Extending the Northeast Terrestrial Habitat Map to Atlantic Canada

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Lead Organization: The Nature Conservancy
Award Recipient and Principle Investigators:

Mark G. Anderson, Ph.D.
The Nature Conservancy
Eastern Division
99 Bedford Street
Boston, MA 02111
Phone: 617-532-8354,
fax: 617-532-8400
manderson@tnc.org

Charles Ferree, M.S.
The Nature Conservancy
Eastern Region
99 Bedford Street
Boston, MA 02111
Phone: 617-532-8300
fax: 617-532-8400
cferree@tnc.org

Lead Agency: University of Massachusetts
Principal Investigator:
Kevin McGarigal, Ph.D.
Department of Conservation
University of Massachusetts
304 Holdsworth Natural Resources Center
Box 34210, Amherst, MA 01003
Fax: (413) 545-4358; Phone: (413) 577-0655
mcgarigalk@eco.umass.edu

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PUBLIC SUMMARY

The Northeast United States and Atlantic Canada share many of the same types of forests, wetlands, and natural communities, and from a wildlife perspective the region is one contiguous forest. However, resources are classified and mapped differently on the two sides of the border, creating challenges for habitat evaluation, species modeling, and predicting the effects of climate change. To remedy this, ecologists from The Nature Conservancy collaborated with a committee of scientists from various Canadian institutions to produce the first international map of terrestrial habitats for northeast North America. The project used extensive spatial data on geology, soils, landforms, wetlands, elevation and climate. Additionally, all four provinces contributed spatially comprehensive forest inventory data consisting of 3 million polygons depicting the tree composition of individual forest stands. The Atlantic Conservation Data Centre contributed precise spatial locations of over 200,000 species. The resulting map shows the distribution of 40 upland and wetland habitats, 29 of which are shared by both countries. It has been integrated with the Northeast Terrestrial Habitat Map that covers 13 northeast states and the District of Columbia in the US. This project was funded by The Department of the Interior Northeast Climate Science Center and the North Atlantic Landscape Conservation Cooperative.

PROJECT SUMMARY

Purpose and Objectives

The objective of this project was to develop a comprehensive terrestrial habitat map for the Atlantic Canada section of the North Atlantic Landscape Conservation Cooperative region by extending the Northeast Terrestrial Habitat Map (Ferree and Anderson 2011) to Maritime Canada and southern Quebec. The final map consists of a spatially comprehensive GIS grid of 30 meter pixels with a legend portraying the habitats of Canada using a standard classification that matches the US classification. The map can be used as a basis for climate change research, conservation inventory, species modeling, ecosystem service estimates, and other cross border research related to the extent and distribution of natural habitats.

Organization and Approach

The map covers all of the land area of New Brunswick, Nova Scotia, Prince Edward Island, and the southern portion of Quebec. Development of the map was guided by a steering committee of Canadian ecologists from provincial agencies, academic institutions, and the Conservation Data Centre (CDC). Contributions of millions of precisely located plots, species occurrences, and forest inventory stand polygons were essential to the success of this project. We had excellent participation from many Canadian agencies and NGOs, and were aided in assembling the steering committee by the Atlantic Conservation Data Centre (AC CDC) and Nature Conservancy Canada (NCC). Our mapping approach followed the one developed for Northeast Terrestrial Habitat Map but the individual models were all created afresh for this project and each was customized to the available data and Canadian landscape. A field-based accuracy assessment was not included in this project.

Steering Committee

To guide the project we established a steering committee of 46 ecologists, biologists, foresters, and GIS analysts representing all four Canadian provinces (Table 1). Members were mostly staff from provincial agencies, but we also had representatives from academic institutions and non-governmental organizations such as Nature Conservancy Canada (NCC) and the Canadian Parks and Wilderness Society (CPAWS). The US Fish and Wildlife's North Atlantic Landscape Conservation Cooperative and NatureServe were represented as well. The committee met quarterly by Web Ex to review products, and was essential in pointing us towards key datasets. For each Web call we prepared materials illustrating issues related to a key topic such as: habitat classification, geophysical analysis, or forest inventory data, and we prepared specific questions concerning the accuracy or utility of a dataset. We started each call with a 20 minute presentation on the subject of interest and then followed with a round robin where each committee member gave their thoughts and perspective on each question. These sessions were invaluable in helping us understand Canadian habitats and develop an appropriate classification system. They were also essential in steering us towards the best available datasets, and several individuals were instrumental in helping us obtain the forest inventory data that became the foundation of the project.

Detailed review of the final product by the steering committee will take place after the submission and posting of the final datasets, at which time the map and dataset will be available to all members of the team for careful inspection of places that they are familiar with. We are developing a process to collect and process feedback on this product so that we can schedule systematic updates to the map.

Table 1. Steering committee for this project.

Members:	**ORG**	**Members:**	**ORG**
Andrew Milliken	fws.gov	Margo Morrison	natureconservancy.ca
Camilla Melrose	gnb.ca	Marie-Josée Côté	mddefp.gouv.qc.ca
Chris Miller	cpaws.org	Mary Lynn McCourt	gov.pe.ca
Claude Morneau	mrn.gouv.qc.ca	Matt Smith	pc.gc.ca
Dan Beaudette	gnb.ca	Mélanie Major	mrn.gouv.qc.ca
David Mackinnon	gov.ns.ca	Mike Montigny	gov.pe.ca
Deanna McCullum	forces.gc.ca	Pascal Hébert	natureconservancy.ca
Devin Ward	gmail.com	Patrick Nussey	natureconservancy.ca
Don Faber-Langendoen	natureserve.org	Peter McLaughlin	gnb.ca
Frédéric Poisson	mddelcc.gouv.qc.ca	Peter Neily	gov.ns.ca
Guyy Jolicoeur	mddep.gouv.qc.ca	R.A. Lautenschlager	mta.ca
James Churchill	gmail.com	Rob Cameron	gov.ns.ca
Jean-Pierre Laniel	mddefp.gouv.qc.ca	Rosemary Curley	gov.pe.ca
Jocelyn Gosselin	mrn.gouv.qc.ca	Sarah Robinson	mta.ca
Joel Bonin	natureconservancy.ca	Scott Makepeace	gnb.ca
Jonathan Kierstead	gov.ns.ca	Scott Schwenk	fws.gov
Josh Noseworthy	natureconservancy.ca	Sean Basquill	gov.ns.ca
Karel Allard	ec.gc.ca	Sean Blaney	mta.ca
Karen Beazley	dal.ca	Shane Heartz	nrcan-rncan.gc.ca
Katie Porter	nsnt.ca	Sherman Boates	gov.ns.ca
Lesley Sneddon	natureserve.org	Steve Gordon	gnb.ca
Line Couillard	mddefp.gouv.qc.ca	Tingxian Li	mddefp.gouv.qc.ca
Louise Gratton	jeangaudet.ca	Vince Zelazny	gmail.com

Source Data

The success of this project was dependent on access to high quality datasets depicting the ecological structure and condition of the region. We compiled over 40 comprehensive datasets covering a breadth of themes from the physical conditions of the region (e.g. precipitation, temperature, landforms, geology), to forest management (stand type, cutting history, soils), to anthropogenic structures (roads, agriculture, development). We highlight the key datasets here but see the accompanying excel table for the full list of data sources.

To map the ecological template of the region we compiled digital geology maps from each province and crosswalked them into nine lithochemical geology classes following Anderson and Ferree (2010). The classes, which have been shown to correspond well with species distribution patterns, are as follows:

1. Acidic Sedimentary
2. Acidic Shale
3. Calcareous Sedimentary
4. Moderately Calcareous Sedimentary
5. Acidic Granitic
6. Mafic
7. Ultramafic
8. Coarse surficial
9 Fine Surficial

Information on soil types was obtained from various sources including some of the forest inventory data described below. Bedrock geology data were particularly useful in modeling "small patch" habitats that occur on very specific edaphic settings such as calcareous fens or coastal plain ponds.

We created a 30-m landform model using a digital elevation model and following methods described in Anderson and Weaver (2015). The model uses topographic slope, aspect, and relative position, in combination with a flow accumulation model to delineate 17 landforms:

1. Cliff
2. Steep slope NE facing
3. Steep slope SW facing
4. Summit
5. Slope crest
6. Sideslope NE facing
7. Sideslope SW facing
8. Cove NE facing
9. Cove SW facing
10. Valley/toeslope
11. Slope bottom flat
12. Low hilltop flat
13, Low hill gentleslope
14. Dry flat
15. Moist flat
16. Wet flat
17. Open water

The landforms were useful in mapping specific habitats and also in recognizing broader landscape patterns such as the drumlin swarms in western Nova Scotia or mountain ranges in northern New Brunswick and Quebec.

Climate data were obtained from WorldClim (Hijmans et al. 2005) which is a set of global climate grids with a spatial resolution of about 1 square kilometer. The data were used to map a variety of climate variables such as mean annual temperature, mean annual precipitation, precipitation during the warmest month etc. Climate data were useful in delimiting the range and limits of some ecosystems.

Hydrology data were obtained from the National Hydro Network (NHN, Government of Canada 2002) which provides a geometric description and a set of basic attributes for Canada's inland surface waters including: lakes, reservoirs, watercourses (rivers and streams), canals, and islands, as well as constructions and obstacles related to surface waters. The NHN is created from existing data at the 1:50,000 scale or better. Wetlands were obtained from several sources including the forest inventory data described below. Wet area maps (Murphy et al 2008) were obtained for parts of Nova Scotia and New Brunswick. Wet area maps are models delineating hydrologically-sensitive areas across New Brunswick, Nova Scotia at high resolution of 10 m generally and 1 m where possible.

We obtained Forest Inventory datasets for each province and three from private timber companies in New Brunswick:

1. Nova Scotia Department of Natural Resources

2. New Brunswick Department of Natural Resources
3. Prince Edward Island, Department of Agriculture and Forestry
4. Quebec Provincial Forest Inventory Database (Perron, J., Morin, P., et al. 2011)
5. J.D. Irving, J.D. Limited, Woodlands Division
6. Acadian Timber
7. Fornebu Lumber Company Inc.

These datasets were used with the permission of their data sources and became the foundation of the habitat map. In general, the provincial datasets are created and managed by the respective Department of Natural Resources or Department of Forestry, each of which maintains ongoing inventory programs to monitor the province's natural resources. In Nova Scotia for example, forest resources are monitored by two complementary measurement systems: photo interpretation and permanent forest inventory plots. The former generates aerial photos for a portion (1/10) of the province each year, and uses paired photographs to delineate homogeneous stands of trees and interpret crown closure, stand height, species and land capability. From these interpreted attributes, estimates such as stand basal area and volume are computed. The permanent forest inventory plots consists of thousands small plots that are visited at regular (5-10 year) intervals. Plot number varies by province but is considerable. Nova Scotia, for example, maintains 3,250 small (0.04 ha) plots on which they track fine-scale forest components such as species composition, volume, and growth. The timber management companies follow a similar set of forest inventory protocols. Again, we are grateful to each province and timber management company for contributing data to this project.

The forest inventory data consist of over three million polygons depicting homogeneous forest stands at a fine scale. Polygon sized ranged from one to several hectares depending on the stand: Nova Scotia (1,090,670 polygons, mean size 5.0 ha), New Brunswick (778,700 polygons, mean size 6.5 ha), Quebec (1,157,000 polygons, mean size 5.7 ha), PEI (174,944 polygons, mean size 2.8 ha). Each polygon had information on 30-40 attributes and these were relatively consistent, although not standardized, among the provinces and timber companies. In addition to basic identification and spatial attributes each polygon had information on its tree overstory composition and structure. For instance, the Nova Scotia inventory lists the four dominant tree species and their percent cover as well as the height and crown closure of the stand (Table 2). Taken collectively these datasets provided comprehensive and detailed information on canopy composition with a level of precision unlike anything available in the United States.

The comprehensive set of forest stand polygons, in concert with the ecological data, formed our essential mapping units. Although the inventory datasets were built primarily as silvicultural and resource management tools, the information they provided on the composition, stand development, and management history of each stand was comprehensive, and included information on the nature of non-forested patches as well. When supplemented with data on geology, soils, wetlands, topography, climate, and elevation we could usually place the stand into one of the habitats described in the classification. In many case the relationship between the unit and the classification type was one-to-one, but in other cases a habitat might consist of a homogenous landscape setting combined with a set of closely related forest units.

Table 2. Example of the Forest Inventory attributes (Nova Scotia)

Field Name	Description	Length	Type
FOREST_	Format conversion artifact. Not a unique identifier, not currently in use	11	D
FOREST_ID	Same as STAND_	11	D
MAPSTAND_	Unique identifier including the MAPSHEET and STAND_ or EUNIT and STAND_	13	C
WETLND	Not currently in use	4	I
LNDCLASS	Forest, non-forest, and island groupings. A redefinition of the first two characters of the FOR_NON item.	2	I
FORNON	Code indicating forest/non-forest grouping	2	I
SPECIES	Up to 4 forest tree species and their percentages in order of percentage values, total percentage 10 (100%), percentage values enter as 01 - 10% 02 - 20% ..... 10 - 100%	16	C
CRNCL	First story crown closure percentage	2	I
HEIGHT	First story height in meters	2	I
ALLHEIGHT	Flag for uneven aged stands '*'	2	C
SS_SPECIES	Second story species group	2	C
SS_CRNCL	Second story crown closure percentage	2	I
SS_HEIGHT	Second story height in meters	2	I
SITE_SW	Softwood metric load capability in m^3/ha/year	2	I
SITE_HW	Hardwood metric load capability in m^3/ha/year	2	I
FLDCHK	Field check code	4	I
COVER-TYPE	Cover type classification based on basal area	1	I
PHOTOYR	Year forest attributes collected. 0 - depletion from satellite	4	I
HECTARES	Stand area in hectares	4	D
MAPSHEET	Mapsheet / tile name. Beginning character indicates the county	8	C
STAND_	Unique stand number within the MAPSHEET or within the EUNIT (exception of 9000's) 9000 - Road corridors 9001 - Rail corridors 9002 - Powerline corridors 9003 - Inland water (does not apply to lake wetlands) 9005 - Abandoned rail corridors 9006 – Ocean (does not apply to coastal habitat)	5	I
FOR_NON	Forest/non-forest - combination of LNDCLASS and FORNON	4	I
SP1	Main species type	2	C
SP1P	Main species percentage code 1-10	2	I
SP2	Second species type	2	C
SP2P	Second species percentage code 1-10	2	I
SP3	Third species type	2	C
SP3P	Third species percentage code 1-10	2	I
SP4	Fourth species type	2	C
SP4P	Fourth species percentage code 1-10	2	I
*WETCLASS	Wet forest stand indicator - a value of 1 indicates wet land/poor soil drainage beneath a forest stand for a significant portion of the growing season	1	I
*WC_TYPE	Wetland / coastal habitat type	2	C
*EUNIT	Editing unit number	3	I
*ESTAND	A unique number for a polygon within the editing unit	5	I
*ID_EFOREST	Combination of EUNIT & ESTAND for a unique stand number within the province (e.g., 023-00123)	9	C

A second key data set was the “element occurrence” database provided by the Atlantic Canada Conservation Data Centre (AC CDC). The Centre compiles and provides objective data about biological diversity in Atlantic Canada, and undertakes fieldwork to further the knowledge of the distribution and status of species and ecological communities of conservation concern.

They provided us with a database of almost 1,000,000 geo-located records of species occurrences including terrestrial vertebrates, vascular plants, bryophytes, macrolichens and many invertebrate groups. We made direct use of the 300,000 occurrences that had precise location to build the habitat models. This included: amphibians (1390), reptiles (10,581), birds (152,637), mammals (462), vascular plants (128,144) and bryophytes (5618).

The AC CDC also developed a table of indicator values for plant species in Atlantic Canada, which allowed us to confirm the presence of a habitat using an overlay of a species point (Table 3). This information was used to provide independent confirmation of patterns found in the forest inventory and ecological setting data, and as the basis for some of the “small patch” habitat models (e.g. edaphic communities that occur in small distinct patches) such as a calcareous cliff.

We compiled several ecological land classification schemes for the region. Canada’s National Ecological Framework was particularly useful in framing the basic distribution patterns of many terrestrial habitats. Most relevant were the Ecoprovince, Ecoregion, and Ecodistrict levels which were used to determine the boundaries of some habitat distributions. Ecoprovince is characterized by major assemblages of structural or surface forms, faunal realms, and macro climate. Ecoregion is characterized by distinctive regional ecological factors. Ecodistrict (a subdivision of ecoregion) is characterized by a distinctive assemblage of relief, landforms, geology, soil, vegetation, water bodies and fauna.

Table 3. Example of the indicator information 2312 plant species mapped in the AC CDC element occurrence data.

Temperate Deciduous	
x	Species of richer deciduous forests in Nova Scotia with overall ranges extending well south of Nova Scotia, at least into central or southern USA as mapped in BONAP's North American Plant Atlas online.
xa	Species of richer deciduous forests in Nova Scotia with overall ranges extending only moderately south of Nova Scotia into northern USA, or further south only in the higher Appalachian Mountains as mapped in BONAP's North American Plant Atlas online.
xb	Species of richer deciduous forests in Nova Scotia with limited range extension south of Nova Scotia into northern USA as mapped in BONAP's North American Plant Atlas online.
ACPF	
x	characteristic of southern Nova Scotia lakeshores, including associated open wetlands AND with floristic affinity to Atlantic Coastal Plain
xa	aquatic species characteristic of southern Nova Scotia lakes AND with floristic affinity to Atlantic Coastal Plain
y	characteristic of southern Nova Scotia lakeshores, including associated open wetlands but lacking floristic affinity to Atlantic Coastal Plain
ya	aquatic species characteristic of southern Nova Scotia lakes, including associated open wetlands but lacking floristic affinity to Atlantic Coastal Plain
o	species with Atlantic Coastal Plain affinity occurring largely or exclusively in non-shoreline habitats (including uplands)
pH	
c	strong indicator of calcareous conditions
c1	fairly strong indicator of calcareous conditions
c2	slight or possible indicator of calcareous conditions; often strong or fairly strong indicator when not in coastal area
ic	fairly indifferent to soil pH, but perhaps leaning to the more calcareous
i	indifferent to soil pH
a-	slight or possible indicator of acidic conditions
a	strong indicator of acidic conditions
halophyte	
x	occurring in strongly saline conditions
b	occurring in brackish conditions but typically excluded from full salinity sites
seep	
shore	associated with seepage along shores, primarily along rivers over top of bedrock or gravel, sometimes with a thin organic layer
forest	associated with seeps and springs under forest cover (sometimes in quite small patches within uplands)
floodplain	
m	plants strongly associated with floodplain terrace meadows along rivers or streams, sometimes including sites that are wet for only a short period annually
mf	plants strongly associated with floodplain terrace meadows and forests along rivers or streams, sometimes including sites that are wet for only a short period annually
f	plants strongly associated with floodplain terrace forests along rivers or streams, sometimes including sites that are wet for only a short period annually
shore	
x	frequently or exclusively present on lake, river and stream shores within the zone kept open by annual water level fluctuation
swamp	
x	occurring in forested or tall shrub wetlands; species only occurring under forest canopy in forested peatlands are not listed here
marsh	
x	occurring in non-peatland, herbaceous-dominated wetlands
peatland	
x	occurring in peatlands but not primarily associated with richer fen communities; these are generally species of open conditions, though many will also occur under forest canopy in forested peatland
f	occurring in peatlands primarily in association with richer fen communities

Terrestrial Habitat Classification System

The classification used for this mapping project was an expansion of the US Northeastern Terrestrial Habitat Classification System (Gawler 2008). This classification was developed as a comprehensive and standardized representation of habitats for wildlife that would be consistent across states and provinces, and consistent with other regional classification and mapping efforts. It is based on the "ecological system" classification created by NatureServe (Comer 2010, Comer et al 2003). Ecological systems are intended to be applicable at medium and large scales, and to supplement the finer-scale approaches used within states and provinces for specific projects and needs. The classification is meant to provide a common base for characterizing wildlife habitats to facilitate cross border communication, and to promote an understanding of terrestrial and aquatic biodiversity patterns across the Northeast. It is not intended to replace or override provincial classifications (which, in many cases, are more detailed), but rather to put them into a broader context.

A number of resources exist that describe the Northeast Terrestrial Habitat Classification System and the mapping methods used to produce the US map in greater detail. We refer readers to the follow documents:

For explanation of the classification system:
Northeastern Terrestrial Wildlife Habitat Classification. Gawler, S. C. 2008a. Report to the Virginia Department of Game and Inland Fisheries on behalf of the Northeast Association of Fish and Wildlife Agencies and the National Fish and Wildlife Foundation. NatureServe, Boston, Massachusetts.102 pp. http://rcngrants.org/project-final-reports

For descriptions and photos of the terrestrial habitats:
Northeast Habitat Guides: A companion to the terrestrial and aquatic habitat maps. Anderson, M.G. M. Clark, C.E. Ferree, A. Jospe, A. Olivero Sheldon and K.J. Weaver. 2013. The Nature Conservancy, Eastern Conservation Science, Eastern Regional Office. Boston, MA. http://nature.ly/NEhabitatguide

For explanation of the mapping methods:
A Map of Terrestrial Habitats of the Northeastern United States: Methods and Approach. Ferree, C., and M.G. Anderson. 2013. The Nature Conservancy, Eastern Conservation Science, Eastern Regional Office. Boston, MA. https://nature.ly/NEhabitat

The term "habitat" generally refers to the environment – physical and biological – that provides the necessary food, shelter, and other needs of a particular organism. However, the Northeast Terrestrial Habitat Classification system uses ecological cover types defined by vegetation to describe habitat types for one or more wildlife species. "Terrestrial" refers to all upland and wetland habitats including estuarine marshes and floodplains. River and stream habitats have been defined in a separate project.

The issue of scale is particularly relevant to a regional classification. Individual animals that make up species populations are mostly responding to very local conditions – a particular type of tree canopy cover, or the availability of standing deadwood, or a litter layer, or the presence of surface water, or any of a myriad of other factors. A regional map cannot represent such fine-scale detail. Instead, we are adopting the widely used convention of habitats as a "coarse filter" in which more broadly defined habitats or community types represent habitat for more than one species (Gawler 2008). Many of these habitats can be mapped at a regional scale, facilitating international approaches to wildlife conservation.

The coarse filter approach can then be supplemented on a local basis by a “fine filter” approach for species-specific needs not otherwise addressed.

Ecological Systems

Ecological systems developed by NatureServe (Comer 2010) were the basic classification scale for this project. Ecological systems are defined as “recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding. They are intended to provide a classification unit that is readily mappable, often from remote imagery, and readily identifiable by conservation and resource managers in the field.” They are defined based on biogeographic region, landscape scale, dominant cover type, and disturbance regime. Examples in the Northeast include Laurentian-Acadian Large River Floodplain or Acadian-Appalachian Alpine Tundra.

Ecological systems are vegetation based and can be described as a collection of finer-scale associations that occur together in some combination on the ground. The name does not refer to a specific spatial scale because environmental and disturbance factors occur at many different scales. To help clarify scale, each ecological system was assigned to one of four landscape patterns: matrix systems, which define the landscape character of an area, occupying large contiguous areas and typically with wide ecological amplitudes, generally occupying areas of > 2,000 hectares under natural conditions (e.g. Boreal Highland/Northern Balsam Fir Forest); large patch systems, which occupy particular landscape settings and have a narrower ecological amplitude, generally occupying 50-2,000 hectares under natural conditions (e.g. Northern Appalachian - Acadian Acidic Swamp); small patch systems, occurring under very localized environmental conditions that are distinctly different from the surrounding landscape (e.g. Laurentian-Acadian Calcareous Cliff and Talus); and linear systems, which occur as long narrow strips, often at the ecotone between terrestrial and aquatic systems (e.g. Laurentian-Acadian Large River Floodplain).

Attention to scale was an important part of the mapping process because the classification includes habitat types that are extensive and cover millions of hectares, as well as small, specific-environment types that may cover only a hectare or two. We recognize that some of these “small patch” habitats were not amenable to regional mapping, but may be important for characterizing wildlife habitat.

The ecological systems nest within macro-groups (broader-scale units such as Northern Hardwood and Conifer Forest) and are tied to, but not a part of, the U.S. National Vegetation Classification standard (FGDC 2008). The hierarchy allows flexibility in applying the classification. We need to understand our eastern habitats, and the ecological consequences and vulnerabilities associated with climate change within a multi-province, multi-state, and international context. A consistent definition, description, and accurate dataset of habitats helps clarify where conservation is most needed, and a mapped classification further allows for analysis of terrestrial habitats and regional connectivity across political borders. The information can lead to an improved understanding of the actions required to address the consequences of climate change on wildlife and plants.

Modification to the Classification for Atlantic Canada

To identify and describe the terrestrial habitats for Atlantic Canada, we first developed a list of potential types based on the US classification and map. This included all habitats occurring in any of the seven states of New England and New York (ME, NH, VT, NY, MA, RI, and CT). The list of potential types was circulated to the steering committee along with descriptions from Anderson et al (2013) that included a characterization of the vegetation, ecological setting, associated species, common names used by the states, and maps of the US distribution. Additionally, we reviewed existing classifications for Maritime Canada and the grouping schemes used in the forest inventory data. Although these were generally not defined the same as the ecological systems, one recent document " *Forest Ecosystem Classification for Nova Scotia, Part I: Vegetation Types* (2010) prepared by the Nova Scotia Department of Natural Resources and authored by Peter Neily, Sean Basquill, Eugene Quigley, Bruce Stewart, and Kevin Keys, was particularly useful. We relied on the authors for clarification.

Through a series of web-ex calls and one face-to-face meeting in New Brunswick, a subset of the steering committee carefully reviewed the list of potential types and sorted them into two categories

1. Accepted with Modification: The habitat occurs in Maritime Canada but the description and concept needed to be expanded to include the Canadian examples. These systems were analogs to the US systems that typically occurred in the same ecological setting and had somewhat similar flora but also contained some distinctly Canadian elements.
2. New/Added: New type that occurs in Canada but was not recognized or described for the US.

As a result, we agreed on 43 terrestrial habitats to be mapped for this project: 27 upland, 14 wetland, and 2 anthropogenic (Table 4 and 5). Seven of these were new and only occur in Atlantic Canada. Four types were modifications of young, planted or heavily managed forest (early seral-conifer, early seral-hardwood, plantation, old field forest) which also occur in the US but cannot be mapped with the currently available data. Early seral forests in the US occur widely but are mapped to their parent type and not broken out as a separate entity. The counterpart of the plantation and old field forest in the US classification is a broadly defined "plantation and ruderal forest." The other 29 types were shared with the US although most required a slightly expanded concept.

We created brief working descriptions of the eleven new habitats that are mapped for Atlantic Canada (Table 6). All other habitats are described in the Northeast Habitat Guides: A companion to the terrestrial and aquatic habitat maps: http://nature.ly/NEhabitatguide . Our intention is to modify the existing US descriptions and add the new Canada types into the habitat guides in 2015.

Habitat Models and Mapping Process

Our basic approach to creating the habitat map was to develop an accurate spatial model for each individual habitat, and then integrate all the models into a single dataset. To model a habitat, we first developed an understanding of its ecology, environmental setting, species composition, and distribution pattern by reviewing the existing literature and talking with Canadian experts familiar with the habitat. Using this information, we developed an ecological signature for each habitat based on canopy cover, tree composition, climate and elevation limits, soil or bedrock preferences, landforms, land position, moisture regime and geographic distribution. Based on the ecological signature, a spatial model of the habitat was then developed using the forest inventory polygons combined with the wall-to-wall ecological information.

Each model was custom built for each habitat, and because the data were somewhat different across provinces most models were actually built for each habitat within each province. We plan to make the models and mapping criteria for each habitat available to interested parties. In spite of the idiosyncrasies in the custom models, we followed a consistent approach to the mapping that we have described and illustrated in a methods document (Ferree and Anderson. 2013). In the US we used millions of small landform-based units as our basic map unit. For each unit we generated information about its ecological characteristics: land cover class, geology, slope, elevation, etc. We then classified the units using Random Forest models calibrated by thousands of known occurrences of the habitat types. In Canada, the three million forest stand polygons replaced the landform units as the basic mapping unit. Like the landform units we attributed the polygons with information on their ecological characteristics. Unlike the landform units we had extensive information on the species composition and structure of every stand polygon which allowed us to map with a level of detail not possible in the US.

Table 4. Terrestrial Habitats of Atlantic Canada: Upland habitats sorted by macro-group

Terrestrial Habitats	Scale	Accepted (w modifications)	New	Total
Upland		**18**	**9**	**27**
Forest				
Eastern North American Boreal Forest				
Boreal Highland/Northern Balsam Fir	Matrix		1	1
Northern Mesic Hardwood & Conifer Forest				
Acadian Low Elevation Spruce-Fir-Hardwood Forest	Large patch - matrix	1		1
Acadian Sub-boreal Spruce Flat	Large patch - matrix	1		1
Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest	Patch: lrg/small	1		1
Appalachian (Hemlock)-Northern Hardwood Forest	Matrix	1		1
Cold Temperate Coastal Conifer Forest	Matrix		1	1
Cold Temperate Northern/Higher Elevation Conifer Forest	Matrix		1	1
Coniferous and Mixedwood Karst Forest	Patch: lrg/small		1	1
Deciduous Karst Forest	Matrix		1	1
Laurentian-Acadian Northern Hardwood Forest	Patch: lrg/small	1		1
Laurentian-Acadian Northern Pine-(Oak) Forest	Matrix	1		1
Laurentian-Acadian Pine-Hemlock-Hardwood Forest	Patch: lrg/small	1		1
Laurentian-Acadian Red Oak-Northern Hardwood Forest	Large patch - matrix	1		1
Early Seral (Intolerant) Conifer Forests	Large patch - matrix		1	1
Early Seral (Intolerant) Hardwood and Mixedwood Forests	Large patch - matrix		1	1
Appalachian and Northeastern Oak - Hardwood & Pine Forest				
North Atlantic Coastal Plain Maritime Forest	Patch: lrg/small	1		1
Northeastern Interior Pine Barrens	Patch: lrg/small	1		1
Temperate and Boreal Plantation Forest				
Plantation forests	Patch: lrg/small		1	1
Eastern North American Ruderal Forest				
Old field Forest	Patch: lrg/small		1	1
Non-Forest				
Eastern North American Alpine Shrub & Grassland				
Acadian-Appalachian Alpine Tundra	Patch: lrg/small	1		1
Eastern North American Cliff & Rock Vegetation				
Acadian-North Atlantic Rocky Coast	Patch: lrg/small	1		1
Laurentian-Acadian Acidic Cliff and Talus	Patch: lrg/small	1		1
Laurentian-Acadian Calcareous Cliff and Talus	Patch: lrg/small	1		1
Northern Calcareous Scrub - Herb Vegetation				
Laurentian-Acadian Calcareous Rocky Outcrop	Patch: lrg/small	1		1
Northern Non-alkaline Scrub - Herb Rock Outcrop & Barrens				
N. Appalachian-Acadian Rocky Heath Outcrop	Patch: lrg/small	1		1
Eastern North American Coastal Beach				
Northern Atlantic Coastal Plain Dune and Swale/Sandy Beach	Patch: lrg/small	1		1
Eastern North American Shrubland & Grassland				
Shrublands & grasslands	Patch: lrg/small	1		1

Table 5. Terrestrial Habitats of Atlantic Canada: Wetland and Anthropogenic habitats sorted by macro-group

Terrestrial Habitats	Scale	Accepted (w modifications)	New	Total
Wetland		**12**	**2**	**14**
Eastern North American Atlantic Salt Marsh				
Acadian Coastal Salt Marsh, Acadian Estuary Marsh	Wetland/patch	1		1
North Atlantic Coastal Plain Tidal Salt Marsh	Wetland/patch	1		1
Eastern North American Wet Meadow & Marsh				
Laurentian-Acadian Freshwater Marsh	Wetland/patch	1		1
Laurentian-Acadian Wet Meadow-Shrub Swamp	Wetland/patch	1		1
North American Boreal & Sub-Boreal Bog & Fen				
Acadian Maritime Bog	Wetland/patch	1		1
Boreal-Laurentian Bog	Wetland/patch	1		1
Boreal-Laurentian-Acadian Acidic Basin Fen	Wetland/patch	1		1
Laurentian-Acadian Alkaline Fen	Wetland/patch	1		
North American Boreal Swamp & Floodplain Forest				
Boreal Wet Conifer Forest	Wetland/patch		1	1
Eastern Boreal Large River Floodplain	Linear	1		1
Northern and Central Floodplain Forest				
Laurentian-Acadian Large River Floodplain	Linear	1		1
Cold Temperate Northern Conifer Swamp	Wetland/patch		1	1
Northern Swamp Forest				
Laurentian-Acadian Alkaline Conifer-Hardwood Swamp	Wetland/patch	1		1
Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp	Wetland/patch	1		1
Anthropogenic		**2**		**2**
Developed				
Developed landcover classes		1		
Agricultural				
Agriculture		1		1
Grand Total (upland, Wetland/patch and anthropogenic)		32	11	43

Table 6. Description of new terrestrial habitats that occur only in Atlantic Canada

Habitat Name	Description
Boreal Highland/Northern Balsam Fir	A high elevation conifer forest of balsam fir and heart-leaved birch (as low as 350 m in Cape Breton region). Red spruces absent but white spruce or jack pine may be present. White spruce proportions usually increase at higher elevations in some occurrences. Shrubs and herbs include *Viburnum edule, Goodyera repens, Sorbus decora,* and *Solidago macrophylla.*
Cold Temperate Northern/Higher Elevation Conifer Forest	A conifer forest of red spruce, yellow birch and other cold temperate species typical of side slopes and gently rolling landscapes. Transitional to Boreal highland/balsam fir forest where white spruce and black spruce replace red spruce, and fir becomes more dominant. Typical herbs include *Dryopteris campyloptera* and *Oxalis montana*.
Cold Temperate Coastal Conifer Forest	A cold conifer forest of exposed areas on the Nova Scotia and Fundy coast. It is dominated by mixtures of white spruce, black spruce, balsam fir and yellow birch, with red spruce becoming common on the Fundy coast. This is a fog forest with thick humus and extensive bryophytes and liverworts. *Vaccinium vitus-idaea* is typical. Most prominent where wind-exposure is high, becoming rare in the more sheltered coasts inland. This forest is important for migratory birds.
Coniferous and Mixedwood Karst Forest	A conifer or mixed forest of regions with unique karst topography and exposed gypsum/limestone bedrock with a thin or variable soil mantle. Identified by the scattered presence of vascular plants associated with karst habitat (*Carex eburnea, Cystopteris bulbifera, Cornus rugose)* and a closed canopy of hemlock and red spruce. Sugar maple and other species are possible. The shrub layer often includes striped maple and round-leaf dogwood, with Christmas fern, wood goldenrod and white baneberry found in the herb layer
Deciduous Karst Forest	A hardwood forest of regions with unique karst topography and exposed gypsum/limestone bedrock. This habitat co-occurs with the coniferous and mixedwood karst forest but is dominated by sugar maple, and identified in part by the scattered presence of vascular plants associated with karst habitat. In the Maritimes, karst topography (highly irregular "egg carton" surface relief) is usually associated with gypsum sites, but similar landforms have been observed over limestone and dolomite. High quality examples of either type of karst forest are relatively rare.
Early Seral (Intolerant) Conifer Forest	Early successional conifer forest dominated by softwoods such as white spruce, tamarack, white pine or balsam fir. Aspen may be present. Both the shrub and herb layers can be species diverse, but they are usually poorly developed. These young conifer forests can have high habitat value for a number of neotropical migrant songbirds and gamebirds.

Habitat Name Continued	Description
Early Seral (Intolerant) Hardwood and Mixedwood Forest	Early successional forest dominated by shade intolerant hardwoods such as red maple, white birch, grey birch, trembling aspen, and large-tooth aspen, This type cover a range of soil moisture and nutrient regimes due to the ability of hardwoods in this group to adapt rooting patterns to site conditions. Well-developed shrub and herb layers along with reduced bryophyte/lichen cover are typical. These are generally short-lived, even-aged forests that result from stand-level disturbance events. Overstory species occur in pure or mixed combinations, often with scattered residuals from the previous stand present. Poorer sites will have bracken, mayflower and teaberry, whereas richer sites will have species such as sarsaparilla, asters, goldenrods and grasses. The bryophyte layer is usually poorly developed.
Boreal Wet Conifer forest	Boreal wet forest with water at or near the surface for most of the year. Generally dominated by black spruce with or without fir. Understory of sphagnum and plants tolerant of wet, acidic organic soils. They typically occur on moderately exposed, level to depressional topography, at elevations high enough to support the boreal highland/northern balsam fir forest.
Cold Temperate Northern Conifer Swamp	Forested coniferous and mixed swamp of the cold temperate region where it intergrades with cold temperate northern/higher elevation conifer forest. White, black and red spruce with alders and wetland herbs
Old Field Forest	Forest originating on abandoned farmland where soils have been enriched through the addition of organic matter by tillage or grass cover (pasture). Forests are early successional and typically dominated by softwood species: white spruce, tamarack, white pine or balsam fir. Aspen is common and can be dominant. Red oak and white ash can sometimes be found on richer old field sites
Plantation forest	Seeded or planted forest stands being intensively managed for timber production and in various stages of development.

Project Results, Analysis and Findings

The results of this project are a spatially comprehensive GIS grid of 30 meter pixels with a legend portraying the extent and distribution of the terrestrial habitats of Atlantic Canada using a standard classification that matches the US classification (Figure 1-3, http://maps.tnc.org/nehabitatmap).

Figure 1. Terrestrial Habitats of Atlantic Canada. This shows the extent of the habitat mapping completed for this project. Use the map viewer to explore the map: http://maps.tnc.org/nehabitatmap

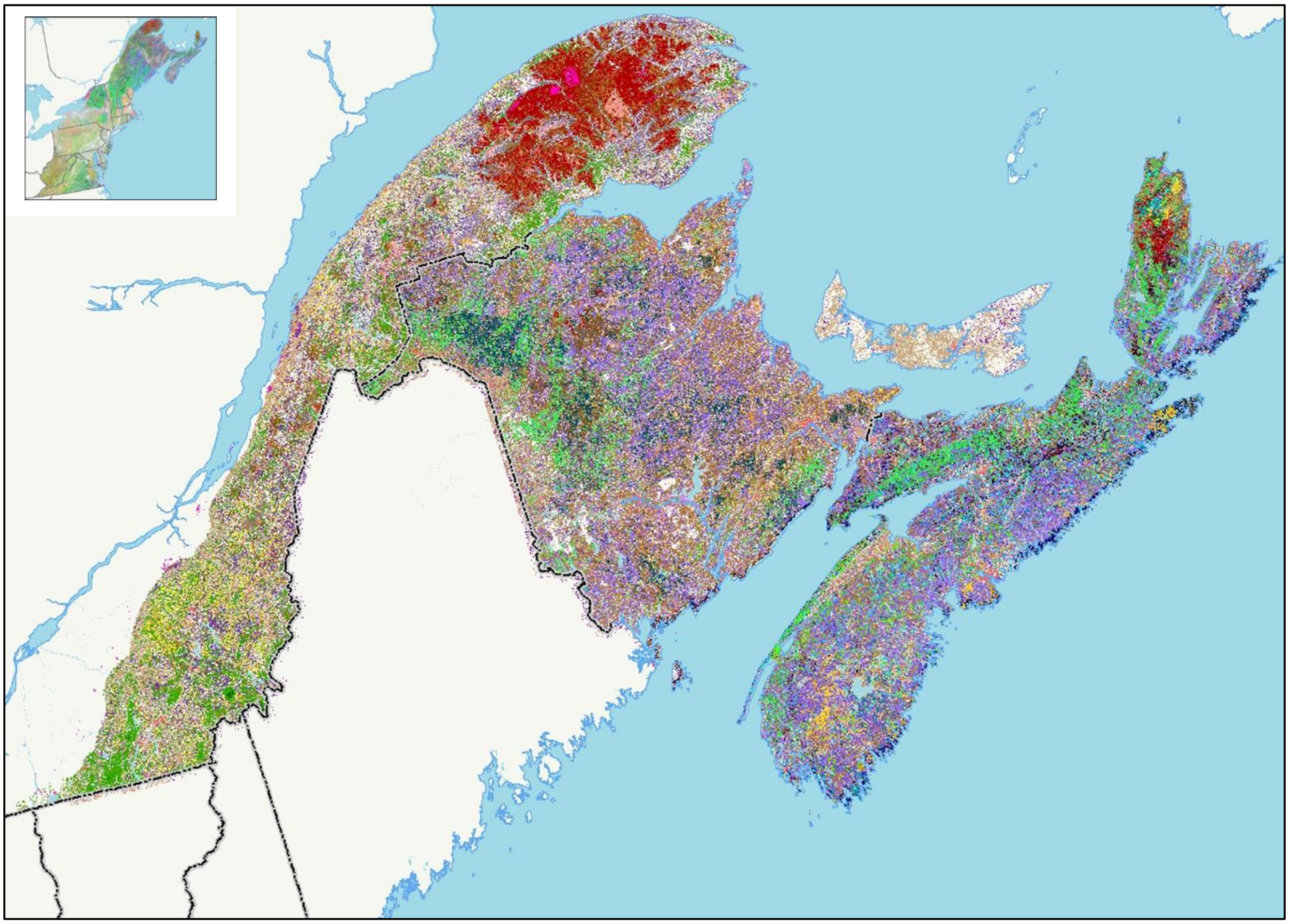
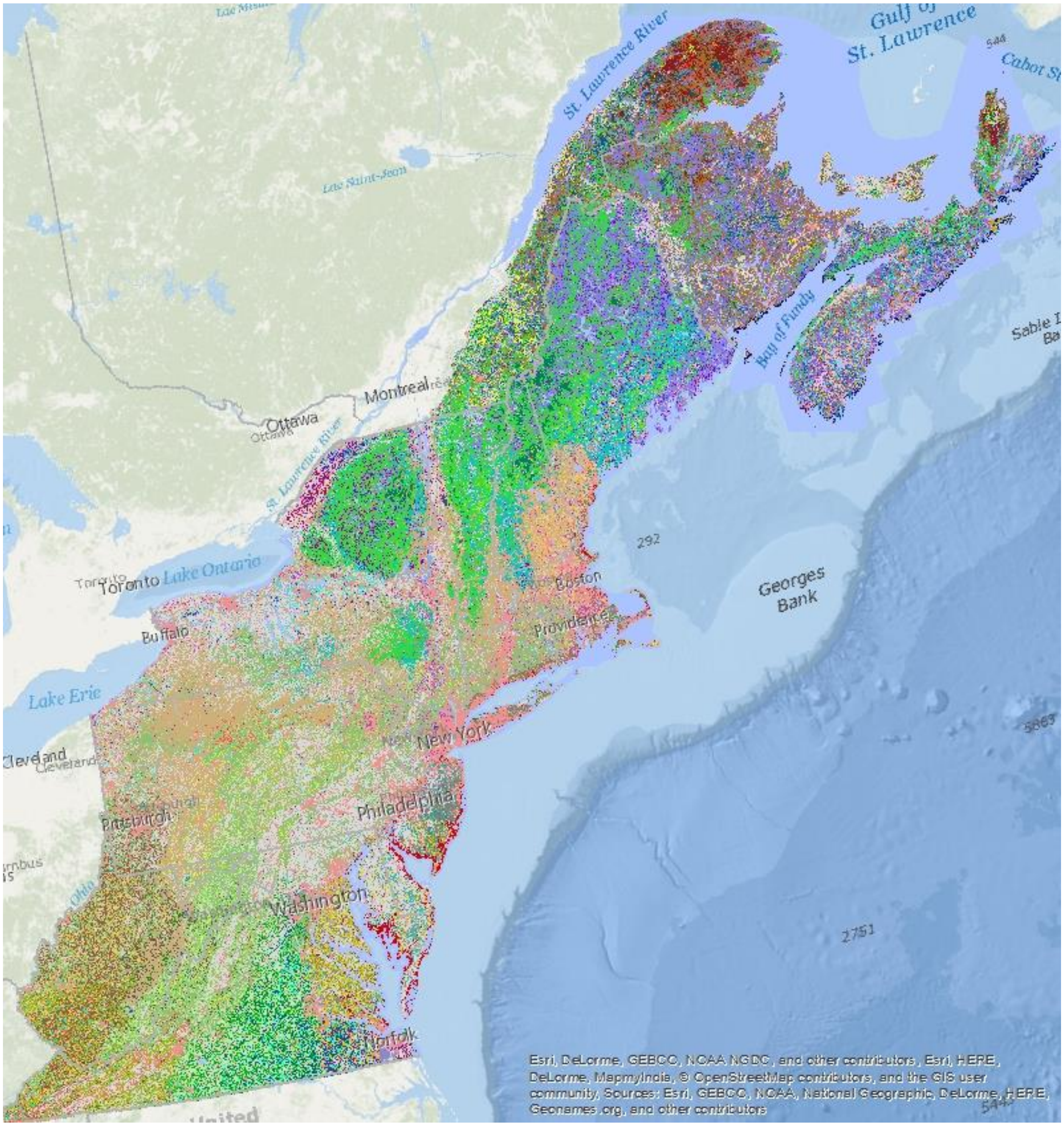


Figure 2. Legend for the Northeast Terrestrial Habitat Map. This legend goes with Figure 1 and 3. Because it is difficult to separate so many colors go to the map viewer to explore the map (http://maps.tnc.org/nehabitatmap) and click on any habitat to get the legend.

Figure 3 Terrestrial Habitats of the US and Atlantic Canada. This shows the full extent of the integrated habitat mapping for the Northeast US and Atlantic Canada. Use the map viewer to explore the map: http://maps.tnc.org/nehabitatmap



Conclusions and Recommendations
The major obstacle we encountered during this project was a simple overload of data, often more than our software could process. Our initial plan of attributing every forest inventory polygon with ecological data that could then be queried proved too cumbersome to perform, and we had to find new ways to process and integrate the information. Moreover, the volume of data did not always give a clear picture as to the ecological character of the stand and we often had to generalize from fine-scale data that gave conflicting information. Finally, simply obtaining the data was also a slower process than we expected and although we are extremely grateful for the contributions that enabled us to map the habitats comprehensively; we did not obtain all the forest inventory datasets until late in the project.

One difference between the US and Canada map is the extensive information on forest condition, and the recognition of seral stages in the Canada map that has no counterpart in the US. The steering committee felt that this information was critical to the utility of the map, and we were, of course, interested in making the map as useful as possible to our Canadian partners. In order to make the US and Canada portions directly equivalent we will need to either develop a forest condition information for the US or simplify the Canada map by creating a legend that illustrates the most likely habitat that the areas in early seral stages will become. We plan to explore these two options in the near future, particularly the possibility of using some of the condition information created by the North Atlantic LCC's Designing Sustainable Landscapes project to estimate seral stage for the US.

A consistent, accurate, cross-border dataset of terrestrial habitats is a foundational product for ecological analysis. This first-of-its-kind product is of high value to the North Atlantic Landscape Conservation Cooperative, many US and Canadian natural resource agencies, academics, and NGOs such as The Nature Conservancy and The Nature Conservancy of Canada. It provides a platform for the coordination of projects with neighboring organizations in the US and Canada.

The habitat map allows users to better understand and anticipate the effects of climate change on forested, agricultural, and freshwater systems across both countries. Northeast species and habitats occur seamlessly across our borders and it is critical that we examine the ecological impacts and vulnerabilities due to climate change within this entire context. This project piloted and developed the methodology for creating a consistent habitat map across the entire climate center region and adjacent Canada. The methods could be applied in other climate centers bordering Canada. Additionally, the map provides a regional spatial classification foundation upon which further research can advance such as modeling expected changes in species distribution, tracking the loss or gain of specific habitats, and examining the connectivity within ecosystems from Virginia to Nova Scotia.

Outreach and Products
Up until this point, our outreach has focused on Canadian agencies and organizations in order to generate interest and support for the map. Additionally we have given a presentation on the results through the NECSC webinar series and presented one poster at the 2015 Northeast Fish and Wildlife Conference. Once the dataset is integrated with the US data we plan to launch an outreach program that includes the following:

1. Web presentations for US and Canada agencies describing the methods and results, with information on how to download and use the dataset. .
2. Revised habitat guides that provide information of the Canada-only habitats such as their distribution, environmental settings, composition and structure, level of securement, and associated species.

A webpage specifically for the project that contains information on the methods and results, instructions for downloading the data, and a web-map service where users can explore the dataset and read about the various habitats. The map service that may be viewed here: http://maps.tnc.org/nehabitatmap

The Northeast Climate Science Center Project Page may be found here:
http://necsc.umass.edu/projects/extending-northeast-terrestrial-habitat-map-atlantic-canada

The North Atlantic Landscape Conservation Cooperative Project Page may be found here:
http://northatlanticlcc.org/spatial-data/terrestrial/tnc-terrestrial-habitat

Restrictions: There are no restrictions on distributing this product. The data sources have viewed the final product and approve it to be shared.

Data Management: We submitted a data management plan in 2014 that complied with the USGS Fundamental Science Practices policy.

Citations

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