Project Title:
Permeable Landscapes for Species of Greatest Conservation Need.

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Project Director: Mark G. Anderson Ph.D. Director of Conservation Science,
The Nature Conservancy, East Division, 99 Bedford Street, 5th Floor, Boston, MA 02111. 617-532-8300 x 8354 phone, 617-532-8400 fax, manderson@tnc.org

Principal Investigators:

Arlene Olivero MS. Aquatic Ecologist
The Nature Conservancy, East Division
99 Bedford Street, 5th Floor, Boston, MA 02111
617-532-8300 x 8344 phone, 617-532-8400 fax
arlene_olivero@tnc.org

Melissa Clark MS. Spatial Ecologist
The Nature Conservancy, East Division
99 Bedford Street, 5th Floor, Boston, MA 02111
617-532-8300 x 8343 phone, 617-532-8400 fax
melissa_clark@tnc.org

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Project Summary

Landscape permeability is the ability of a heterogeneous land area to provide for passage of animals, equivalent to what some authors call "habitat connectivity." In this project we will evaluate and map the relative landscape permeability across a region of thirteen states using natural cover and anthropogenic barriers, and then test how the permeability patterns change when we account for climate gradients, landscape diversity, and climate change velocity. The analysis will be based new analytical tools (e.g. Circuitscape and Resistant Kernel models) applied to the regional maps of habitats and geophysical features. We aim to identify where the most important regional movement concentrations are under different scenarios, and particularly those areas where movements may be funneled due to constriction in the landscape. Using this information, we will measure the amount of flow, permeability, and resistance present in the region's roads and secured-lands network. The project will be by guided by a thirteen-state steering committee. We propose to spend the first quarter preparing the permeability data sets, the second quarter analyzing the patterns relative to climate and other gradients, the third quarter evaluating roads and secured lands, and the last quarter preparing the final products and examining them in the Connecticut River watershed.

Permeable Landscapes for Conservation under Climate Change.

This proposal addresses RCN Topic 4: *Identification of Regional Focal Areas and Corridors for the Conservation of Species of Great Conservation Need in the Northeast*

Product: A data set showing the relative permeability of the landscape, and patterns of potential movement flows, across a region of thirteen states; and a report detailing where landscape permeability changes might be particularly important due to climate gradients or landscape diversity. Analytical products will include: 1) the identification of regionally important regional movement concentrations - areas where movements may be funneled due to constriction in the landscape; 2) an analysis of the region's secured land network with respect to how it contributes to maintaining landscape permeability and a scoring of each tract with respect to connectivity; 3) Ranking and scoring of all major roads with respect to how much potential movement they restrict, and estimates of the increase to landscape permeability gained by mitigating the effects of each barrier.

Geographic Extent: The area covered in the report will include all states from Maine to Virginia, west to New York, Pennsylvania and West Virginia.

Background: Climate change is expected to shift seasonal temperature and precipitation patterns and 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 little extinction (Botkin et al. 2007). Now, pervasive landscape fragmentation disrupts ecological processes and impedes the ability of many species to move or adapt to changes. 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 of species responding to a changing climate.

Permeability 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). We use the term 'permeability' to distinguish from 'connectivity' that is commonly defined as the capacity of individual species to move between areas of good habitat via corridors and linkage zones (Lindenmayer and Fischer 2006, Beier et al. 2010). In contrast, facilitating the large-scale ecological reorganization expected from climate change - many types 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.

Tools have recently been developed to measure permeability as a continuous surface avoiding the need for discrete cores and linkages typical of many connectivity models. One of these, Circuitscape (Shaw and McRae 2008), has been used to interesting effect to examine how the physical arrangement of natural and modified habitats in the Northeast potentially affects the east-west and north-south flow of species migrations (Anderson et al 2012, Pelletier et al 2014). Circuitscape is based on electric current theory, and estimates the spatial patterns of permeability as the degree of directional "current flow" across a landscape (McRae et al. 2008). Phillips et al (2008) introduced a related concept of "network flow" to optimize a landscape for many species over time and the two approached can be used in a complementary way (Carroll et al 2013). As similar concept "conductance" was used in McGarigal et al. 2010 Conservation Assessment and Prioritization System (CAPS) http://www.umass.edu/landeco/index.html based on an resistant kernel model. All these tools model landscapes as conductive surfaces, with low resistances assigned to habitats that are most permeable to movement, and high resistances assigned to poor dispersal habitat or to movement barriers. Importantly, both programs measure how flow is channeled and funneled through each landscape cell based on the accumulation and configuration of surrounding cells; "current density" in circuitscape terminology. Thus a cell of landscape is scored not only on its own permeability characteristics but on how much flow (potential movement) is directed and channeled through it from surrounding cells. Finally there have been recent efforts to integrate climate gradients directly into models of permeability so that not only is the resistance of the landscape accounted for but the need to stay within a certain climatic regime (Nunez et al 2013).

In this revised proposal we aim to build on the above work to explicitly address climate change by modeling a continuous surface of relative permeability for the Northeast that integrates climate gradients and velocity, and landscape diversity specifically into the analysis. We will overlay the analysis with other regional scale datasets such as the secured land dataset and the terrestrial habitat map created and compiled under previous RCN grants: RCN 2007-01: Creation of Regional Habitat Cover Maps: Application of the NE Terrestrial Habitat Classification System, and RCN 2008-03 Regional Focal Areas for Species of Greatest Conservation Need based on Site Adaptive Capacity, Network Resilience, and Connectivity. We will use the results to highlight key linkages that appear to be important from several perspectives. The results and datasets will be made available to the Designing Sustainable Landscape developers, Agency staff, and the public.

Proposed Steps

Complete Literature Review on Permeability.
Summarize current literature on landscape permeability, migration and dispersal under climate change, and fragmentation. Differentiate the continuous permeability concepts from connectivity and corridors. Make the case for permeability as the right metric for climate change.

Perform Climate Change Specific Analysis of Permeability Assuming Various Hypotheses.
We will model permeability using the following inputs:

<u>Climate gradients:</u> Use mapped climate gradients for the regions (PRISM) to create a resistance layer that favors movement along unidirectional temperature gradients.

<u>Landscape Diversity</u>: Use maps of landscape diversity (topographic, elevation, and wetland density) to create a resistance grid where diverse landscapes have less resistance and flat landscapes have more.

<u>Climate velocity:</u> (if available) Use maps of the direction and velocity of climate changes with areas of high velocity as more resistance (Dobrowski 2010).

<u>Natural Cover:</u> Create maps of natural land cover, development and roads, to create a resistance grid where natural cover has less resistance than developed lands (the control)

<u>Integrated</u>: Integrate and compare the above models using Circuitscape to understand the sensitivity of the results to the various resistance grids and develop an integrated analysis that accounts for uncertainty across all the models.

Identify Key Linkage Areas for in the NALCC under Climate Change

We will overlay the results of the various permeability analyses with ecological and anthropogenic data in order to address specific conservation questions. For the ecological characterization we will use the map of terrestrial habitats, and the geophysical settings based on geology and landforms. To measure human uses and barriers, we will overlay the permeability analysis with the secured land data set and with major roads. Our goal is to answer the following questions:

1) Where are the key linkages using the areas of highly concentrated flow under multiple climate scenarios?
2) Which linkages are consistently found across multiple scales
3) Are some habitats positioned within or away from key linkages?
4) How does permeability correspond to the locations of existing secured lands and what is the relative degree that each secured land plays in maintaining it? Are some secured lands strategically placed to enhance permeability of the larger landscape?
5) Which major roads constitute the largest obstructions to regional scale permeability and which the least?

To answer these questions, we will combine the various permeability runs done with different climate scenarios or at different scales to identify the places that are identified under multiple scenarios and scales. We will intersect the permeability layers with the Northeast Terrestrial Habitat map and characterize each habitat by its permeability score to identify the areas of each habitat with the highest permeability. We will characterize each unit of secured land by its permeability score to identify the lands that currently contribute the most connectivity to the regional landscape or to their local landscape. Additionally we will identify the secured lands that fall in the least permeable landscapes. Finally we will intersect and characterize each segment of road with the value of its permeability and current density score (the degree of flow that passes over the road at any given cell), its traffic volume, and other information. The objective being to score and rank each road segment and estimate the relative degree to which each road segments decreases permeability.

We will examine the results in finer detail in a study region corresponding the LCC, Connecticut River watershed area. The goal will be to compare the results with other datasets developed specifically for the study area and test whether they correspond with other analysis of climate linkages in the area. The data will be provided to the appropriate staff for merging with the designing sustainable landscape outputs for the CT river valley.

Final
Write report and publish datasets on the Web
Present results at one Fish and Wildlife Workshop.

Timeline 2014

March – April:	Literature review, Create resistance grids, Establish small steering committee
May – June:	Run Circuitscape with various resistances at multiple scales
July –August:	Analyze and integrate results, Identify NALCC linkages
Sept-Oct:	Write up and circulate results for review
Nov- Dec:	Test and discuss results for the CT river watershed
January 2015	Prepare distributable datasets, Submit final report and data.

We will convene a committee of scientists representing Fish and Wildlife agencies, private organizations, and others to guide and review the work. Using calls or Web Ex we will display results of various analyses, explain how it was calculated, and review its utility to the users. In this manner we hope to ensure that our methods are appropriate to the intent of the users. As this grant progress, detail on how each overlay and analysis will be will be circulated. The final report will document the methods used to calculate permeability, the results of the various analysis, and an interpretation of its meaning with respect to conservation.

Detail on the State Steering Committee: To ensure the relevance of this work we will form a small steering committee meeting to guide the project and ensure the utility of the products. This collaborative network of scientists from state Fish and Wildlife agencies and private conservation organizations will participate in 1) reviewing the outputs of the circuitscape and the landscape conductance analyses, 2) review of the methods used to overlay and summarize the permeability results by habitat and secured lands, 3) review of the results including maps and charts, 4) quality control of the final report. We will host periodic Web Ex calls and web postings to maintain this discussion.

Background on TNC's Regional Science Office.
The Nature Conservancy's (TNC) Eastern Conservation Science office works collaboratively with state offices and science partners in government agencies and academic institutions to develop and maintain data on species and ecosystems of the region. For over 19 years we have compiled and managed information on the locations and quality of each conservation features within our region. Additionally our spatial databases include comprehensive region-wide information on constraints and human uses such as roads, dam, housing density, and managed lands.

Deliverables: A report including a description of the methods and the results of the analysis with respect to species, habitats, roads and secured lands. A data set containing information on landscape permeability across the region at the finest scale possible (estimated 90 m)

Proposed Budget:

Estimate of Project Costs:

	RCN Request	TNC Match	Total Cost
Salary[1]	$ 25,000	$ 25,000	$ 50,000
Fringe (42%)[2]	$ 10,500	$ 10,500	$ 21,000
Supplies/Materials[4]	$ 5,000	$ 5,000	$ 10,000
Indirect (23.13%)[3]	$ 9,368	$ 9,368	$ 18,735
Total	$ 49,868	$ 49,868	$ 99,735

Estimate of Project Costs:

[1]TNC staff time estimate of $50,000 represents approximately 210 days at current rates. A portion of this will serve as match and a portion will be grant-funded. The source of funds paying for the match costs is non-federal (private fundraising); and the match costs will not serve as match on any other federal grant. Personnel providing grant/match hours on this project include the Director of Conservation Science, Aquatic Ecologist, Spatial Data Analyst and other TNC staff.

[2]Fringe benefits for regular staff at 42% in accordance with our July 1, 2010 NICRA with the U.S. Department of the Interior (copy available upon request). Fringe benefits typically include paid time off, insurance, FICA, worker's comp, state unemployment taxes, 401(k), etc.

[3]Indirects costs in accordance with our July 1, 2010 NICRA with the U.S. Department of the Interior (copy available upon request).

[5]Supplies and Materials include the costs associated with hosting Web Ex meeting and final production costs such as printing, supplies/materials, phone costs associated with network conference calls, costs associated with final report production, etc.

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Principal Investigator Qualifications

Mark G. Anderson, PhD is the Director of Conservation Science of The Nature Conservancy's Eastern Region where he developed and performed ecological and biophysical assessments of large regions. Dr. Anderson developed the ecoregion assessment methodology and led science teams to apply the methodology to 8 ecoregion and in measuring conservation progress across TNC's eastern region. Dr. Anderson has been with TNC since 1991 and his papers have appeared in journals ranging from Bioscience to Environmental Management. His most recent publication is a chapter on integrating ecoregional planning at greater spatial scales. in S.C. Trombulak and R.F. Baldwin (eds.), Landscape-scale Conservation Planning.

Arlene P. Olivero, MS, is the Aquatic Ecologist and Geographic Information Systems Manager in TNC's eastern region. Ms. Olivero is responsible for GIS data preparation, analysis, documentation, map production, and technical support. She has led the aquatic portion of TNC's ecoregional assessments since 1998 and is co-leader of the regional Stream Habitat classification project (RCN 2006).

Melissa Clark, MS is the Spatial Data Manager in TNC's Eastern Conservation Science Office. Ms. Clark is responsible for development of complex modeling of landscape properties like connectivity and permeability. Her research interests include terrestrial resilience, landscape connectivity, conservation measures, marine spatial planning, and data access and distribution. Melissa has been with TNC since 2007 and is a co-leader on the species adaptive capacity project.