8	-0.31	42.6	23.5	2.4	784.1	741.1
Fish	Blueback Herring	*Alosa aestivalis*	2	NU	-0.11	0.21	-0.17	0.96	-0.52	6.4	39.6	13.2	12.0	15.9	10.2	-0.20	30.6	32.7	3.0	321.0	188.3
Fish	Ohio Lamprey	*Ichthyomyzon bdellium*	21	A	-0.12	0.48	0.52	-0.46	-0.50	6.9	91.5	3.6	3.4	16.5	10.6	-0.12	26.7	10.8	13.9	1128.0	1127.9
Fish	Channel Darter	*Percina copelandi*	23	A	-0.13	0.61	0.18	-0.42	-0.44	7.2	72.7	3.3	3.4	18.1	9.7	-0.33	40.5	20.3	9.2	1104.1	1104.1
Fish	Eastern Silvery Minnow	*Hybognathus regius*	38	NU	-0.13	0.29	-0.27	0.49	-0.47	6.6	41.8	10.0	10.1	17.5	9.1	-0.48	16.7	9.5	21.1	441.4	422.4
Fish	Northern Brook Lamprey	*Ichthyomyzon fossor*	11	S	-0.13	-0.24	-0.90	1.21	-0.25	5.4	22.0	23.6	22.5	24.2	10.7	-0.10	17.0	8.7	8.9	191.3	190.1
Fish	Burbot	*Lota lota*	8	P	-0.14	0.27	-0.15	0.83	-0.58	6.5	51.1	16.4	16.0	14.1	10.5	-0.13	24.4	14.9	7.6	161.4	150.6
Fish	Variegate Darter	*Etheostoma variatum*	7	P	-0.14	0.22	0.12	0.09	-0.43	6.4	66.6	9.9	9.7	18.4	10.6	-0.11	23.3	9.0	5.8	616.1	536.0
Fish	Atlantic Sturgeon	*Acipenser oxyrinchus*	8	P	-0.16	0.35	-0.46	0.51	-0.68	6.7	45.9	11.8	11.5	11.0	9.8	-0.31	47.1	36.9	3.3	150.0	137.8
Fish	Silver Lamprey	*Ichthyomyzon unicuspis*	17	A	-0.18	0.41	-0.23	0.22	-0.56	6.8	41.6	10.1	9.4	14.7	8.3	-0.65	31.3	20.3	17.4	702.7	655.7
Fish	American Brook Lamprey	*Lampetra appendix*	29	P	-0.19	0.28	-0.27	0.56	-0.60	6.6	34.4	9.5	9.5	13.5	9.5	-0.38	33.3	24.2	9.7	142.5	141.7
Fish	Stripeback Darter	*Percina notogramma*	3	P	-0.20	0.75	-0.38	0.76	-0.88	7.4	26.1	11.4	10.6	4.9	9.0	-0.50	47.5	43.1	4.1	645.0	645.0
Fish	Shortnose Sturgeon	*Acipenser brevirostrum*	21	A	-0.21	0.33	-0.35	0.22	-0.70	6.7	41.9	7.5	6.6	10.3	9.0	-0.49	48.8	35.1	4.1	210.6	201.3
Fish	Mooneye	*Hiodon tergisus*	20	A	-0.23	0.76	0.09	-0.41	-0.71	7.5	61.1	3.3	3.1	9.9	8.9	-0.52	49.5	27.9	8.7	502.0	492.8
Fish	Eastern Sand Darter	*Ammocrypta pellucida*	20	S	-0.25	-0.04	-0.57	0.81	-0.53	6.0	34.3	17.3	16.5	15.6	11.0	-0.03	23.1	13.9	20.2	358.9	323.2
Fish	Slimy Sculpin	*Cottus cognatus*	1	NU	-0.27	0.77	-0.12	-0.65	-0.72	7.5	33.3	0.8	0.8	9.6	7.5	-0.84	30.3	9.8	22.6	312.0	312.0
Fish	Trout-perch	*Percopsis omiscomaycus*	2	A	-0.28	0.25	-0.17	0.49	-0.77	6.5	34.3	8.2	8.5	8.2	8.1	-0.70	19.8	16.1	22.8	102.0	65.0
Fish	Pearl Dace	*Margariscus margarita*	2	NU	-0.28	0.68	-0.11	-0.52	-0.75	7.3	33.9	1.2	1.1	8.7	8.1	-0.71	29.4	6.2	30.7	312.0	312.0
Fish	Tessellated Darter	*Etheostoma olmstedi*	5	NU	-0.29	0.66	0.01	-0.74	-0.73	7.3	45.6	0.5	0.5	9.3	9.5	-0.39	22.4	6.9	35.2	1373.6	1373.6
Fish	Comely Shiner	*Notropis amoenus*	2	NU	-0.32	0.69	-0.11	-0.38	-0.86	7.3	34.0	1.7	1.8	5.4	8.1	-0.71	30.1	25.0	30.3	312.0	312.0
Fish	Checkered Sculpin	*Cottus sp. 7*	2	A	-0.33	0.64	-0.19	0.19	-0.97	7.2	32.2	4.6	3.4	1.9	7.2	-0.93	31.9	17.9	45.3	177.5	177.5
Fish	Swallowtail Shiner	*Notropis procne*	3	NU	-0.39	0.51	-0.25	-0.30	-0.89	7.0	29.4	2.8	2.1	4.5	7.9	-0.74	23.9	6.7	50.4	312.0	312.0
Fish	Streamline Chub	*Erimystax dissimilis*	1	P	-0.39	-0.30	-0.88	0.49	-0.50	5.5	38.3	9.1	8.8	16.4	11.0	-0.03	27.2	8.2	9.1	691.0	691.0
Fish	Warmouth	*Lepomis gulosus*	2	P	-0.41	0.77	-0.13	-0.74	-0.77	7.5	43.3	0.6	0.9	8.0	8.7	-0.55	26.1	9.4	16.5	1177.0	658.0
Fish	Glassy Darter	*Etheostoma vitreum*	11	P	-0.45	-0.48	-1.01	1.26	-0.72	5.2	15.2	24.1	22.1	9.8	11.6	0.13	37.8	29.9	3.7	592.7	583.4
Fish	Threespine Stickleback	*Gasterosteus aculeatus*	1	NU	-0.49	0.72	-0.38	-0.83	-1.03	7.4	26.0	0.3	0.4	0.1	6.7	-1.04	153.8	88.3	0.0	0.0	0.0
Fish	Mountain Brook Lamprey	*Ichthyomyzon greeleyi*	6	P	-0.52	-0.07	-0.46	-0.11	-0.87	5.9	30.3	5.0	4.7	5.0	8.6	-0.58	21.9	7.9	23.6	225.7	223.6
Fish	Blackbanded Sunfish	*Enneacanthus chaetodon*	3	P	-0.58	-0.81	-1.36	0.62	-0.58	4.5	9.7	7.2	7.4	14.1	10.0	-0.25	15.2	7.7	7.4	11.3	6.8
Fish	Spotfin Killfish	*Fundulus luciae*	1	NU	-0.69	-1.07	-1.55	1.92	-0.93	4.1	6.7	42.7	40.7	3.2	8.0	-0.73	35.0	54.4	2.9	28.0	28.0
Fish	Ironcolor Shiner	*Notropis chalybaeus*	4	P	-0.70	-0.74	-1.60	0.81	-0.84	4.7	11.1	15.8	17.0	6.1	9.2	-0.45	38.8	31.0	4.5	836.8	836.8
Fish	Mud Sunfish	*Acantharchus pomotis*	2	P	-1.10	-1.82	-3.02	0.96	-0.78	2.7	0.7	12.8	14.5	7.8	9.1	-0.46	10.6	6.1	11.4	307.5	307.5
Fish Total			708		-0.04	0.33	0.13	0.13	-0.30	6.7	67.9	8.2	8.0	22.4	10.7	-0.10	24.9	14.1	11.5	497.2	484.5

Table E: Invertebrates: sorted by the average resilience score of all locations.

					Resilience: Average Z-scores					Components: Average Values					Flow Values		Condition Values				
Taxa Group	Common Name	*Standard Name*	**Number of Hexagon Locations**	**Data Adequacy**	Ave Resilience (Z)	Landform Variety (Z)	Elevation Range (Z)	Wetland Density (Z)	Connectedness (Z)	Landform Variety (count)	Elevation range (meters)	Wetland C (%)	Wetland M (%)	Connectedness (%)	Flow Concentrations	Flow Conentrations (Z)	Road Density (m per 1000 acres)	Developed (%)	Agriculture (%)	Max connected streams	Mean connected streams
Inverts	Spruce Knob Three-tooth	*Triodopsis picea*	4	P	0.28	0.23	0.51	0.28	0.26	6.5	79.4	14.3	11.4	39.6	14.8	0.88	13.6	5.0	3.5	52.3	49.8
Inverts	Yellow Bog Anarta	*Anarta luteola*	2	P	0.26	0.80	0.36	0.22	0.00	7.5	58.4	5.8	5.1	31.6	13.8	0.63	10.8	6.1	2.9	5.5	4.3
Inverts	Cylindrical Papershell	*Anodontoides ferussacian*	1	P	0.22	0.58	0.43	1.15	-0.26	7.1	62.0	13.5	14.0	23.9	10.8	-0.06	12.3	5.3	19.8	746.0	746.0
Inverts	Elktoe	*Alasmidonta marginata*	12	P	0.17	0.94	0.93	-0.74	-0.18	7.8	117.5	0.5	0.6	26.2	11.4	0.07	20.5	9.4	14.7	1196.8	1184.2
Inverts	Angular Disc	*Discus catskillensis*	2	NU	0.12	-0.14	0.99	-0.92	0.29	5.8	116.1	0.0	0.0	40.8	16.3	1.23	5.5	2.3	5.6	116.5	60.7
Inverts	Brook Floater	*Alasmidonta varicosa*	187	S	0.09	0.27	-0.19	0.57	-0.06	6.5	41.2	10.7	10.7	30.0	11.2	0.03	18.4	10.3	7.9	415.9	408.3
Inverts	James Spinymussel	*Pleurobema collina*	19	A	0.06	0.73	0.47	-0.68	-0.20	7.4	75.0	0.6	0.6	25.7	12.1	0.24	16.5	8.1	17.4	727.6	721.4
Inverts	Northern Lance Mussel	*Elliptio fisheriana*	4	P	0.05	1.19	0.67	-0.90	-0.44	8.2	91.6	0.1	0.1	18.4	11.4	0.06	17.3	8.3	22.0	1176.5	1176.5
Inverts	Alewife Floater	*Anodonta implicata*	3	NU	0.04	0.43	-0.15	0.06	-0.10	6.8	42.1	4.1	5.1	28.7	10.7	-0.09	18.4	5.9	3.6	328.7	327.5
Inverts	Groundwater Planarian sp.	*Procotyla typhlops*	1	A	0.03	0.53	0.02	-0.79	0.00	7.0	39.6	0.2	0.8	31.6	10.9	-0.04	14.2	6.0	5.6	126.0	15.2
Inverts	Cherrystone Drop Snail	*Hendersonia occulta*	19	A	0.01	0.60	0.70	-0.65	-0.29	7.1	108.2	1.0	0.8	23.0	12.2	0.27	20.0	8.1	20.1	1278.2	1278.2
Inverts	Eastern Pearlshell	*Margaritifera margaritife*	42	P	0.00	0.41	0.20	0.32	-0.33	6.8	58.2	8.4	7.9	21.6	10.7	-0.10	23.0	13.3	9.0	128.8	124.7
Inverts	Cave Lumbriculid Worm sp.	*Stylodrilus beattiei*	4	S	-0.01	0.65	0.63	-0.90	-0.28	7.3	87.3	0.0	0.0	23.3	9.0	-0.49	22.0	17.7	25.3	959.3	959.3
Inverts	Wavyrayed Lampmussel	*Lampsilis fasciola*	9	A	-0.02	0.28	0.52	-0.35	-0.23	6.6	113.8	5.4	6.4	24.8	11.1	0.01	27.4	15.3	4.0	505.3	430.1
Inverts	Yellow Lampmussel	*Lampsilis cariosa*	170	S	-0.04	0.16	-0.46	0.60	-0.19	6.3	35.4	13.1	12.9	26.0	10.2	-0.20	23.7	14.4	8.2	524.9	515.2
Inverts	Hoffmaster's Cave Planarian	*Macrocotyla hoffmasteri*	5	S	-0.05	0.73	0.76	-0.88	-0.43	7.4	95.0	0.1	0.1	18.6	9.1	-0.47	11.0	4.5	26.9	835.6	835.6
Inverts	Green Floater	*Lasmigona subviridis*	53	A	-0.07	0.67	0.27	-0.32	-0.46	7.3	67.0	3.1	2.9	17.5	10.4	-0.16	23.3	11.7	18.3	855.3	849.8
Inverts	Creek heelsplitter	*Lasmigona compressa*	4	P	-0.08	0.50	0.05	0.39	-0.52	7.0	45.7	6.0	7.6	16.0	9.9	-0.27	16.6	7.9	31.1	231.0	231.0
Inverts	Striped Whitelip	*Webbhelix multilineata*	2	A	-0.11	0.22	0.03	0.21	-0.22	6.4	50.8	15.3	12.2	25.0	11.9	0.19	22.4	21.1	2.1	756.5	715.3
Inverts	Appalachian Springsnail	*Fontigens bottimeri*	10	S	-0.13	0.88	0.20	-0.38	-0.65	7.7	51.4	2.5	2.0	11.7	8.9	-0.52	50.5	28.0	15.8	1435.2	1435.2
Inverts	Blue Ridge Springsnail	*Fontigens orolibas*	1	P	-0.15	0.94	-0.05	0.00	-0.76	7.8	37.3	2.7	2.6	8.4	7.8	-0.77	19.8	2.3	41.7	312.0	312.0
Inverts	New England Siltsnail	*Floridobia winkleyi*	6	P	-0.16	0.08	-0.74	1.68	-0.60	6.2	20.0	35.2	35.0	13.4	9.2	-0.45	24.3	14.6	9.2	35.3	30.7
Inverts	Coastal Marsh Snail	*Littoridinops tenuipes*	2	NU	-0.18	-0.35	-1.11	2.11	-0.43	5.4	12.7	55.5	55.3	18.4	10.0	-0.25	20.3	10.4	9.6	17.0	17.0
Inverts	Triangle Floater	*Alasmidonta undulata*	224	P	-0.18	0.30	-0.24	0.75	-0.64	6.6	39.0	12.7	12.2	12.3	9.9	-0.29	36.4	24.7	8.2	122.2	110.4
Inverts	Deertoe	*Truncilla truncata*	12	A	-0.18	0.74	0.11	-0.49	-0.60	7.4	66.6	2.3	1.9	13.4	10.1	-0.23	24.0	14.2	13.7	1324.7	1321.7
Inverts	Tidewater Mucket	*Leptodea ochracea*	123	A	-0.19	-0.05	-0.87	0.76	-0.32	6.0	20.1	14.6	14.5	21.9	9.3	-0.43	30.9	21.3	3.5	191.1	177.9
Inverts	Mossy Valvata/Boreal Turret S	*Valvata sincera*	4	P	-0.19	0.55	-0.16	0.46	-0.73	7.1	37.2	7.0	7.0	9.3	9.2	-0.45	45.6	30.2	5.1	27.8	11.4
Inverts	Yellow Lance	*Elliptio lanceolata*	28	A	-0.20	0.15	-0.36	0.27	-0.45	6.3	33.6	8.4	8.0	17.9	11.2	0.02	16.2	8.1	21.9	1167.5	1124.1
Inverts	Dwarf Wedgemussel	*Alasmidonta heterodon*	58	S	-0.23	0.10	-0.36	0.66	-0.59	6.2	40.1	12.0	11.6	13.8	10.0	-0.25	27.1	16.8	10.0	380.3	377.4
Inverts	Virginia River Snail	*Elimia virginica*	8	NU	-0.26	0.31	-0.32	0.27	-0.65	6.6	34.4	6.7	7.5	11.7	8.9	-0.52	36.8	27.9	8.8	243.5	218.0
Inverts	Black Sandshell	*Ligumia recta*	27	A	-0.26	0.16	-0.23	0.11	-0.57	6.3	53.7	10.8	10.7	14.3	10.0	-0.26	25.2	13.3	14.9	906.5	900.1
Inverts	Pocketbook Mussel	*Lampsilis ovata*	20	A	-0.29	-0.16	-0.39	0.54	-0.55	5.7	54.9	15.0	15.0	14.8	10.3	-0.19	24.2	12.4	15.2	506.5	456.8
Inverts	Eastern Lampmussel	*Lampsilis radiata*	25	NU	-0.30	-0.23	-0.87	1.09	-0.53	5.6	20.3	20.8	19.9	15.4	11.3	0.04	22.2	12.4	8.7	1124.8	1108.7
Inverts	Eastern Pond Mussel	*Ligumia nasuta*	124	A	-0.33	-0.02	-0.76	0.83	-0.69	6.0	23.5	15.3	15.2	10.8	9.1	-0.46	38.3	27.1	6.0	150.5	143.6
Inverts	Fragile Papershell	*Leptodea fragilis*	16	P	-0.35	0.08	-0.50	0.26	-0.66	6.2	53.0	8.1	9.2	11.5	8.5	-0.60	32.6	19.5	21.5	1085.9	1058.1
Inverts	Rainbow	*Villosa iris*	11	P	-0.47	-0.58	-1.31	0.94	-0.78	5.0	12.7	19.5	19.8	7.9	8.5	-0.61	26.1	9.4	21.7	218.3	205.9
Inverts Total			1242		-0.12	0.22	-0.31	0.51	-0.40	6.4	41.4	11.6	11.3	19.4	10.2	-0.21	27.4	17.2	9.6	427.8	416.7

Table F-J. Summary of species occurrences within the resilient sites (hexagons) and within the largest focal areas. Counts refer to the number of hexagons that contain the species, but note that some hexagons contain more than one location of the same species. Sites (1000 acre hexagons) are distributed across the resilience classes based on the Z-score (e.g. 0+ equals 0-1 standard deviations above the mean value, 1+ equals 1 to 2 standard deviations above the mean, etc.). The "Hexagons by Settings" column corresponds to Maps 5.18 and 5.19, and the "Hexagons Unstratified" corresponds to Map 5.20. Focal areas are summarized by the number of hexagons IN or OUT of a focal area (Map 5.19). Species with a data adequacy of NU (Not Usable) were left in the table for information only, but no conclusions should be made from this data.

Table F: Amphibians and Reptiles: sorted by the percent of locations with high resilience scores.

			Sites: Hexagons by Setting (Map 5.18, 5.19)										Sites: Hexagons Unstratified (Map 5.20)								Largest Focal Areas (Map 5.21)			
Taxa Group	Species	Data Adequacy	Total Hexagons with Species	1-	0-	0+	1+	2+	3+	(blank)	Total Above Ave	% Above Average BY SETTING	Total Hexagons with Species	1-	0-	0+	1+	(blank)	Total above average	% Above Average: UNSTRATIFED	Total Hexagons with Species	OUT	IN	% Within Large Focal Areas
Amphibian	Cow Knob Salamander	S	20			16	4				20	100%	20			20			20	100%	20	17	3	17%
Amphibian	Mountain Chorus Frog	P	4			4					4	100%	4			4			4	100%	4	4	0	0%
Amphibian	Black Mountain Salamander	A	11		1	9	1				10	91%	11		1	10			10	91%	11	9	2	18%
Amphibian	Green Salamander	A	46		6	35	4	1			40	87%	46		6	39	1		40	87%	46	43	3	6%
Amphibian	Jefferson Salamander	A	184		50	102	28	4			134	73%	184		73	111			111	60%	184	155	29	16%
Amphibian	Longtail Salamander	NU	21		7	13		1			14	67%	21		8	13			13	62%	21	19	2	8%
Amphibian	Marbled Salamander	P	147		55	81	11				92	63%	147		78	69			69	47%	147	124	23	16%
Amphibian	Upland//Southeastern Chorus Frog	P	8		3	5					5	63%	8		3	5			5	63%	8	8	0	0%
Amphibian	Eastern Hellbender	S	49		19	27	3				30	61%	49		20	29			29	59%	49	45	4	8%
Amphibian	Eastern Spadefoot Toad	A	90		36	27	19	7	1		54	60%	90		64	26			26	29%	90	65	25	28%
Amphibian	Common Mudpuppy	P	9		4	5					5	56%	9		7	2			2	22%	9	8	1	10%
Amphibian	Fowler's Toad	P	16		8	7		1			8	50%	16		10	6			6	38%	16	12	4	28%
Amphibian	Wehrle's Salamander	NU	6		3	3					3	50%	6		3	3			3	50%	6	6	0	6%
Amphibian	Northern Leopard Frog	P	19		10	8	1				9	47%	19		15	4			4	21%	19	19	0	0%
Amphibian	Eastern/Tiger Salamander	S	77	4	39	28	6				34	44%	77	4	70	3			3	4%	77	65	12	16%
Amphibian	Blue-spotted Salamander	A	315		215	87	11	2			100	32%	315		257	58			58	18%	315	303	12	4%
Amphibian	Carpenter Frog	A	20	7	12		1				1	5%	20	7	13				0	0%	20	19	1	5%
Amphibian Total			1042	11	468	457	89	16	1		563	54%	1042	11	628	402	1		403	39%	1042	920	123	12%
Reptile	Redbelly/Red-bellied Cooter/Turtle	NU	1			1					1	100%	1		1				0	0%	1	1	0	0%
Reptile	Rough Green Snake	NU	1			1					1	100%	1			1			1	100%	1	1	0	0%
Reptile	Smooth Green Snake	NU	4			3	1				4	100%	4			4			4	100%	4	4	0	12%
Reptile	Timber/Canebrake Rattlesnake	A	223		18	142	47	14	2		205	92%	223		23	187	13		200	90%	223	152	71	32%
Reptile	Broadhead Skink	P	3		1	2					2	67%	3		1	2			2	67%	3	3	0	0%
Reptile	Eastern Hognose Snake	P	40		14	25		1			26	65%	40		22	18			18	45%	40	37	3	8%
Reptile	Wood Turtle	S	1183		479	556	133	15			704	60%	1183		655	521	7		528	45%	1183	958	225	19%
Reptile	Corn Snake	P	17		7	7	3				10	59%	17		15	2			2	12%	17	11	6	34%
Reptile	Copperhead	NU	15		7	8					8	53%	15		9	6			6	40%	15	15	0	0%
Reptile	Blanding's Turtle	S	310		168	119	20	3			142	46%	310		208	102			102	33%	310	284	26	9%
Reptile	Eastern Box Turtle	NU	707	2	395	236	59	13	1	1	309	44%	707	2	569	135		1	135	19%	707	604	103	15%
Reptile	Bog Turtle	S	364		217	104	36	6	1		147	40%	364		279	85			85	23%	364	313	51	14%
Reptile	Spotted Turtle	A	834		510	264	49	8	3		324	39%	834		637	196	1		197	24%	834	757	77	9%
Reptile	Northern Map Turtle	A	13		8	2	3				5	38%	13		10	3			3	23%	13	12	1	9%
Reptile	Queen Snake	NU	3		3						0	0%	3		3				0	0%	3	3	0	0%
Reptile Total			3718	2	1827	1470	351	60	7	1	1888	51%	3718	2	2432	1262	21	1	1283	35%	3719	3154	565	15%

Table G: Mammals: sorted by the percent of locations with above average resilience scores.

			Sites: Hexagons by Setting (Map 5.18, 5.19)										Sites: Hexagons Unstratified (Map 5.20)								Largest Focal Areas (Map 5.21)			
Taxa Group	Species	Data Adequacy	Total Hexagons with Species	1-	0-	0+	1+	2+	3+	(blank)	Total Above Ave	% Above Average BY SETTING	Total Hexagons with Species	1-	0-	0+	1+	(blank)	Total above average	% Above Average: UNSTRATIFED	Total Hexagons with Species	OUT	IN	% Within Large Focal Areas
Mammal	Southern Bog Lemming	P	35		1	28	5	1			34	97%	35		9	26			26	74%	35	23	12	35%
Mammal	Long-tailed or Rock Shrew	A	37		4	28	5				33	89%	37		4	32	1		33	89%	37	33	4	10%
Mammal	Silver-haired Bat	NU	27		4	20	3				23	85%	27		4	23			23	85%	27	25	2	8%
Mammal	Eastern Red Bat	NU	6		1	4	1				5	83%	6		2	4			4	67%	6	5	1	17%
Mammal	Allegheny Woodrat	A	344		65	244	31	4			279	81%	344		66	277	1		278	81%	344	314	30	9%
Mammal	Fisher	NU	5		1	2	1	1			4	80%	5		2	3			3	60%	5	3	2	47%
Mammal	Bobcat	NU	133		34	77	18	4			99	74%	133		51	79	3		82	62%	133	79	54	41%
Mammal	Appalachian Cottontail	S	15		4	8	3				11	73%	15		4	11			11	73%	15	15	0	1%
Mammal	Eastern Small-footed Bat	S	195		62	110	18	5			133	68%	195		70	122	3		125	64%	195	172	23	12%
Mammal	Indiana Bat	S	122		50	50	17	5			72	59%	122		57	64	1		65	53%	122	109	13	11%
Mammal	Smoky Shrew	NU	9		4	5					5	56%	9		5	4			4	44%	9	9	0	0%
Mammal	New England Cottontail	P	72		41	29	2				31	43%	72		50	22			22	31%	72	69	3	4%
Mammal	Least Shrew	P	7		4	3					3	43%	7		6	1			1	14%	7	7	0	0%
Mammal	Least Weasel	A	8		5	3					3	38%	8		6	2			2	25%	8	8	0	0%
Mammal	Hoary Bat	NU	6		4	2					2	33%	6		5	1			1	17%	6	6	0	0%
Mammal Total			1021		284	613	104	20			737	72%	1021		341	671	9		680	67%	1021	876	145	14%

Table H: Birds (well represented-species): Species with 60 percent or more location in sites with above average resilience scores, sorted by the percent of locations with high scores.

			Sites: Hexagons by Setting (Map 5.18, 5.19)										Sites: Hexagons Unstratified (Map 5.20)								Largest Focal Areas (Map 5.21)			
Taxa Group	Species	Data Adequacy	Total Hexagons with Species	1-	0-	0+	1+	2+	3+	(blank)	Total Above Ave	% Above Average BY SETTING	Total Hexagons with Species	1-	0-	0+	1+	(blank)	Total above average	% Above Average: UNSTRATIFED	Total Hexagons with Species	OUT	IN	% Within Large Focal Areas
Bird	American Three-toed Woodpecker	S	10			5	5				10	100%	10			6	4		10	100%	10	4	6	56%
Bird	Bicknell's Thrush	S	62			29	33				62	100%	62			52	10		62	100%	62	54	8	13%
Bird	Black-and-White Warbler	NU	13			10	3				13	100%	13		9	4			4	31%	13	2	11	83%
Bird	Blackpoll Warbler	P	6			5	1				6	100%	6			6			6	100%	6	6	0	3%
Bird	Brown Pelican	P	1			1					1	100%	1			1			1	100%	1	1	0	0%
Bird	Gray-Cheeked Thrush	P	1			1					1	100%	1		1				0	0%	1	1	0	6%
Bird	Olive-sided Flycatcher	NU	1			1					1	100%	1			1			1	100%	1	0	1	51%
Bird	Rusty Blackbird	P	27			16	10	1			27	100%	27			25	2		27	100%	27	7	20	73%
Bird	Spruce Grouse	S	32			23	9				32	100%	32			26	6		32	100%	32	8	24	74%
Bird	Swainson's Thrush	NU	16			10	6				16	100%	16			16			16	100%	16	10	6	39%
Bird	Yellow Rail	P	8			3	4	1			8	100%	8			8			8	100%	8	2	6	77%
Bird	Common Loon	A	365		17	159	158	26	5		348	95%	365		26	206	133		339	93%	365	158	207	57%
Bird	Blackburnian Warbler	P	19		1	17	1				18	95%	19		5	14			14	74%	19	10	9	48%
Bird	Cerulean Warbler	P	52		3	35	10	4			49	94%	52		9	42	1		43	83%	52	23	29	56%
Bird	Canada Warbler	NU	15		1	12	2				14	93%	15		3	12			12	80%	15	8	7	45%
Bird	Golden Eagle	P	14		1	6	6	1			13	93%	14		1	12	1		13	93%	14	11	3	25%
Bird	Black-throated Green Warbler	NU	27		2	16	8	1			25	93%	27		9	18			18	67%	27	11	17	61%
Bird	Acadian Flycatcher	P	13		2	10		1			11	85%	13		7	6			6	46%	13	6	7	56%
Bird	Northern Goshawk	P	56		10	28	18				46	82%	56		12	43	1		44	79%	56	41	15	28%
Bird	Whip-poor-will	NU	48		9	30	9				39	81%	48		20	28			28	58%	48	35	13	27%
Bird	Black-billed Cuckoo	NU	47		9	23	11	3	1		38	81%	47		30	17			17	36%	47	22	25	54%
Bird	Bay-breasted Warbler	P	5		1	2	2				4	80%	5		1	3	1		4	80%	5	4	1	27%
Bird	Cape May Warbler	P	5		1	2	2				4	80%	5		1	3	1		4	80%	5	3	2	37%
Bird	Hooded Warbler	NU	46	1	10	23	11	1			35	76%	46	1	24	20	1		21	46%	46	26	20	44%
Bird	Chuck-will's-widow	P	4		1	1	2				3	75%	4		4				0	0%	4	4	0	0%
Bird	Piping Plover	S	404	10	74	245	40	11	3	21	299	74%	404	10	145	227	1	21	228	56%	404	376	29	7%
Bird	Red-shouldered Hawk	NU	145		40	89	15	1			105	72%	145		71	72	2		74	51%	145	85	60	41%
Bird	Northern Parula	P	46	1	12	25	6	1	1		33	72%	46	1	30	15			15	33%	46	33	13	27%
Bird	Gull-billed Tern	S	28	1	2	14	5	1		5	20	71%	28	1	6	16		5	16	57%	28	23	5	18%
Bird	Veery	NU	276		81	153	37	4	1		195	71%	276		118	158			158	57%	276	182	94	34%
Bird	Red Knot	P	57	3	13	13	21	6		1	40	70%	57	3	36	17		1	17	30%	57	35	22	38%
Bird	Forster's Tern	P	30		5	14	5	2		4	21	70%	30		16	10		4	10	33%	30	23	7	22%
Bird	Common Tern	A	358	5	64	201	37	12		39	250	70%	358	5	140	174		39	174	49%	358	326	32	9%
Bird	Willet	NU	13		4	7	1	1			9	69%	13		7	6			6	46%	13	13	0	0%
Bird	Golden-winged Warbler	A	57		18	34	4	1			39	68%	57		20	37			37	65%	57	37	20	35%
Bird	Least Tern	S	376	16	83	214	35	5	1	22	255	68%	376	16	151	187		22	187	50%	376	355	21	6%
Bird	Black-throated Blue Warbler	NU	15	1	4	8	1	1			10	67%	15	1	5	8	1		9	60%	15	7	8	55%
Bird	Field Sparrow	NU	6		2	2	2				4	67%	6		6				0	0%	6	4	2	32%
Bird	Royal Tern	P	3		1	2					2	67%	3		1	2			2	67%	3	3	0	0%
Bird	American Bittern	A	174	1	58	99	15	1			115	66%	174	1	78	95			95	55%	174	156	18	11%
Bird	Black Tern	S	47		15	19	8	4		1	31	66%	47		25	20	1	1	21	45%	47	38	9	20%
Bird	Tricolored Heron	P	41	2	7	17	7	3		5	27	66%	41	2	19	15		5	15	37%	41	34	7	18%
Bird	Bald Eagle	S	2270	40	703	875	446	141	28	37	1490	66%	2270	48	1194	970	21	37	991	44%	2270	1693	577	25%
Bird	Black Rail	A	26		9	10	7				17	65%	26		25	1			1	4%	26	17	9	36%
Bird	Roseate Tern	S	110	2	14	68	2	1		23	71	65%	110	2	25	60		23	60	55%	110	107	3	3%
Bird	Osprey	P	238	3	85	103	37	7	1	2	148	62%	238	3	158	73	2	2	75	32%	238	195	43	18%
Bird	Least Bittern	S	242	2	89	103	39	8		1	150	62%	242	2	145	93	1	1	94	39%	242	207	35	14%
Bird	Black Skimmer	A	86	5	13	45	5	3		15	53	62%	86	5	26	40		15	40	47%	86	80	6	7%
Bird	Brown Thrasher	NU	228	3	89	97	35	4			136	60%	228	3	196	29			29	13%	228	141	87	38%

Table H: Birds (poorly represented-species): Species with less than 60 percent of their locations in sites with above average resilience scores, sorted by the percent in above-averge scoring sites.

			Sites: Hexagons by Setting (Map 5.18, 5.19)										Sites: Hexagons Unstratified (Map 5.20)								Largest Focal Areas (Map 5.21)			
Taxa Group	Species	Data Adequacy	Total Hexagons with Species	1-	0-	0+	1+	2+	3+	(blank)	Total Above Ave	% Above Average BY SETTING	Total Hexagons with Species	1-	0-	0+	1+	(blank)	Total above average	% Above Average: UNSTRATIFED	Total Hexagons with Species	OUT	IN	% Within Large Focal Areas
Bird	Wood Thrush	NU	1010	5	413	444	136	11	1		592	59%	1010	5	733	271	1		272	27%	1010	722	288	28%
Bird	Little Blue Heron	A	66	1	17	28	6	4		10	38	58%	66	1	33	22		10	22	33%	66	57	9	14%
Bird	Yellow-breasted Chat	NU	25		11	12	2				14	56%	25		18	7			7	28%	25	19	6	24%
Bird	Cattle Egret	A	34	1	6	12	4	3		8	19	56%	34	1	14	11		8	11	32%	34	29	5	13%
Bird	Great Blue Heron	A	428	1	188	197	37	5			239	56%	428	1	222	205			205	48%	428	390	38	9%
Bird	Kentucky Warbler	P	27		12	9	6				15	56%	27		17	10			10	37%	27	24	3	12%
Bird	Sharp-Shinned Hawk	P	45	2	18	21	4				25	56%	45	2	23	20			20	44%	45	39	6	12%
Bird	Peregrine Falcon	S	284	20	103	102	42	12	1	4	157	55%	284	21	125	119	15	4	134	47%	284	252	32	11%
Bird	Snowy Egret	A	87	2	19	32	8	7	1	18	48	55%	87	2	40	27		18	27	31%	87	75	12	14%
Bird	Red-headed Woodpecker	P	142	1	63	56	22				78	55%	142	1	119	22			22	15%	142	98	44	31%
Bird	Pied-billed Grebe	A	217	1	96	86	23	8	1	2	118	54%	217	2	128	82	3	2	85	39%	217	184	33	15%
Bird	Arctic Tern	S	35		3	19				13	19	54%	35		5	17		13	17	49%	35	34	1	2%
Bird	Northern Harrier	S	301	9	128	110	39	12		3	161	53%	301	9	208	78	3	3	81	27%	301	240	61	20%
Bird	Saltmarsh Sharp-tailed Sparrow	P	43		19	17	4	2		1	23	53%	43		27	15		1	15	35%	43	41	2	6%
Bird	Glossy Ibis	A	74	2	15	25	8	6		18	39	53%	74	2	31	23		18	23	31%	74	63	11	15%
Bird	Seaside Sparrow	P	25		12	11	1	1			13	52%	25		15	10			10	40%	25	25	0	0%
Bird	Broad-winged Hawk	NU	29	1	13	11	3	1			15	52%	29	1	19	9			9	31%	29	24	5	17%
Bird	Atlantic Puffin	P	4			2				2	2	50%	4			2		2	2	50%	4	4	0	0%
Bird	Cooper's Hawk	P	237	5	117	89	23	3			115	49%	237	5	174	58			58	24%	237	187	51	21%
Bird	Sora Rail	S	65		34	25	6				31	48%	65		51	14			14	22%	65	60	5	8%
Bird	Great Egret	A	89	2	26	33	5	3	1	19	42	47%	89	2	44	24		19	24	27%	89	83	6	7%
Bird	Common Moorhen	A	65		35	23	7				30	46%	65		47	18			18	28%	65	61	4	6%
Bird	Black-crowned Night-heron	A	103	2	36	32	8	7		18	47	46%	103	2	60	23		18	23	22%	103	90	13	13%
Bird	Prothonotary Warbler	P	18		10	7	1				8	44%	18		14	4			4	22%	18	18	0	2%
Bird	Sedge Wren	S	101		56	31	8	5		1	44	44%	101		72	27	1	1	28	28%	101	86	15	15%
Bird	King Rail	A	58		33	19	5	1			25	43%	58		45	13			13	22%	58	51	7	13%
Bird	Harlequin Duck	P	28		1	12				15	12	43%	28		1	12		15	12	43%	28	28	0	0%
Bird	Common Nighthawk	P	12		7	4	1				5	42%	12		9	3			3	25%	12	9	3	29%
Bird	American Oystercatcher	P	49	4	13	15	4	1		12	20	41%	49	4	21	12		12	12	24%	49	47	2	5%
Bird	Yellow-crowned Night-heron	A	88	7	40	29	3	2		7	34	39%	88	7	64	10		7	10	11%	88	84	4	5%
Bird	Marsh Wren	P	32	2	18	10	2				12	38%	32	2	25	5			5	16%	32	31	1	3%
Bird	Long-eared Owl	A	42		27	12	3				15	36%	42		36	6			6	14%	42	37	5	12%
Bird	Bobolink	P	92	4	56	29	3				32	35%	92	5	74	13			13	14%	92	83	9	10%
Bird	Razorbill	P	6			2				4	2	33%	6			2		4	2	33%	6	6	0	0%
Bird	Grasshopper Sparrow	A	183	7	117	42	11	4	2		59	32%	183	7	152	23	1		24	13%	183	163	20	11%
Bird	Vesper Sparrow	P	113	3	74	26	10				36	32%	113	3	104	6			6	5%	113	102	11	10%
Bird	Short-eared Owl	S	103	5	65	23	6	1	1	2	31	30%	103	5	82	14		2	14	14%	103	99	4	4%
Bird	Horned Lark	NU	10		7	3					3	30%	10		9	1			1	10%	10	9	1	9%
Bird	Eastern Meadowlark	NU	73	2	50	17	4				21	29%	73	2	66	5			5	7%	73	65	7	10%
Bird	Henslow's Sparrow	S	52	2	36	13	1				14	27%	52	2	39	11			11	21%	52	51	1	2%
Bird	Upland Sandpiper	S	271	7	196	52	12	3		1	67	25%	271	7	226	37		1	37	14%	271	254	17	6%
Bird	Barn Owl	A	145		113	26	3			3	29	20%	145	1	129	12		3	12	8%	145	141	4	3%
Bird	Dickcissel	P	16		13	3					3	19%	16		14	2			2	13%	16	16	0	0%
Bird	Loggerhead Shrike	S	23	1	19	3					3	13%	23	1	21	1			1	4%	23	23	0	0%
Bird	Great Cormorant	NU	9			1				8	1	11%	9			1		8	1	11%	9	9	0	0%
Bird	Blue-winged Warbler	NU	2		2						0	0%	2		2				0	0%	2	2	0	0%
Bird	Great Black-backed Gull	NU	1		1						0	0%	1		1				0	0%	1	1	0	0%
Bird	Northen Bobwhite	NU	4		4						0	0%	4		4				0	0%	4	4	0	0%
Bird Total			11135	###	3895	4700	1592	359	49	345	6700	60%	11135	###	6168	4201	214	345	4415	40%	11135	8846	2289	21%

Table I: Fish: sorted by the percent of locations in sites with above average resilience scores.

			Sites: Hexagons by Setting (Map 5.18, 5.19)										Sites: Hexagons Unstratified (Map 5.20)								Largest Focal Areas (Map 5.21)			
Taxa Group	Species	Data Adequacy	Total Hexagons with Species	1-	0-	0+	1+	2+	3+	(blank)	Total Above Ave	% Above Average BY SETTING	Total Hexagons with Species	1-	0-	0+	1+	(blank)	Total above average	% Above Average: UNSTRATIFED	Total Hexagons with Species	OUT	IN	% Within Large Focal Areas
Fish	Appalachia Darter	A	3			2	1				3	100%	3			3			3	100%	3	3	0	13%
Fish	Blue Ridge Sculpin	NU	1			1					1	100%	1			1			1	100%	1	1	0	0%
Fish	Cheat Minnow	A	7			6		1			7	100%	7			7			7	100%	7	6	1	19%
Fish	Comely Shiner	NU	2			2					2	100%	2		2				0	0%	2	2	0	0%
Fish	Least Brook Lamprey	NU	2			2					2	100%	2			2			2	100%	2	2	0	0%
Fish	New River Shiner	A	4			4					4	100%	4			4			4	100%	4	4	0	0%
Fish	Pearl Dace	NU	2			2					2	100%	2		2				0	0%	2	2	0	0%
Fish	Potomac Sculpin	P	2			2					2	100%	2			2			2	100%	2	2	0	0%
Fish	Slimy Sculpin	NU	1			1					1	100%	1		1				0	0%	1	1	0	0%
Fish	Stripeback Darter	P	3			3					3	100%	3		3				0	0%	3	3	0	0%
Fish	Swamp Darter	NU	8			5	3				8	100%	8		3	5			5	63%	8	3	5	63%
Fish	Tonguetied Minnow	A	10			10					10	100%	10			10			10	100%	10	10	0	0%
Fish	Round Whitefish	A	15		1	6	8				14	93%	15		1	7	7		14	93%	15	9	6	41%
Fish	Bigmouth Chub	A	23		2	19	2				21	91%	23		2	21			21	91%	23	22	1	2%
Fish	Mountain Redbelly Dace	A	22		2	18	2				20	91%	22		2	20			20	91%	22	22	0	0%
Fish	Candy Darter	A	15		2	12	1				13	87%	15		2	13			13	87%	15	15	0	0%
Fish	Silver Lamprey	A	17		3	8	6				14	82%	17		14	3			3	18%	17	15	2	12%
Fish	Northern Brook Lamprey	S	11		3	4	4				8	73%	11		4	7			7	64%	11	9	2	17%
Fish	Blackchin Shiner	A	24		7	9	6	2			17	71%	24		11	13			13	54%	24	18	6	26%
Fish	Spotted Darter	A	3		1	1	1				2	67%	3		1	2			2	67%	3	2	1	33%
Fish	Swallowtail Shiner	NU	3		1	2					2	67%	3		3				0	0%	3	3	0	0%
Fish	Channel Darter	A	23		8	13	2				15	65%	23		15	8			8	35%	23	21	2	8%
Fish	Tessellated Darter	NU	5		2	3					3	60%	5		5				0	0%	5	5	0	0%
Fish	Longnose Sucker	P	88		36	49	3				52	59%	88		41	47			47	53%	88	80	8	9%
Fish	Eastern Silvery Minnow	NU	38		17	13	6	2			21	55%	38		26	12			12	32%	38	37	1	4%
Fish	Eastern Sand Darter	S	20		9	9	2				11	55%	20		13	7			7	35%	20	18	2	9%
Fish	Glassy Darter	P	11		5	3	3				6	55%	11		11				0	0%	11	11	0	0%
Fish	River Redhorse	P	15		7	8					8	53%	15		7	8			8	53%	15	15	0	0%
Fish	Bridle Shiner	NU	102		50	44	7	1			52	51%	102		57	45			45	44%	102	91	11	11%
Fish	American Eel	NU	2		1		1				1	50%	2		1	1			1	50%	2	2	0	0%
Fish	Blueback Herring	NU	2		1	1					1	50%	2		1	1			1	50%	2	1	1	50%
Fish	Burbot	P	8		4	3	1				4	50%	8		5	3			3	38%	8	7	1	9%
Fish	Checkered Sculpin	A	2		1	1					1	50%	2		2				0	0%	2	2	0	0%
Fish	Ironcolor Shiner	P	4	1	1	1	1				2	50%	4	1	3				0	0%	4	4	0	7%
Fish	Kanawha Minnow	A	6		3	3					3	50%	6		3	3			3	50%	6	6	0	0%
Fish	Mooneye	A	20		10	8	1	1			10	50%	20		18	2			2	10%	20	19	1	6%
Fish	Torrent Sucker	A	2		1	1					1	50%	2		1	1			1	50%	2	2	0	0%
Fish	Trout-perch	A	2		1	1					1	50%	2		2				0	0%	2	2	0	0%
Fish	Banded Sunfish	NU	27		14	10	3				13	48%	27		18	9			9	33%	27	21	6	23%
Fish	Bluebreast Darter	A	23		12	11					11	48%	23		12	11			11	48%	23	23	0	0%
Fish	American Brook Lamprey	P	29		16	9	4				13	45%	29		23	6			6	21%	29	25	3	12%
Fish	Ohio Lamprey	A	21		13	8					8	38%	21		14	7			7	33%	21	21	0	0%
Fish	Atlantic Sturgeon	P	8		4	2	1			1	3	38%	8		5	2		1	2	25%	8	8	0	0%
Fish	Stonecat	P	14		9	4	1				5	36%	14		9	5			5	36%	14	14	0	0%
Fish	Blackbanded Sunfish	P	3	1	1	1					1	33%	3	1	2				0	0%	3	3	0	0%
Fish	Sauger	NU	6		4	2					2	33%	6		4	2			2	33%	6	6	0	0%
Fish	Shortnose Sturgeon	A	21		14	6	1				7	33%	21		18	3			3	14%	21	21	0	1%
Fish	Longhead Darter	A	8		6	2					2	25%	8		6	2			2	25%	8	8	0	0%
Fish	Variegate Darter	P	7		6	1					1	14%	7		6	1			1	14%	7	7	0	0%
Fish	Mountain Brook Lamprey	P	6	1	5						0	0%	6	1	5				0	0%	6	6	0	0%
Fish	Mud Sunfish	P	2	1	1						0	0%	2	1	1				0	0%	2	2	0	0%
Fish	Spotfin Killfish	NU	1		1						0	0%	1		1				0	0%	1	1	0	0%
Fish	Streamline Chub	P	1		1						0	0%	1		1				0	0%	1	1	0	0%
Fish	Threespine Stickleback	NU	1		1						0	0%	1		1				0	0%	1	1	0	0%
Fish	Warmouth	P	2		2						0	0%	2		2				0	0%	2	2	0	0%
Fish Total			708	4	289	336	71	7		1	414	58%	708	4	390	306	7	1	313	44%	708	646	62	9%

Table J: Invertebrates: sorted by the percent of locations in sites with above average resilience scores.

			Sites: Hexagons by Setting (Map 5.18, 5.19)										Sites: Hexagons Unstratified (Map 5.20)								Largest Focal Areas (Map 5.21)			
Taxa Group	Species	Data Adequacy	Total Hexagons with Species	1-	0-	0+	1+	2+	3+	(blank)	Total Above Ave	% Above Average BY SETTING	Total Hexagons with Species	1-	0-	0+	1+	(blank)	Total above average	% Above Average: UNSTRATIFED	Total Hexagons with Species	OUT	IN	% Within Large Focal Areas
Inverts	Angular Disc	NU	2			2					2	100%	2			2			2	100%	2	2	0	0%
Inverts	Blue Ridge Springsnail	P	1			1					1	100%	1		1				0	0%	1	1	0	0%
Inverts	Coastal Marsh Snail	NU	2				2				2	100%	2		2				0	0%	2	2	0	8%
Inverts	Cylindrical Papershell	P	1				1				1	100%	1			1			1	100%	1	0	1	97%
Inverts	Groundwater Planarian sp.	A	1			1					1	100%	1			1			1	100%	1	1	0	0%
Inverts	Spruce Knob Three-tooth	P	4			4					4	100%	4			4			4	100%	4	4	0	0%
Inverts	Striped Whitelip	A	2			2					2	100%	2		1	1			1	50%	2	2	0	0%
Inverts	Yellow Bog Anarta	P	2			2					2	100%	2			2			2	100%	2	2	0	5%
Inverts	Elktoe	P	12		2	10					10	83%	12		3	9			9	75%	12	12	0	0%
Inverts	Creek heelsplitter	P	4		1	3					3	75%	4		2	2			2	50%	4	3	1	22%
Inverts	Deertoe	A	12		3	8	1				9	75%	12		8	4			4	33%	12	12	0	0%
Inverts	Northern Lance Mussel	P	4		1	3					3	75%	4		1	3			3	75%	4	4	0	0%
Inverts	Brook Floater	S	187		51	83	39	14			136	73%	187		79	108			108	58%	187	127	60	32%
Inverts	Eastern Pearlshell	P	42		13	26	2	1			29	69%	42		20	22			22	52%	42	40	2	5%
Inverts	James Spinymussel	A	19		6	11	2				13	68%	19		10	9			9	47%	19	17	2	11%
Inverts	New England Siltsnail	P	6		2	2	2				4	67%	6		6				0	0%	6	6	0	3%
Inverts	Eastern Lampmussel	NU	25		9	11	5				16	64%	25		24	1			1	4%	25	21	4	16%
Inverts	Cherrystone Drop Snail	A	19		7	8	4				12	63%	19		12	7			7	37%	19	19	0	0%
Inverts	Hoffmaster's Cave Planarian	S	5		2	3					3	60%	5		2	3			3	60%	5	5	0	0%
Inverts	Yellow Lampmussel	S	170		72	58	25	12	3		98	58%	170		106	59	5		64	38%	170	131	39	23%
Inverts	Black Sandshell	A	27		13	11	3				14	52%	27		22	5			5	19%	27	25	2	6%
Inverts	Tidewater Mucket	A	123	1	60	47	11	4			62	50%	123	1	89	32	1		33	27%	123	105	18	15%
Inverts	Cave Lumbriculid Worm sp.	S	4		2	2					2	50%	4		2	2			2	50%	4	4	0	0%
Inverts	Virginia River Snail	NU	8		4	3	1				4	50%	8		6	2			2	25%	8	8	0	0%
Inverts	Yellow Lance	A	28		14	12	1	1			14	50%	28		20	8			8	29%	28	26	2	8%
Inverts	Green Floater	A	53		28	21	2	1	1		25	47%	53		31	22			22	42%	53	51	2	4%
Inverts	Dwarf Wedgemussel	S	58	4	27	19	7	1			27	47%	58	4	38	16			16	28%	58	52	6	10%
Inverts	Triangle Floater	P	224	1	126	90	5	2			97	43%	224	1	161	62			62	28%	224	208	16	7%
Inverts	Appalachian Springsnail	S	10		6	3	1				4	40%	10		8	2			2	20%	10	9	1	7%
Inverts	Alewife Floater	NU	3		2	1					1	33%	3		2	1			1	33%	3	3	0	1%
Inverts	Wavyrayed Lampmussel	A	9		6	3					3	33%	9		6	3			3	33%	9	9	0	0%
Inverts	Fragile Papershell	P	16		9	5				2	5	31%	16		10	4		2	4	25%	16	15	1	5%
Inverts	Pocketbook Mussel	A	20		14	5	1				6	30%	20		16	4			4	20%	20	18	2	9%
Inverts	Eastern Pond Mussel	A	124	1	86	29	6			2	35	28%	124	1	105	16		2	16	13%	124	121	3	2%
Inverts	Rainbow	P	11		8	1	1			1	2	18%	11		9	1		1	1	9%	11	11	0	0%
Inverts	Mossy Valvata/Boreal Turret Snail	P	4		4						0	0%	4		4				0	0%	4	4	0	0%
Inverts Total			1242	7	578	490	122	36	4	5	652	52%	1242	7	806	418	6	5	424	34%	1242	1079	163	13%

Detail on Ecological Land Units

Adapted from Ecological Land Units: Elevation Zones, Geology, and Landforms, Ferree, C. and Anderson, M.A. 2008. Ecological Land Units. Version 11/2008. The Nature Conservancy Eastern Conservation Science Office. Boston, MA.

The Ecological Land Unit (ELU) dataset is a composite of several layers of abiotic information that critically influence the form, function, and distribution of ecosystems - elevation zone, bedrock geology, and landforms. Each 30m grid cell is assigned a given elevation, bedrock or surficial geology, and landform class. The three components can be viewed or queried separately or in combination. Elevation has been shown to be a powerful predictor of the distribution of forest communities in the Northeast. Temperature, precipitation, and exposure commonly vary with changing altitude. Bedrock geology strongly influences area soil and water chemistry. Bedrock types also differ in how they weather and in the physical characteristics of the residual soil type. Rowe (1998) contends that landform is "the anchor and control of terrestrial ecosystems." Landforms are largely responsible for local variation in solar radiation, moisture availability, soil development, and susceptibility to wind and other disturbance. We adopted the Fels and Matson (1997) system for landform modeling, in which combinations of slope and landscape position are used to define topographic units such as ridges, sideslopes, coves, and flats on the landscape. Six ecologically relevant elevation zones were defined; over 250 bedrock and surficial geology classes were collapsed into 9 ecologically distinct geology classes; and GIS modeling gave us 13 ecologically significant landform classes. Combination of these resource grids resulted in over 700 unique ELUs in the region.

Elevation classes

Elevation has been shown to be a powerful predictor of the distribution of forest communities in the Northeast. Temperature, precipitation, and exposure commonly vary with changing altitude. We broke continuous elevation data from the National Elevation Dataset of the USGS into discrete elevation classes with relevance to the distribution of forest types region-wide. Meaningful biotic zones would be defined with quite different elevation cut-offs in the northern and southern parts of the region, so class ranges necessarily approximate critical ecological values.

Table 1. Ranges for elevation classes.

Elevzone	*(feet)*	*Characteristic forest type in Lower New England*
1000/2000	0-20ft & 20-800ft	Oak, pine-oak, pine-hemlock, maritime spruce, floodplain forest
3000	800-1700ft	Hemlock-N. hardwoods, N. hardwoods, lowland spruce-fir
4000	1700-2500ft	Northern hardwoods, spruce-hardwoods
5000, 6000	2500-3600ft, >3600ft	Krummholz, montane spruce-fir, alpine communities

Bedrock geology and deep sediments

Bedrock geology strongly influences area soil and water chemistry. Even in glaciated landscapes, studies suggest that soil parent material is commonly of local origin, rarely being ice-transported more that a few miles from its source. Bedrock types also differ in how they weather and in the physical characteristics of the residual soil type. Because of this, local lithology is usually the principle determinant of soil chemistry, texture, and nutrient availability. Many ecological community types are closely related to the chemistry and drainage of the soils or are associated with particular bedrock exposures.

We grouped bedrock units on the bedrock geology maps of the northeast 14 states into five bedrock classes (Table 2). We based our scheme on broad classification schemes developed by other investigators which emphasize chemistry and texture, and on bedrock settings that are important to many ecological communities, particularly to herbaceous associations.

In some settings deep sediments of glacial origin mantle the bedrock. The consolidated bedrock of valleys of pro-glacial lakes, for example, may lie under many meters of fine lacustrine sediments, and deep coarse deltaic or outwash deposits often overlay the bedrock in pine barrens and sand plains in the northeast. In these settings it is the nature of the sediments—their texture, compactness, and moisture-holding capacity, their nutrient availability, their ability to anchor overstory trees in a wind disturbance--that is ecologically relevant, and not the nature of the underlying bedrock. We used a USGS dataset of sediments of the glaciated northeast to identify such places. The USGS map was compiled at a coarse scale (1:1,000,000), but we made the data a little "smarter" by informing it with our landform map (please see landforms development section that accompanies this metadata). Our landform layer was compiled at a much finer scale (the scale of the digital elevation models from which they were shaped, 1:24,000), and we allowed the deep coarse or fine sediments of the USGS dataset to be mapped only on those landforms on which they would naturally be expected to occur. In the case of sandy, coarse sediments, this would be in broad basin and valley/toe slope settings; in the case of fine clayey lacustrine or marine sediments, in these same settings, plus low hills and lower sideslopes. The seven bedrock classes were numbered 100 through 700 (Table 2), and the coarse and fine sediments classes were numbered 800 and 900, respectively.

Table 2. Bedrock geology classes.

Geology Class	Lithologies (including metamorphic equivalents)
Ultramafic: magnesium rich alkaline rock	Serpentine, soapstone, pyroxenite, dunite, peridotite, talc schist
Mafic: quartz poor alkaline to slightly acidic rock	Ultrabasic: anorthosite, Basic: gabbro, diabase, basalt, Intermediate: diorite, andesite, syenite, trachyte, Metamorphic equivalents : Greenstone, amphibolites, epidiorite, granulite, bostonite, essexite
Acidic Granitic: quartz rich, resistant acidic igneous rock	Granite, granodiorite, rhyolite, felsite, pegmatite, Metamorphic equivalents : Granitic gneiss, charnocktites, migmatites
Acidic Sedimentary: fine to coarse grained, acidic sedimentary rock	Mudstone, claystone, siltstone, Non-fissile shale, sandstone, breccia, conglomerate, greywake, arenites, Metamorphic equivalents: slate, phyllite, pelite, schist, pelitic schist, granofel, quartzite
Acidic Shale: fine grained acidic sedimentary rock with fissile texture	Fissile shales only
Calcareous Sedimentary: basic/alkaline, soft sedimentary rock with high calcium content	Limestone, dolomite, dolostone, other carbonate-rich clastic rocks, Metamorphic equivalents : Marble
Moderately Calcareous Sedimentary: neutral to basic, moderately soft sedimentary rock with some calcium	Calcareous shale and sandstone, calc-silicate granofel, Metamorphic equivalents: calcareous schists and phyllite
Fine Sediment: fine-grained surficial sediments	Unconsolidated mud, clay, drift, ancient lake deposits
Coarse Sediment: coarse-grained surficial sediments.	Unconsolidated sand, gravel, pebble, till.

Landforms

Stanley Rowe called landform "the anchor and control of terrestrial ecosystems." It breaks up broad landscapes into local topographic units, and in doing so provides for meso- and microclimatic expression of broader climatic character. It is largely responsible for local variation in solar radiation, soil development, moisture availability, and susceptibility to wind and other disturbance. As one of the five "genetic influences" in the process of soil formation, it is tightly tied to rates of erosion and deposition, and therefore to soil depth, texture, and nutrient availability. These are, with moisture, the primary edaphic controllers of plant productivity and species distributions. If the other four influences on soil formation (climate, time, parent material, and biota) are constant over a given space, it is variation in landform that drives variation in the distribution and composition of natural communities.

Of the environmental variables discussed here, it is landform that most resists quantification. Landform is a compound measure, which can be decomposed into the primary terrain attributes of elevation, slope, aspect, surface curvature, and upslope catchment area. The wide availability and improving quality of digital elevation data has made the quantification of primary terrain attributes a simple matter. Compound topographic indices have been derived from these primary attributes to model various ecological processes. We adopted the Fels and Matson (1997) approach to landform modeling. They described a metric that combines information on slope and landscape position to define topographic units such as ridges, sideslopes, coves, and flats on the landscape. That approach is described here: feel free to skip over the details, to the set of defined landforms that emerges from the process (Figure 1 and Table 3 below).

The parent dataset for the two grids used to construct the landforms is the 30 meter National Elevation Dataset digital elevation model (DEM) of the USGS. Step one was to derive a grid of discrete slope classes relevant to the Northern Appalachian landscape. We remapped slopes to create classes of 0-2˚ (0.0-3.5%), 2-6˚ (3.5–10.5%), 6-24˚ (10.5–44.5%), 24-35˚ (44.5-70.0%), and >35˚ (>70.0%) (vertical axes of Figure1). Ground checks have shown that, because the NED dataset averages slopes over 30 meter intervals, raster cells in the 2 steepest elevation classes contain actual terrain slopes of from about 35 to 60 degrees (in the 24-35˚ class) and 60 to 90 degrees (in the steepest class).

The next step was the calculation of a landscape position index (LPI), a unitless measure of the position of a point on the landscape surface in relation to its surroundings. It is calculated, for each elevation model point, as a distance-weighted mean of the elevation differences between that point and all other elevation model points within a user-specified radius:

$$LPI_o = [\sum_{1,n} (z_i - z_o) / d_i] / n,$$

where: z_o = elevation of the focal point whose LPI is being calculated,

z_i = elevation of point i of n model points within the search radius of the focal point

d_i = horizontal distance between the focal point and point i

n = the total number of model points within the specified search distance

If the point being evaluated is in a valley, surrounding model points will be mostly higher than the focal point and the index will have a positive value. Negative values indicate that the focal point is close to a ridge top or summit, and values approaching zero indicate low relief or a mid-slope position (Fig. 1).

The specified search distance, sometimes referred to as the "fractal dimension" of the landscape, is half of the average ridge-to-stream distance. We used two methods to fix this distance for each subsection within the region, one digital and one analog. The "curvature" function of the ArcInfo Grid module uses the DEM to calculate change in slope ("slope of the slope") in the landscape. This grid, when displayed as a stretched grayscale image, highlights valley and ridge structure, the "bones" of the landscape, and ridge-to-stream distances can be sampled on-screen. For our analog approach we used 7.5' USGS topographic quadsheets. In each case, we averaged several measurements of ridge-to-stream distances, in landscapes representative of the subsection, to obtain the fractal dimension. This dimension can vary considerably from one subsection to another.

[There is a third approach to fixing the landscape fractal dimension that is intriguing. A semivariogram of a clip of the DEM for a typical portion of the regional landscape can be constructed— it quantifies the spatial autocorrelation of the digital elevation points by calculating the squared difference in elevation between each and every pair of points in the landscape, then plotting half that squared difference (the "semivariance") against the distance of separation. A model is then fitted to the empirical semiovariogram "cloud of points." (This model is used to guide the prediction of unknown points in a kriging interpolation.) The form of the model is typically an asymptotic curve that rises fairly steeply and evenly near the origin (high spatial autocorrelation for points near one another) and flattens out at a semivariance "sill" value, beyond which distance there is little or no correlation between points. Though the sill distance, in the subsections where we tried this approach, was 2 or 3 times the "fractal distance" as measured with the first 2 methods, the relationship between the two was fairly consistent. With a little more experimentation, the DEM semivariogram could prove to be a useful landscape analysis tool.]

The next step was to divide the grid of continuous LPI values into discrete classes of high, moderately high, moderately low, and low landscape position. Histograms of the landscape position grid values were examined, a first set of break values selected, and the resulting classes visualized and evaluated. We did this for several different types of landscapes (rolling hills, steeply cut mountainsides, kame complexes in a primarily wet landscape, broad valleys), in areas of familiar geomorphology. The process was repeated many times, until we felt that the class breaks accurately caught the structure of the land, in each of the different landscape types. Success was measured by how well the four index classes represented the following landscape features:

- High landscape position (very convex): sharp ridges, summits, knobs
- Moderately high landscape position: upper side slopes, rounded summits and ridges, low hills and kamic convexities
- Moderately low landscape position: lower sideslopes and toe slopes, gentle valleys and draws, broad flats
- Low landscape position (very concave): steeply cut stream beds and coves, and flats at the foot of steep slopes

We assigned values 1-5 to the five slope classes, and 10, 20, 30, and 40 to the four LPI classes. Following Fels and Matson (1997), we summed the grids to produce a matrix of values (Fig. 1), and gave descriptive names to landforms that corresponded to matrix values. We collapsed all units in slope classes 4 and 5 into "steep" and "cliff" units, respectively. The ecological significance of these units, which are generally small and thinly distributed, lies in their very steepness, regardless of where they occur on the landscape.

Recognizing the ecological importance of separating occurrences of “flats” (0-2°) into primarily dry areas and areas of high moisture availability, we calculated a simple moisture index that maps variation in moisture accumulation and soil residence time. We used National Wetlands Inventory datasets to calibrate the index and set a wet/dry threshold, then applied it to the flats landform to make the split. The formula for the moisture index is:

$$\text{Moist\_index} = \ln [(\text{flow\_accumulation} + 1) /(\text{slope} + 1)]$$

Grids for both flow accumulation and slope were derived from the DEM by ArcInfo Grid functions of the same names.

For the ecoregional ELU dataset, upper and lower sideslopes are combined, and a simple ecologically relevant aspect split is embedded in the sideslope and cove slope landforms (Figure 2 and Table 3).

Last, waterbodies from the National Hydrography Dataset (NHD), which was compiled at a scale of 1:100,000 and is available for the whole region, were incorporated into the landform layer with codes 51 (broader river reaches represented as polygons) and 52 (lakes, ponds, and reservoirs). Single-line stream and river arcs from the NHD were not burned into the landforms--only those river reaches that are mapped as polygons.

Landform units for an area of varied topography in the southeastern New Hampshire are shown in map view in Figure 2.

<u>The Ecological Land Unit Grid</u>

With the elevation, substrate, and landform layers, all the elements for assembling ecological land units, or ELUs, are in place. ELU code values for each cell in the region-wide grid are simply the summed class values for elevation zone, substrate, and landform for that cell. For example, a cell in a wet flat (landform 31) at 1400 feet (elevation class 2000) on granitic bedrock (substrate class 500) would be coded 2531.

ELU_code = Elev class (ft) + Substrate class + Landform

Elev class (ft)	Substrate class	Landform
1000 (0-20)	100 Acidic sed/metased	4 Steep slope
2000 (20-800)	200 Acidic shale	5 Cliff
3000 (800-1700)	300 Calc sed/metased	11 Flat summit/ridgetop
4000 (1700-2500)	400 Mod. calc sed/metased	13 Slope crest
5000 (2500-3600)	500 Acidic granitic	21 Hilltop (flat)
600 (3600+)	600 Mafic/intermed granitic	22 Hill (gentle slope)
	700 Ultramafic	23 N-facing sideslope
	800 Coarse sediments	24 S-facing sideslope
	900 Fine sediments	30 Dry flat
		31 Wet flat
		32 Valley/toe slope
		41 Flat at bottom of steep slope
		43 N-facing cove/draw
		44 S-facing cove/draw
		51 River
		52 Lake/pond/reservoir

Fig. 1: Formulation of landform models from land position and slope classes.

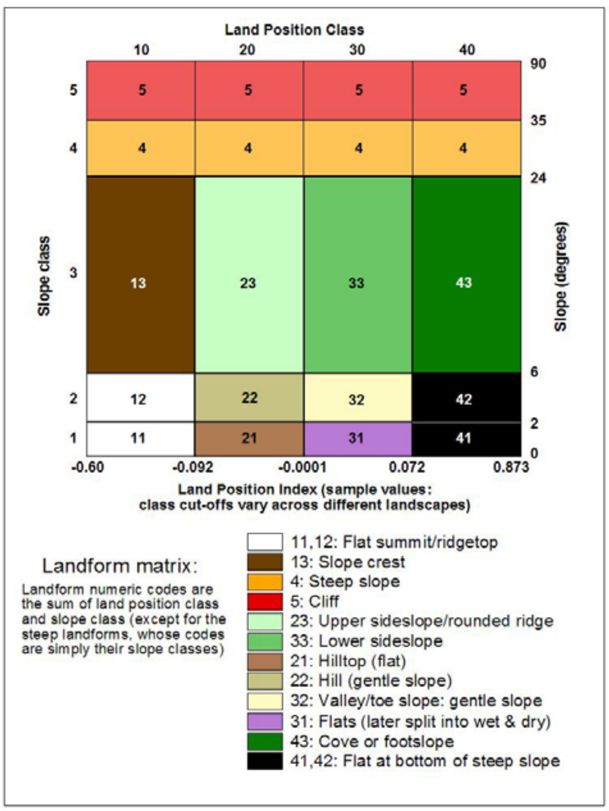
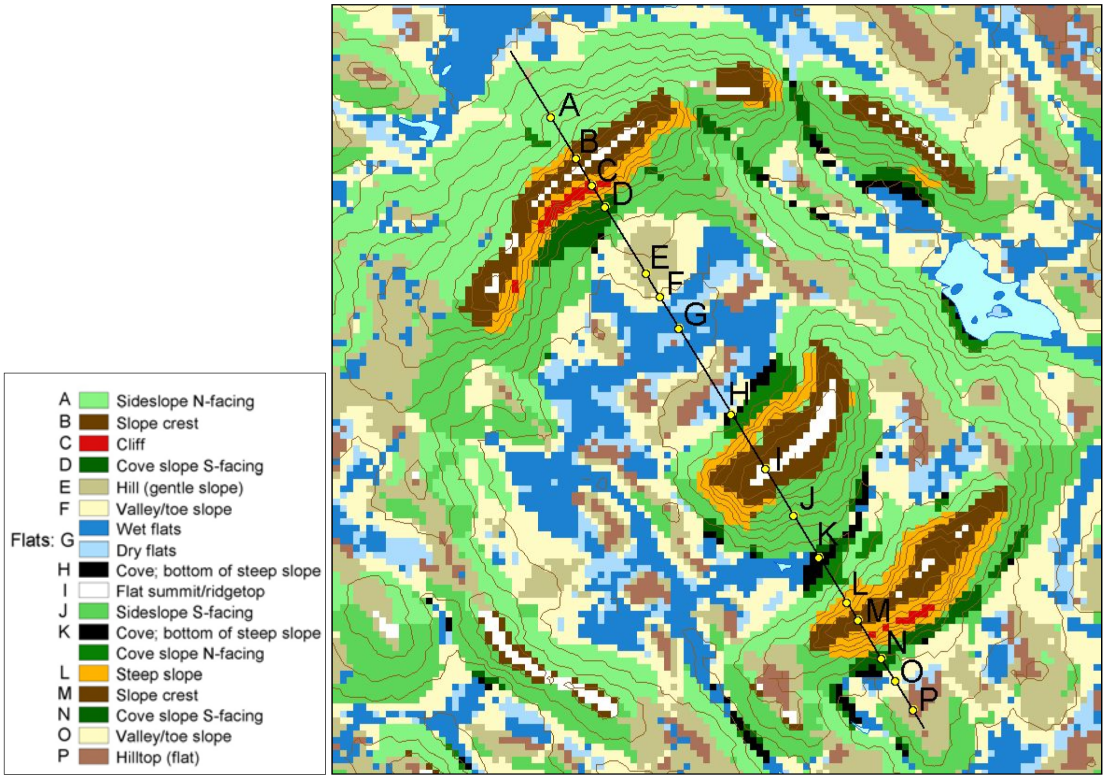


Fig. 2: Landforms in Pawtuckaway State Park, NH



For more information on landform development, please consult the full article "Fels, J, and K.C. Matson. 1997. A cognitively-based approach for hydrogeomorphic land classification using digital terrain models." which is available on the internet at: www.ncgia.ucsb.edu/conf/SANTA_FE_CD-ROM/sf_papers/fels_john/fels_and_matson.html

Detailed Data Sources and Methods

Elevation

U.S. Geological Survey. 2002-2008.National Elevation Dataset (NED) 30m. Sioux Falls, SD http://ned.usgs.gov/

Gesch, D.B., 2007, The National Elevation Dataset, in Maune, D., ed., Digital Elevation Model Technologies and Applications: The DEM Users Manual, 2nd Edition: Bethesda, Maryland, American Society for Photogrammetry and Remote Sensing, p. 99-118.

Gesch, D., Oimoen, M., Greenlee, S., Nelson, C., Steuck, M., and Tyler, D., 2002, The National Elevation Dataset: Photogrammetric Engineering and Remote Sensing, v. 68, no. 1, p. 5-11.

Regionally Significant Species of Greatest Conservation Need

A. **NatureServe 2011 NatureServe Central Databases. Arlington, Virginia. U.S.A. Precise locational (Element Occurrence) data polygons for all species in the following states: Connecticut, Delaware, District of Columbia, Maryland, Maine, New Hampshire, New Jersey, New York, Rhode Island, Virginia, Vermont, and West Virginia. Data Source: NatureServe (www.natureserve.org) and its Natural Heritage member programs.** NatureServe and its Natural Heritage member programs have developed a Multi-Jurisdictional Dataset (MJD). The creation of the MJD is aimed at improving conservation planning and actions by providing access to a comprehensive dataset of U.S. and Canadian species and ecological communities. These data are dependent on the research and observations of many scientists and institutions, and reflect our current state of knowledge. Many areas have never been thoroughly surveyed, however, and the absence of data in any particular geographic area does not necessarily mean that species or ecological communities of concern are not present. The data was exported from NatureServe 2/2011.
B. **Pennsylvania Natural Heritage Program, Pittsburg, PA. U.S.A.** The Pennsylvania Natural Heritage Program (PNHP) is a partnership of the Department of Conservation and Natural Resources, the Western Pennsylvania Conservancy, the Pennsylvania Fish and Boat Commission, and the Pennsylvania Game Commission. The Pennsylvania Natural Heritage Program (PNHP) provided The Nature Conservancy (TNC) with GIS shapefiles and tabular data for Element Occurrences for non-Federally listed tracked birds, mammals, terrestrial invertebrates, plants, and natural communities contained in the PNHP database for the entire state of Pennsylvania. For amphibians, reptiles, fish, aquatic invertebrates (e.g., mussels, odonates) and species listed under the US Endangered Species Act, PNHP was only able to provide Environmental Review polygons. The data was exported from the Pennsylvania Natural Herigate Program 2/2011.
C. **Massachusetts Natural Heritage & Endangered Species Program. Westborough, Massachusetts. U.S.A.** The Massachusetts Natural Heritage & Endangered Species Program is part of the Massachusetts Division of Fisheries and Wildlife. The Massachusetts Natural Heritage and Endangered Species Program provided The Nature Conservancy with GIS shapefiles and tabular data for all Element Occurrences contained in the NHESP database for species and natural communities

within the state. The data was exported from the Massachusetts Natural Heritage & Endangered Species Program 1/2011.

D. **Delaware Natural Heritage and Endangered Species Program. Smyrna, Delaware. U.S.A.** The Delaware Natural Heritage and Endangered Species Program is part of the Delaware Division of Fish and Wildlife. The Delaware Natural Heritage and Endangered Species Program provided The Nature Conservancy with GIS shapefiles and tabular data for all Element Occurrences contained in the NHESP database for species and natural communities within the state. The data was exported from the Delaware Natural Heritage and Endangered Species Program 2005.

How did we consistently map species occurrences and do the hexagon overlay? All source species occurrence datasets were converted to point features if they were not already in point format for this intersection. Centroids were created by The Nature Conservancy from the following sources using the XTools extension (ver. 6.0) for ArcGIS:

- Massachusetts Natural Heritage & Endangered Species Program Element Occurrence Record Source polygons
- Massachusetts Natural Heritage & Endangered Species Program Element Occurrence Record Source lines
- NatureServe Multi-Jurisdictional Dataset polygons
- Pennsylvania Natural Heritage Program Environmental Review polygons

These were combined with data already in point format from:

- Delaware Natural Heritage and Endangered Species Program Element Occurrence Record
- Massachusetts Natural Heritage & Endangered Species Program Element Occurrence Record source points
- Pennsylvania Natural Heritage Program Element Occurrence Record point representations of polygon records

The following types of centroids were classified as precise enough for the overlay with 1000 acre hexagons:

1) The NatureServe MJD most precise available polygon occurrences where the representational accuracy was listed as very high, high, or medium.
2) The NatureServe MJD most precise available polygon occurrences where the representational accuracy was listed as unknown or blank but the polygon was < 125 acres in size, the minimum size allowable for a procedural feature to be classified as of medium representational accuracy
3) All occurrences obtained from Massachusetts Natural Heritage Program
4) All occurrences obtained from Delaware Natural Heritage Program
5) Pennsylvania Natural Heritage Program Element Occurrence Records for non-Federally listed tracked birds, mammals, terrestrial invertebrates, plants, and natural communities

The following types of occurrences were classified as not precise enough for the centroid overlay with 1000 acre hexagons:

1. The NatureServe MJD most precise available polygon occurrences where the representational accuracy was listed as low or very low
2. The NatureServe MJD most precise available polygon occurrences where the representational accuracy was listed as unknown or blank and the polygon was >= 125 acres in size
3. Pennsylvania amphibians, reptiles, fish, aquatic invertebrates (e.g., mussels, odonates) and species listed under the US Endangered Species Act for which PNHP could only provide Environmental Review polygons.

<u>Roads and Railroads</u>

Roads: Tele Atlas North America, Inc., 2009. U.S. and Canada Streets Cartographic. 1:100,000 Tele Atlas StreetMap Premium v. 7.2 ESRI® Data & Maps: StreetMap. 2009 Data Update: North America. Redlands, California, USA. U.S. and Canada Streets Cartographic represents streets, highways, interstate highways, roads with and without limited access, secondary and connecting roads, local and rural roads, roads with special characteristics, access ramps, and ferries within the United States and Canada.

Railroads: Tele Atlas North America, Inc. 2009. U.S. and Canada Railroads. 1:100,000. ESRI® Data & Maps: StreetMap. 2009 Data Update: North America. Redlands, California, USA. U.S. and Canada Railroads represent the railroads of the United States and Canada.

How did we create Road/Railroad Density? We calculated a wall-to-wall dataset of the road and railroad density (meters/hectare) within a 1,000 meter radius of each 30m pixel for the New England and Mid-Atlantic States. We compiled roads from the following sources: 1) Roads: Tele Atlas North America, Inc., 2009. U.S. and Canada Streets Cartographic. 1:100,000 Tele Atlas StreetMap Premium v. 7.2 ESRI® Data & Maps: StreetMap. 2009 Data Update: North America. Redlands, California, USA. U.S. 2) Railroads: Tele Atlas North America, Inc. 2009. U.S. and Canada Railroads. 1:100,000. ESRI® Data & Maps: StreetMap. 2009 Data Update: North America. Redlands, California, USA. From this dataset we excluded 4-wheel drive trails, walking trails, and ferry lines because these features were not consistently mapped across states. Using the remaining class 1-8 roads and all railroads, we calculated the density of line features using the ESRI ArcGIS 9.3 Workstation GRID command LINEDENSITY (<lines>, {item}, {cellsize}, <SIMPLE | KERNEL>,{unit_scale_factor}, {radius}) with the parameters linedensity (mrg_rd18rr.shp, none, 30, simple, 10000, 1000). We had to divide the region into 8 tiles for analysis and create integer outputs due to the large file sizes involved. Each of the 8 tile areas was also buffered out by 10km prior to running through the linedensity command to make sure the border section of each tile was accurately calculated. These 10km buffer area results were then clipped off before combining the 8 tiles into a resultant regional dataset. The final dataset was also clipped to the state boundaries.

Land Cover

U.S. Geological Survey. 2011. National Land Cover Dataset 2006. Sioux Falls, SD
http://www.mrlc.gov/nlcd2006_downloads.php

NLCD 2006 quantifies land cover and land cover change between the years 2001 to 2006 and provides an updated version of NLCD 2001. These products represent the first time this type of 30-meter cell land cover change has been produced for the conterminous United States. Products were generated by comparing spectral characteristics of Landsat imagery between 2001 and 2006, on an individual path/row basis, using protocols to identify and label change based on the trajectory from NLCD 2001 products. A formal accuracy assessment of the NLCD 2006 land cover change product is planned for 2011.

NLCD 2006 Product Descriptions:

NLCD 2006 Land Cover - An updated circa 2006 land cover layer (raster) for the conterminous United States for all pixels. The resultant product for the northeast distinguishes 15 land cover classes: Open Water, Developed Open Space, Developed Low Intensity, Developed Medium Intensity, Developed High Intensity, Barren Land (Rock/Sand/Clay), Deciduous Forest, Evergreen Forest, Mixed Forest, Shrub/Scrub, Grassland/Herbaceous, Pasture/Hay, Cultivated Crops, Woody Wetlands, and Emergent Herbaceous Wetlands.

NLCD 2006 Land Cover Change – A land cover layer (raster) containing only those pixels identified as changed between NLCD 2001 Land Cover Version 2.0 and NLCD 2006 Land Cover products for the conterminous United States.

NLCD 2006 Percent Developed Imperviousness - An updated circa 2006 continuous imperviousness estimate layer (raster) for the conterminous United States for all pixels. The impervious surface data classifies each 30m pixel into 101 possible values (0% - 100%).

NLCD 2001/2006 Percent Developed Imperviousness Change – A raster layer containing the difference of those imperviousness values that changed between NLCD 2001 Percent Developed Imperviousness Version 2.0 and NLCD 2006 Percent Developed Imperviousness.

Stream Barriers: Dams and Waterfalls

1. **Dams. The Nature Conservancy. 2011. Northeast Regional Dam Dataset Version 3/1/2011. The Nature Conservancy Eastern Conservation Science Office. Boston, MA.** This dataset represents the result of a project to compile a dataset of dam barriers in the northeast states (ME, NH, VT, MA, CT, RI, NY, PA, NJ, DE, MD, VA, WV, DC) and spatially link the dams to the correct stream flowline in the USGS National Hydrography Plus (NHD-Plus) 1:100,000 stream dataset. A standardized, repeatable, feasible, and most accurate dam snapping method was developed and implemented to create this dataset. Primary steps included 1) snapping each state's dams to the 1:100,000 NHD flowlines, using a 100m snapping tolerance, 2) coding the dams for prioritization for manual review, 3) manual error checking of the prioritized dams, 4) returning the data to the states for expert review, and 5) re-incorporated the state edits into the final snapped dataset. Detailed data sources include
   - CT: Connecticut DEP, Inland Water Resources Div. Publication date 1996. Retrieved April 2009.
   - DE: Delaware Dams: DNREC; 2007
   - MA: MA Division of Ecological Restoration April 2009
   - MD: MD Department of Natural Resources 2/12/2007, publication date 2009
   - ME: Army Corp of Engineers (USACE), Maine Emergency Management Agency (MEMA), Maine Department of Environmental Protection (MEDEP)(comp., ed.), Maine Office of Geographic Information Systems (comp., ed.). Publication date 2006
   - NH: NH Department of Environmental Services 4/2009
   - NJ: NJDEP - Bureau of Dam Safety and Flood Control Publication Date: 2001
   - NY: NYS Department of Environmental Conservation 2007; USGS Great Lakes Science Center Retrieved 4/15/2009
   - PA: Division of Dam Safety, Department of Environmental Protection 01/28/2010; PA Fish and Boat Commission Retrieved 7/20/2009
   - RI: RI Department of Environmental Management 6/2009
   - VA: VA Dept. of Game & Inland Fisheries 6/2009
   - VT: Vermont Agency of Natural Resources, Department of Environmental Conservation 4/2009 & 11/2009
   - WV: WV DNR: Wildlife Diversity and Technical Support Units 9/2009; WV Non-coal dams 6/2002, DMR Dams 6/2009, NID dams 10/2000: WV State GIS Data Clearinghouse: http://wvgis.wvu.edu/data/data.php
   - US Army Corps' National Inventory of Dams Retrieved 4/29/2008
   - USGS Geographic Names Information System (GNIS) 1/2009

2. **Waterfall: U.S. Geological Survey. 2009. Geographic Names Information System (GNIS) 1.2009. http://nhd.usgs.gov/gnis.html** Waterfall features were extracted from the Geographic Names Information System (GNIS) system. The GNIS was developed by the U.S. Geological Survey in cooperation with the U.S. Board on Geographic Names, and contains information about physical and cultural geographic features in the United States and associated areas, both current and historical. The database holds the Federally recognized name of each feature and defines the location of the feature by state, county, USGS topographic map, and geographic coordinates.

How did we create funcationally connected stream networks between dams? Functionally connected stream networks were calculated in a GIS using the Barrier Analysis Tool (BAT), a custom ArcGIS 9.3 toolbar that was developed for The Nature Conservancy by Duncan Hornby of the GeoData Institute at the University of Southampton, England. Inputs for the BAT include a single-flowline drendritic hydrography network and point locations representing barriers.

A single flowline network was developed from the USGS National Hydrography Plus (NHD-Plus) 1:100,000 scale hydrography for all streams with drainage areas >1 sq.mi. through a series of attribute queries and manual edits. This network was run through the BAT which produced a list of outstanding errors. These errors included loops created from digitizing errors in the NHDPlus (e.g. streams that cross ridgelines thus connecting two networks) as well as other special circumstances (e.g. canals which cut across the natural topography thereby creating loops). Manual editing was done to fix these segments and terminated when the BAT no longer produced error lists.

Dam location points were “snapped” to the hydrography network. Topological concurrence between the point locations and the hydrography lines was necessary for the subsequent analysis in BAT. Dams within 100m of the hydrography were snapped using the free ArcGIS Hawth’s tools. After dams were snapped, several error checks were run. These include reviewing: 1) that river names match in dam dataset and stream dataset 2) large dams that snapped to small streams 3) all dams on larger rivers 4) all large dams. These error checking fields were used to prioritize dams for manual review. After TNC performed internal manual review, snapped dam data was returned to the state contacts who had provided the data or other regional experts for their review.

The snapped dams and edited hydrography were entered into the BAT which used the dams to “fracture” the network, thus creating connected networks bounded by dams, waterfalls, or the topmost headwater node.

Example of functionally connected stream networks. Each network is bounded by dams and/or the topmost extent of headwater streams. Showing a unique color for each connected network