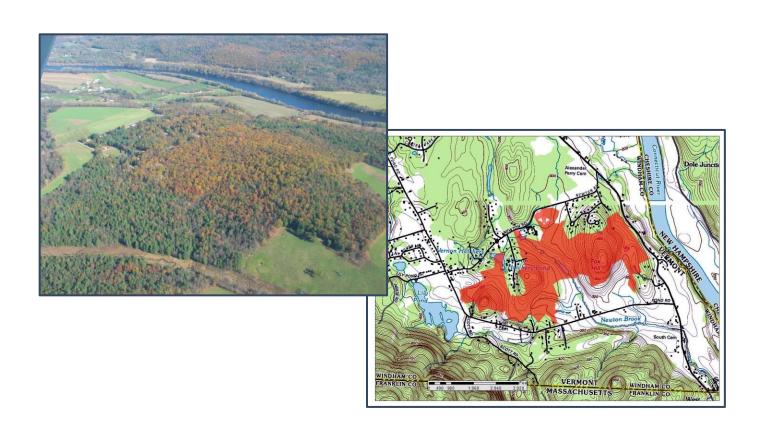# Vermont Habitat Blocks and Habitat Connectivity:
An Analysis using Geographic Information Systems

Vermont Fish and Wildlife Department
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ACKNOWLEDGEMENTS

Cover photo and map: The Fox Hill habitat block in Vernon.

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INTRODUCTION

Many wildlife species rely on large blocks of contiguous forest and secure connections to other large forest blocks for all or part of their habitat needs. For instance, the home range of an adult male black bear can be as large as 50 square miles. Black bear, fisher, otter, bobcats, and other species of wildlife move great distances to find food, water, dens, refuge, and other important habitat resources. Many songbirds require large areas of forest cover that are free from fragmentation and human disturbance. There are many other recognized ecological, social, and economic values of large contiguous forest blocks. These areas represent many of the natural heritage values and support the rural working landscape that makes Vermont unique in the developing landscape of the northeast.

Although total forest cover in Vermont has increased over the past few decades, contiguous blocks of forest have decreased in size as a result of residential and other development, road construction, and other forms of permanent land clearing. More recently, wind energy projects are recognized for their fragmenting effect on large blocks of contiguous habitat.

For purposes of this project a habitat block is defined as a contiguous area of natural vegetative cover with little or no permanent internal fragmentation from human development. The boundaries of habitat blocks are delimited by roads, other forms of permanent development, and agricultural lands. The term habitat block is used instead of forest block to reflect the varied habitat types that occur within these blocks, including interior forest habitat, forested and open wetlands, ponds and streams, cliffs, rock outcrops, and early successional forest.

Vermont's first Wildlife Action Plan was completed in 2005 (Kart et al. 2005). A priority conservation strategy identified in the Wildlife Action Plan was to "Identify and prioritize, for conservation, existing contiguous forest blocks and associated linkages that allow for upward and northward movement (of species) in response to climate change." This Vermont Habitat Blocks and Habitat Connectivity project was was undertaken to address this conservation strategy of the Wildlife Action Plan.

PURPOSE

This project was conducted in order to better understand the statewide distribution of contiguous habitat blocks. In addition, the goal has been to prioritize the significance of habitat blocks for their biological and conservation values and to assess potential threat to them from future habitat fragmentation. Finally, this project identifies likely road crossings and provides a basis for evaluating wildlife corridors (wildlife linkage habitat) and landscape connectivity. The specific objectives of the project include:

1. Identify habitat blocks using best-available Geographic Information Systems (GIS) data and accepted scientific methods.
2. Rank the habitat blocks for their biological and conservation value and for the potential threat to them from fragmentation.
3. Identify and rank the relative importance of potential wildlife road crossings statewide based on the structural suitability of adjacent habitat.
4. Develop a cost grid based on land cover data that can be used as a tool for evaluating potential road crossings and identifying potential wildlife corridors between identified habitat blocks using GIS software.

BACKGROUND

Habitat blocks are areas of contiguous forest and other natural habitats that are unfragmented by roads, development, or agriculture. Vermont's habitat blocks are primarily forests, but also include wetlands, rivers and streams, lakes and ponds, cliffs, and rock outcrops. Forests included in habitat blocks may be young, early-successional stands, actively managed forests, or mature forests with little or no recent logging activity. The defining factor is that there is little or no permanent habitat fragmentation from roads, agricultural lands, and other forms of development within a habitat block.

When referring to natural communities, wildlife habitat, and landscapes, fragmentation means dividing land with naturally occurring vegetation and ecological processes into smaller and smaller areas as a result of roads, land clearing, development, or other land uses that remove vegetation and create physical barriers to species' movement and ecological processes between previously connected natural vegetation.

Habitat blocks provide many ecological and biological values critical for protecting native species and the integrity of natural systems. These values include (Austin et al. 2004):
- supporting natural ecological processes such as predator-prey interactions and natural disturbance regimes;
- helping to maintain air and water quality;
- supporting the biological requirements of many plant and animal species, especially those that require interior forest habitat or require large areas to survive;
- supporting viable populations of wide-ranging animals by allowing access to important feeding habitat, reproduction, and genetic exchange; and
- serving as habitat for source populations of dispersing animals for recolonization of nearby habitats that may have lost their original populations of those species.

In addition, habitat blocks provide other social and economic benefits, which include (Austin et al. 2004):
- supporting public access to and appreciation of Vermont's forested landscape;
- providing important opportunities for education and research of forested ecosystems;
- providing forest management opportunities for sustainable harvesting of forest products; and
- providing forest management opportunities to maintain a mixture of young, intermediate, and older forest habitat.

One of the important reasons that habitat blocks provide these values is that they include areas of interior forest. Interior forest is forest that shows no detectable edge influence from adjacent development. Edge influence or edge effect is the change in composition, structure, or function of the forest near it's edge, as a result of influences from the adjacent development or land use (Harris 1984; Harper et al. 2005). Edge effects also occur in natural settings between two very different habitats or natural communities (such as lake shoreline and

adjacent forest), but the focus in this project is on the edge effects on forests from adjacent development.

Habitat Loss and Fragmentation

Habitat loss and fragmentation are considered two of the major factors driving loss of biological diversity and degradation of ecosystem services (such as air quality and climate regulation), both in the United States and globally (Hansen et al. 2005; Millenium Ecosystem Assessment 2005; Hoekstra et al. 2005; Harris 1984; and Saunders et al. 1991). In Vermont, habitat loss (the permanent conversion of habitat to a developed state) is probably most significant for sensitive habitats (such as wetlands, shoreline and riparian habitat, and vernal pools), rare species habitats, and rare natural communities (such as Pine-Oak-Heath Sandplain Forest and Limestone Bluff Cedar-Pine Forest). Whereas loss of these sensitive and rare habitats receives considerable conservation attention, fragmentation of Vermont's predominately forested landscape continues with much less attention.

However, the Vermont Fish and Wildlife Department and the Vermont Agency of Transportation have been working cooperatively for many years on addressing the effects of transportation on wildlife conservation (Austin et al. 2006; Austin et al. 2010). Also, the Roundtable on Parcelization and Forest Fragmentation, convened by Vermont Natural Resources Council and made up of over 100 private and public forest-related interestes, has made a series of recommendations on steps that can be taken to reduce parcelization and forest fragmentation in Vermont (Fidel 2007).

In most of Vermont, forest and habitat fragmentation results primarily from the construction of roads and associated development. In the Champlain Valley and some other areas of the state with highly productive soils, agricultural conversion has also been an important factor leading to habitat fragmentation.

There has been considerable scientific research on the biological and ecological effects of ecosystem fragmentation. Two review articles are especially helpful in summarizing this well-studied field (Saunders et al. 1991; Trombulak and Frissell 2000). Trombulak and Frissell's (2000) article focuses on the effects of roads (the primary source of habitat fragmentation) and breaks these ecological effects into the following seven categories.

Mortality from road construction. Road construction kills all plants and other sessile organisms as well as some slow-moving animals in the path of the road.

Mortality from collision with vehicles. Mortality of wildlife from collisions with vehicles is well-known by most Vermonters and is well studied. The majority of the information obtained from road-kills on Vermont highways is for larger mammals, especially deer, moose, bear, fox, coyote, and bobcat. However, many smaller mammals (mice, voles, moles, shrews, squirrels, skunks, muskrats, raccoon, weasels, mink, and otter), amphibians (frogs and salamanders),

reptiles (snakes and turtles), and birds are also killed by vehicle collisions. The number of insects killed along roads must be very high, and although there is probably little reason for concern about mortality of very common species, the effects on populations of rarer species of butterflies, dragonflies, and bees are unknown.

Modification of animal behavior. This is possibly the most recognized effect of habitat fragmentation on wildlife – many species avoid roads, especially roads that are wide, paved, and have high traffic volumes. Animal behavior is modified through at least five mechanisms: home range shifts, altered movement patterns, altered reproductive success, altered escape response, and altered physiological state (Trombulak and Frissell 2000). In North Carolina, black bears shifted their home ranges away from high road density areas (Brody and Pelton 1989). In a Vermont study, black bears selected areas away from roads (mean distance 674 meters for adult males) and many animals used roads as their home range boundaries, but seldom crossed these roads during daily and seasonal movement, especially in years with natural food availability (Hammond 2002).

Roads and other forms of habitat fragmentation create edge effect, reduce the area of interior forest habitat, and result in more forest fragments of smaller size. Forests in fragmented landscapes have been shown to support fewer forest interior nesting migratory birds (Donovan and Flather 2002). There is also increased nest predation by raccoons and other species and nest parasitism by brown-headed cowbirds in smaller forested patches of fragmented landscapes (Robinson et al. 1995; Keyser et al. 1998; Trine 1998). These examples show modification of behavior by nesting birds, predators, and bird nest-parasites in response partly to habitat fragmentation.

Disruption of the physical environment. Road construction results in transformation of the physical environment under the road but also has significant effects on the physical environment adjacent to the road. At least eight characteristics of the physical environment are altered by roads: soil compaction, increase in soil temperature, decrease in soil water content, increase in light, increase in dust, alteration of surface and ground water flow, alteration in the patterns of surface water runoff, and increase in sedimentation of adjacent streams, ponds, and wetlands (Trombulak and Frissell 2000). An additional physical alteration is the change in local wind patterns adjacent to roads and other permanent openings.

These physical alterations adjacent to roads or other permanent opening are what result in edge effects, which are most commonly observed as changes in species composition or structure of the adjacent forests. Changes in light, wind, and moisture alter canopy cover, plant recruitment, herbaceous plant density and richness, decomposition rates, tree blow-down from increased wind, and many other factors (Harper et al. 2005; Burke and Nol 1998). Edge effects on plant species composition have been shown to penetrate up to 60 meters (197 feet) on south-facing edges and 20 meters (66 feet) on north-facing edges in North Carolina mixed hardwood forests (Fraver 1994).

Alteration of the chemical environment. There has been extensive study of the effects of roads on the chemical environment. At least five classes of chemicals are introduced into the environment associated with road maintenance and use: heavy metals, salts, organic molecules, ozone, and nutrients (Trombulak and Frissell 2000). In Vermont, primarily as a result of road salt application and runoff, chloride concentations have been steadily increasing in Lake Champlain and most of its major tributaries since the early 1990s and there is growing concern about the effects on aquatic ecosystems (Shambaugh 2008). Phosphorus and sediments are also associated with road runoff in Vermont. In the Winooski River watershed, etimates are that over 40,000 metric tons of sediments are eroded from unpaved roads and over 15,000 kg of total phosphorus (Wemble 2013).

Spread of exotic species. Invasive, exotic species are recognized as one of the primary threats to biological diversity as they commonly out-compete native species (Allendorf and Lundquist 2003). Roads and other forms of fragmentation provide dispersal routes along which invasive, exotic species move through the landscape. The altered physical site conditions along roads make invasion more likely by removing native species and providing easier movement by wild or human vectors (Trombulak and Frissell 2000). Disturbed soil, increased light levels, and increases in soil nutrient levels are all features associated with road margins and disturbed forest edges that contribute to invasive plant species spread into forests (Saunders et al. 1991; Hutchinson and Vankat 1997). American robin nests in invasive, exotic honeysuckle and buckthorn have been shown to experience higher nest predation than nests in comparable native shrubs in an Illinois forest fragment (Schmidt and Whelan 1999).

Changes in human use of land and water. Roads that fragment forests provide additional access for human use and development. Although human uses such as hiking may have relatively minor ecological effects, residential or other development along roads significantly increase the level of fragmentation.

The U. S. Department of Agriculture Forest Service's program Forests on the Edge (http://www.fs.fed.us/openspace/fote/index.html) identifies many of the ecological and social values of intact forest ecosystems (Stein et al. 2005).

Wildlife Corridors and Landscape Connectivity

There is general agreement among conservation biologists that landscape connectivity and wildlife corridors can mitigate some of the adverse effects of habitat fragmentation on wildlife populations and biological diversity (Beier and Noss 1998; Noss and Cooperrider 1994; Haddad et al. 2003; Damschen et al. 2006).

Wildlife corridors (also referred to as wildlife connecting habitat or linkage habitat)[1] are lands and waters that connect larger patches of habitat together within a landscape and allow the movement, migration, and dispersal of animals and plants (Austin et al. 2004). Corridors describe specific paths along which animals and plants move and migrate, usually providing connections between blocks of suitable habitat across a dissimilar landscape matrix (Beier and Noss 1998). Although individual species may vary in the rate and extent to which they use corridors, the majority of mobile species rely on them for a variety of purposes (Gilbert-Norton et al. 2010).

Landscape connectivity is the opposite of fragmentation – it refers to the degree to which blocks of suitable habitat are connected to each other (Noss and Cooperrider 1994). Landscape connectivity can be described in at least two ways: structural connectivity refers to a property of the landscape and the spatial arrangement of habitat patches and barriers; functional connectivity refers to the behavior of the dispersing organism or an ecological process and how they are affected by landscape structure (Crooks and Sanjayan 2006; Boitani et al. 2007; Baguette and Van Dyck 2007).

Functional landscape connectivity is the type of connectivity that is most important for effective conservation as it describes the actual movement of organisms or processes (Noss and Cooperrider 1994; Boitani et al. 2007). In contrast, structural landscape connectivity is the most easily measured and applied to conservation planning, but it is only the physical background and does not guarantee functional connectivity (Boitani et al. 2007). A landscape with structural connectivity may provide functional connectivity for some species or processes and not for others (Crooks and Sanjayan 2006). This habitat block project is based on structural landscape connectivity – functional connectivity will need to be assessed separately based on field assessments of actual wildlife movement. However, research in Vermont and elsewhere on the movement, behavior, and habitat selection of various species of wildlife such as black bear and bobcat offer important empirical data to effectively correlate structural and functional habitat connectivity.

Maintaining functional landscape connectivity as development continues to fragment habitat is an important conservation goal. Identifying potential corridors and structural landscape connectivity using available GIS data and least-cost path models is a common approach (Beier et al. 2008; Watts et al. 2010; Jantz and Goetz 2008). Some authors recommend modeling corridors using generic focal species (Watts et al. 2010) or multiple focal species that are likely to serve as a collective umbrella for many native species and ecological processes (Beier et al. 2008).

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[1] These terms are sometimes used interchangeably, but do have distinct meanings that can be useful in distinguishing between closely related concepts of animal and plant movement and propagation of ecological processes. Corridor generally refers to a swath of land that allows movement of particular species between two or more areas of disjunct but suitable habitat. Corridors are often thought of as narrow strips of land, but may also be wider areas of suitable habitat used for animal or plant movement and migration. Linkage generally refers to broader regions of connectivity that allow the movement of multiple species and that maintain ecological processes. (Meiklejohn et al. 2009).

Climate Change

Our understanding of climate change has improved dramatically over the past ten years. In the Northeastern United States we can expect winter temperatures to rise by 5 to 12°F by the end of the century, summer temperatures to exceed 90°F for 30 to 60 days, increases in the likelihood and severity of heavy rainfall events, 20 to 30 percent increase in winter precipitation with more precipitation falling as rain as winter temperatures rise, increases in the likelihood of summer and fall droughts with extended periods of low stream flow, and a longer growing season (NECIA 2006). These changes are expected to affect species distributions, terrestrial and aquatic natural communities, and natural disturbance regimes in many ways that are still uncertain. Although we know from the fossil records that many species have persisted through periods of changing climates over the millennia by adaptation and by shifting their geographic ranges, the fossil record of extinctions and extirpations suggests that adaptations and range shifts are more limited during periods of rapid climate change, such as the changes that are now predicted (Davis and Shaw 2001).

Maintaining or improving landscape habitat connectivity is recognized as a primary strategy for conserving biological diversity in the face of a rapidly changing climate (Opdam and Wascher 2004; Krosby et al. 2010; Heller and Zavaleta 2009; Kart et al 2005). In response to rapidly changing climate, metapopulations of species are most likely to be able to shift their geographic ranges in landscapes with the least amount of habitat fragmentation (with the greatest landscape connectivity) (Opdam and Wascher 2004).

Although there are many recommendations in the scientific literature on strategies to conserve fish, wildlife, plants, habitats, and all aspects of biological diversity in response to the changing climate, traditional conservation strategies will remain effective (Hunter et al. 2010). These strategies include maintaining robust populations of species across their geographic ranges, designing a resilient network of conserved lands that represent the full array of biological and physical environments with redundancy, and maintaining landscape connectivity between conserved lands with riparian zones and other features. Other scientists recommend that an emphasis should be placed on protecting the full ranges of recurring geophysical settings (soil types, geologic classes, elevation ranges, and latitude) instead of focusing on individual species to effectively address conservation in the face of climate change. These authors refer to this approach as conserving the biodiversity "arenas" or "stages" instead of conserving the individual "actors" (Beier and Brost 2010; Anderson and Ferree 2010). The importance of landscape connectivity is recognized in all of these conservation approaches.

METHODS

The habitat block project is the result of the cooperative work of the steering committee members and the two authors. Jon Osborne conducted all the GIS work for the project. Eric Sorenson served as project manager. The Steering Committee met four times from October 2007 until July 2009. The purpose of each meeting was to discuss ideas on how to achieve the four objective of the project:

1. Identify habitat blocks using best-available Geographic Information Systems (GIS) data and accepted scientific methods.
2. Rank the habitat blocks for their biological and conservation value and for the potential threat to them from fragmentation.
3. Identify and rank the relative importance of potential wildlife road crossings statewide based on the structural suitability of adjacent habitat.
4. Develop a cost grid based on land cover data that can be used as a tool for evaluating potential road crossings and identifying potential wildlife corridors between identified habitat blocks using GIS software.

At each meeting the steering committee discussed specific topics and made decisions on how to proceed. Although consensus was reached during most decisions, it was not possible to reach consensus in all cases. Varying opinions on how to proceed were recorded in meeting minutes.

The steering committee was intentionally comprised of experts in a wide array of ecological sciences. This allowed for the use of professional knowledge and judgment in directing data analysis. Much of the Steering Committee's work was to provide iterative reviews on the results of the GIS analysis and suggestions on how it could be improved. GIS results were presented to the committee at each meeting and real-time manipulation and display of the data analyses in response to suggestions made it possible to make substantial progress at each meeting.

Some of the issues resolved at steering committee meetings and reflected in the final project results include:
- What land cover data should be used for the project?
- Whether Class 4 roads should be considered a fragmenting feature for defining the habitat blocks?
- What minimum habitat block size should we use for the project?
- What biological/ecological and physical landscape factors and related GIS data should be used for the assessment of biological and physical diversity value of habitat blocks?
- What factors and related GIS data should be used for the assessment of potential threat to habitat blocks?
- What weighting should be used for each factor in the biological and threat analyses?

- What factors should be used (and do we have adequate GIS data) in designing the corridor model and the potential road crossing locations?
- What relative "cost" should be assigned to each land cover type for developing the cost grid for the state?

This project describes the methods and results chosen by Vermont Fish and Wildlife Department and the partners that served on the steering committee to identify habitat blocks and to rank their relative conservation importance. The results of this analysis are considered reliable and based on scientifically valid and appropriate data, sound professional judgment and opinion, and analytical methods that have been accepted and used elsewhere for similar analyses by scientists in the United States and elsewhere. Never-the-less, the Department views the development of our understanding of habitat blocks and landscape scale habitat connectivity as an iterative process that should and must evolve over time as our knowledge grows.

In order to provide as much transparency to the project results as possible, the following Results sections provide explanations of the decisions made and, when appropriate, provide comments on how the results could be interpreted. Notes included with the descriptions of some factor rankings are meant to explain specific issued that are raised by the associated results.

RESULTS

The project results are separated into multiple sections. The first section describes the process that was used to identify and delineate unfragmented habitat blocks. The next sections describe several tools that were developed in the early stages of the project that were used to analyze and evaluate the significance of habitat blocks and to identify and rank potential road crossings and wildlife corridors. The next sections describe the steps taken to rank habitat blocks for their biological and physical diversity values and rank them for the potential threat of fragmentation. The final results sections describe steps used to identify likely wildlife road crossing areas for all of Vermont's roads and how the cost grid can be used to identify likely wildlife corridors between selected blocks using GIS software.
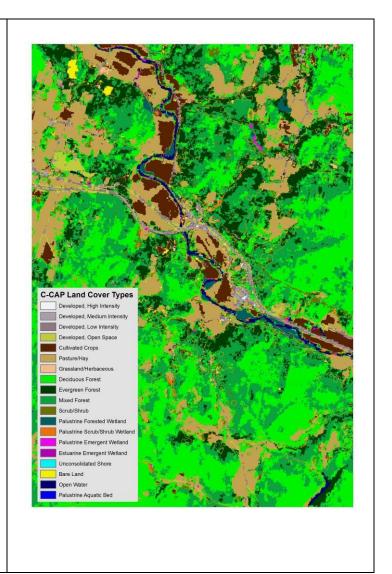
In addition to this description of steps taken and the accompanying images, the results of habitat block ranking can be viewed on the Agency of Natural Resources *Natural Resources Atlas* (http://anrmaps.vermont.gov/websites/anra/). Project GIS data and the accompanying metadata is available from the Vermont Center for Geographic Information (http://vcgi.vermont.gov/).
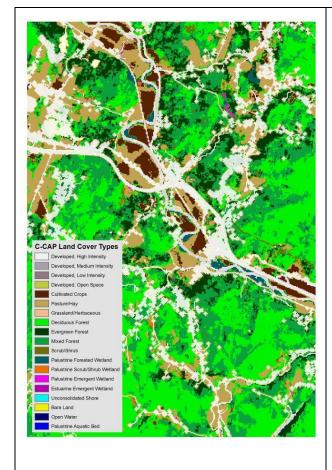
Identification of Habitat Blocks

The analysis relied upon 2006 land cover data from National Oceanic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program (C-CAP). The C-CAP land cover types were classified by whether they should be included in habitat blocks or not, as follows:

Land Cover Type	Block	% Cover
Developed, High Intensity	No	0.12
Developed, Medium Intensity	No	0.69
Developed, Low Intensity	No	1.25
Developed, Open Space	No	0.74
Cultivated Crops	No	4.50
Pasture/Hay	No	10.38
Grassland/Herbaceous	Yes	0.35
Deciduous Forest	Yes	37.09
Evergreen Forest	Yes	14.66
Mixed Forest	Yes	19.29
Scrub/Shrub	Yes	2.43
Palustrine Forested Wetland	Yes	2.05
Palustrine Scrub/Shrub Wetland	Yes	0.94
Palustrine Emergent Wetland	Yes	0.38
Estuarine Emergent Wetland	Yes	0.00
Unconsolidated Shore	Yes	0.02
Bare Land	No	0.18
Open Water	Yes	4.90
Palustrine Aquatic Bed	Yes	0.02
		100

The image on the right shows the C-CAP land cover types for the Richmond, Jericho, and Williston area, including the Winooski River and Interstate 89.

C-CAP Land Cover Types

- Developed, High Intensity
- Developed, Medium Intensity
- Developed, Low Intensity
- Developed, Open Space
- Cultivated Crops
- Pasture/Hay
- Grassland/Herbaceous
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Scrub/Shrub
- Palustrine Forested Wetland
- Palustrine Scrub/Shrub Wetland
- Palustrine Emergent Wetland
- Estuarine Emergent Wetland
- Unconsolidated Shore
- Bare Land
- Open Water
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- Palustrine Scrub/Shrub Wetland
- Palustrine Emergent Wetland
- Estuarine Emergent Wetland
- Unconsolidated Shore
- Bare Land
- Open Water
- Palustrine Aquatic Bed

The C-CAP land cover data were refined to improve block delineations using several GIS layers, including roads, E911 buildings, and hydrography. These layers are shown in white on the image to the left. The following decisions were used in defining habitat blocks:
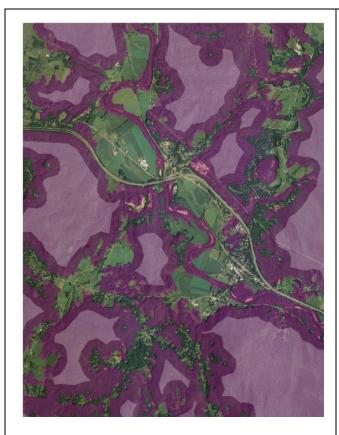
- Class 1, 2, and 3 roads were considered block fragmenting features.
- Class 4 roads were not used to define block boundaries as they are mostly narrow and have minimal traffic. It was recognized that the presence of Class 4 roads within habitat blocks causes some fragmentation and these roads are potential locations for future development and fragmentation.
- Power lines were treated similarly to Class 4 roads.
- Open waters of ponds and rivers were included in habitat blocks and not considered fragmenting features. Although bodies of water may represent movement barriers to some wildlife species, ponds and rivers are natural habitats, as are cliffs and wetlands.
- Habitat blocks less than 20 acres were eliminated from the analysis. These small habitat areas may provide some wildlife, biological diversity, or connectivity functions, but they provide little interior forest habitat. Their removal also reduced "noise" in the analysis.

To the right is a close up of Richmond, Williston, and Jericho with 2006 aerial photographs and showing the final habitat blocks in purple.

By this process, 4,055 habitat blocks were identified in Vermont.

Delineation of Habitat Block Core Areas (>250 ac.)

Interior portions of habitat blocks, generally 200 meters from habitat block edges, were classified as core areas. The distance from the edge of a habitat block to the core area (buffering habitat) varies depending on the land use adjacent to the habitat block. A habitat block adjacent to agricultural lands has more core area (a narrower band of buffering habitat) than the identical block situated next to high density residential development. Core areas are where interior forest conditions are likely to occur without significant edge effect.

A minimum core area was considered to be 250 acres in order to support interior forest habitat conditions. Therefore, core areas are only delineated for those habitat blocks that provide greater than 250 acres of core area.

In the close up of Richmond, Jericho, and Williston to the left, core area are shown in light purple.
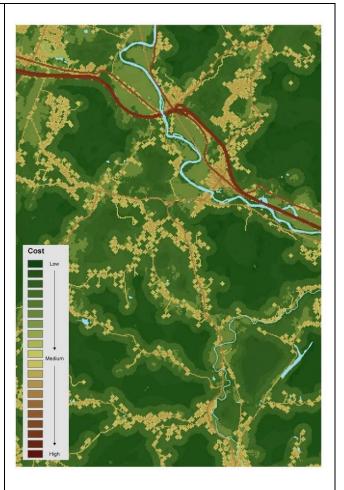
Developing the Cost Grid

The cost grid is a tool to help evaluate the suitability of habitat and land cover types for wildlife movement and was used in several later steps in the habitat block analyses. The refined C-CAP data that was used to delineate habitat blocks was the basis for the cost grid. The relative cost for wildlife movement within each land cover type was added, with higher numbers indicating greater cost of movement, as follows:

Land Cover Type	Cost	% Cover
Developed, High Intensity	60	0.12
Developed, Medium Intensity	50	0.69
Developed, Low Intensity	40	1.25
Developed, Open Space	30	0.74
Cultivated Crops	11	4.50
Pasture/Hay	10	10.38
Grassland/Herbaceous	9	0.35
Deciduous Forest	5	37.09
Evergreen Forest	1	14.66
Mixed Forest	4	19.29
Scrub/Shrub	6	2.43
Palustrine Forested Wetland	2	2.05
Palustrine Scrub/Shrub Wetland	3	0.94
Palustrine Emergent Wetland	7	0.38
Estuarine Emergent Wetland	7	0.00
Unconsolidated Shore	8	0.02
Bare Land	20	0.18
Open Water	12	4.90
Palustrine Aquatic Bed	13	0.02
		100

Additional modifiers were used to refine the cost grid and more accurately predict animal movement, including road traffic volume, presence of ridgeline and riparian corridors, steep slopes, bridge crossings, and block core areas. These factors are most important in the evaluating potential wildlife corridors and are therefore described in more detail in the Wildlife Corridor section of the report.
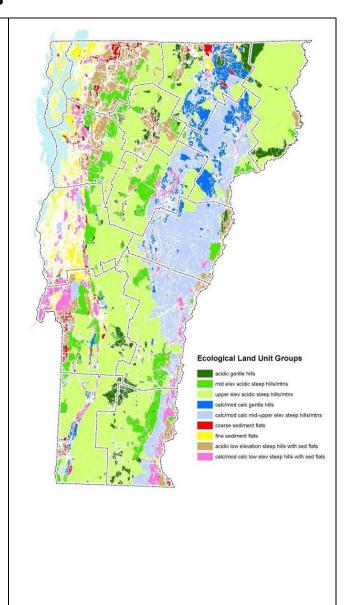
The map on the right shows the cost grid for parts of Richmond, Jericho, and Williston, with the darker green colors indicating evergreen, mixed, and deciduous forests, and the darkest red-brown indicating high intensity development, especially roads with high traffic volume, such as Interstate 89.

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Ecological Landscape Unit Groups

A classification of habitat blocks was developed based on Ecological Landscape Units (ELUs) and their relative abundance in each habitat block. ELUs were developed by The Nature Conservancy and are based on the physical landscape features (elevation zone, substrate, landform, and aspect) present for each 30-meter pixel. The multivariate analysis technique used to classify the habitat blocks into ELU Groups was very similar to the process used to classify natural communities based on species composition (Two-Way Indicator Species Analysis, McCune and Mefford 2006)). The nine ELU Groups are:

- acidic gentle hills;
- mid elevation acidic steep hills/mountains;
- upper elevation acidic steep hills/mountains;
- calcareous/moderately calcareous gentle hills;
- calcareous/moderately calcareous mid to upper elevation steep hills/mountains;
- coarse sediment flats;
- fine sediment flats;
- acidic low elevation steep hills with sediment flats;
- calcareous/moderately calcareous low elevation steep hills with sediment flats.

Ecological Land Unit Groups

- acidic gentle hills
- mid elev acidic steep hills/mtns
- upper elev acidic steep hills/mtns
- calc/mod calc gentle hills
- calc/mod calc mid-upper elev steep hills/mtns
- coarse sediment flats
- fine sediment flats
- acidic low elevation steep hills with sed flats
- calc/mod calc low elev steep hills with sed flats

Assessment of Biological and Physical Diversity Value of Habitat Blocks

The 4,055 habitat blocks identified in Vermont using the methods outlined above were evaluated using 11 factors to assess their biological value and their contribution in representing physical landscape diversity. For each factor, the ecological importance of the factor is described as is the process used to evaluate the blocks for this factor. The 11 factors were each weighted to reflect the relative importance of the factor in determining the final biological and physical diversity rank for the blocks. Factor weightings ranged from 15 percent to 5 percent; the rationale is provided for each factor weighting. These 11 factors and the final block weighted score are described on the following pages.

For each factor description there is an accompanying map of Vermont that shows all habitat blocks ranked for that factor. In these maps, the highest ranked habitat blocks are colored dark green, the moderately ranked blocks are yellow, and the lowest ranked blocks are red.
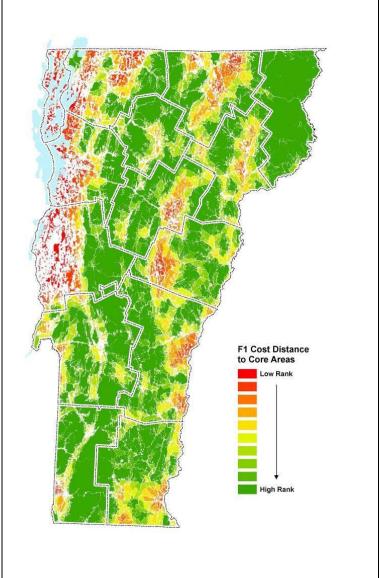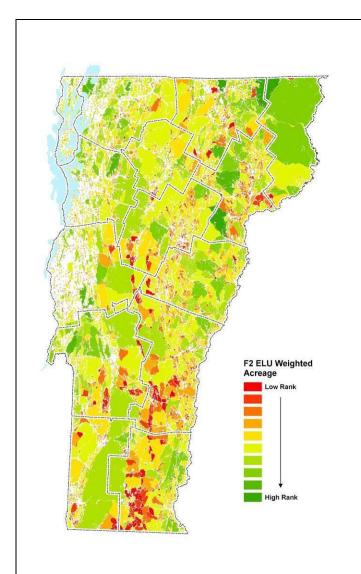
Cost Distance to Core Areas

To evaluate a habitat block's contribution to connectivity at a landscape level, the cost grid was used to calculate the cost for wildlife to travel between large core areas (> 2,000 acres). Large habitat blocks with core area greater than 2,000 acres rank highest, smaller blocks that have good connectivity to the larger blocks rank moderately high, while isolated blocks that have poor connectivity (high cost to travel) to larger blocks rank lowest. Viewed by itself, this map shows clearly the areas of Vermont with high habitat connectivity and those areas that are highly fragmented by development.

Factor weight: 15%
Rationale: Habitat blocks that are large and have good connectivity to other blocks provide the most important anchors for landscape connectivity and make a significant contribution to the primary habitat blocks functions of providing interior forest habitat and maintaining ecological processes.

Note: This factor assesses landscape connectivity in Vermont. Probably more than any other factor evaluated, this factor should ideally be assessed on a regional basis, not based on Vermont's political boundaries. Although that regional assessment was not possible as part of the scope of this project, other projects are addressing habitat connectivity at the regional scale, such as Two Countries, One Forest (http://www.2c1forest.org/), Staying Connected Initiative (http://stayingconnectedinitiative.org/), and The Nature Conservancy's modeling landscape permeability (Anderson et al. 2012, http://www.conservationgateway.org/).

F1 Cost Distance to Core Areas

Low Rank

High Rank

F2 ELU Weighted Acreage

Low Rank

High Rank

ELU Weighted Acreage

The nine Ecological Landscape Unit (ELU) Groups developed for the project were used to represent physical landscape diversity in habitat block rankings. For each of the nine ELU groups, we calculated what percentage of the landscape they occupy (ranging from 1.9 percent for coarse sediment flats to 49.2 percent for upper elevation acidic steep hills/mountains) and the average block size for each of the groups (ranging from 162 acres for coarse sediment flats to 9,684 acres for upper elevation acidic steep hills/mountains). A habitat block of a rare ELU group (one that occupies a small percentage of the landscape, such as coarse sediment flats) that is larger than the average block size for that ELU group ranks higher than a habitat block of a common ELU group that is larger than the average block size for its ELU group.

The goal of this factor is to give higher rank to those blocks that represent less common physical features in the landscape, with additional weight given to large blocks within each category.

Factor weight: 10%
Rationale: Representing physical landscape diversity is recognized as an important strategy for conserving biological diversity. The approach used here is one way to address this complex issue but does not address all types of physical landscape diversity.
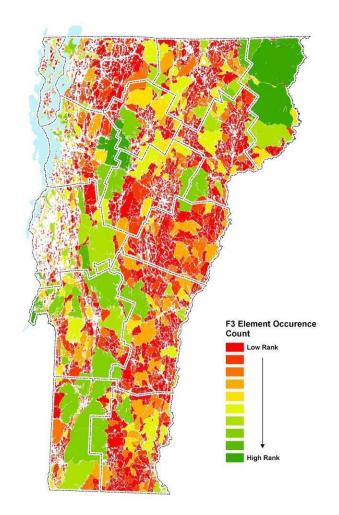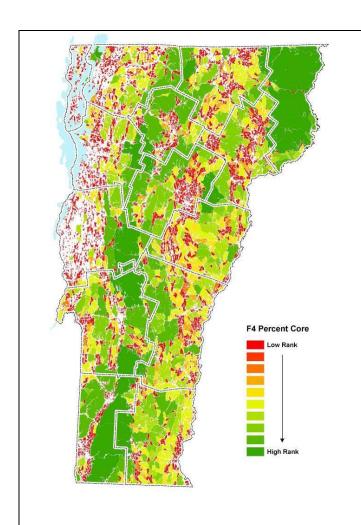
Element Occurrence Count

An element occurrence is a place on the ground where there is a rare species or state-significant natural community that has been mapped by Vermont Fish and Wildlife Department. Conservation of rare species and state-significant natural communities is an important component of conserving biological diversity. Habitat blocks with more rare species or state-significant natural communities rank higher than blocks with fewer or no element occurrences. Element occurrences of widespread (S4) and common (S5) natural communities were excluded as there has been little inventory of these community types except on state land.

Factor weight: 10%
Rationale: Rare species and natural communities are critical components of biological diversity and their presence increases the conservation value of a block. However, the primary habitat block functions of providing interior forest habitat and maintaining ecological processes are typically not altered by the presence or absence of rare species.

Note: Rare species and natural community inventories have not been completed statewide, so some habitat blocks and regions of the state that have been more thoroughly inventoried have higher block ranks, such as Mount Mansfield and the Nulhegan Basin. Also, as this factor is based on a count of element occurrences within a block, larger blocks generally rank higher than smaller blocks. Although this method favors larger blocks, it also clearly identifies smaller blocks that are known "hotspots" of rare species and significant natural communities, such as Bald Mountain and the Missisquoi Delta.

F3 Element Occurence Count

Low Rank

High Rank

F4 Percent Core

Low Rank

High Rank

Percent Core

Each habitat block with at least 250 acres of core was ranked based on its ratio of core area to total block area. Habitat blocks with a higher percentage of core provide more interior habitat values for wildlife. 250 acres was considered to be a minimum core area to support interior forest habitat values. The percent of a habitat block that is core is directly related to the size of the habitat block (larger blocks have more core), the shape of the habitat block (round blocks have more core than elongated blocks), and the degree to which the block boundary is formed by fragmenting features (blocks with roads and developments that partially penetrate into the block have less core area – this is really a part of the shape of the habitat block).

Factor weight: 15%
Rationale: Percent core relates directly to primary habitat block functions of providing interior forest habitat and maintaining ecological processes.
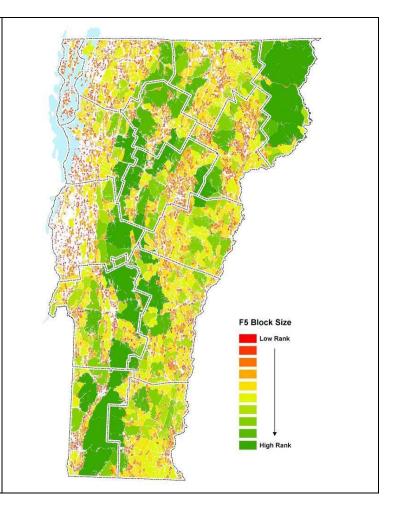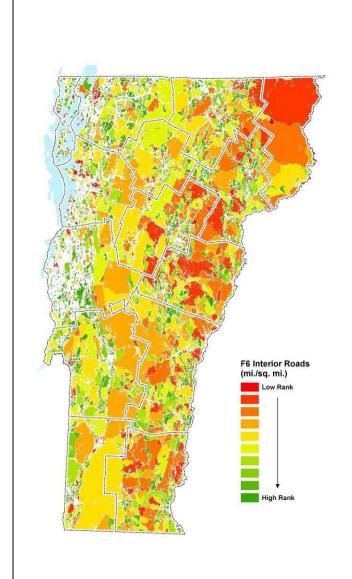
Block Size

Larger blocks provide more interior forest habitat values, better support the needs of wide-ranging wildlife, and are most likely to include a diversity of physical and environmental conditions found in that biophysical region.

Factor weight: 15%
Rationale: Block size relates directly to the primary habitat block functions of providing interior forest habitat and maintaining ecological processes.

Note: The largest habitat blocks in Vermont are at higher elevations in the Green Mountains and other remote areas, such as the Northeast Kingdom, Groton State Forest, and the Taconic Mountains. The Champlain Valley, Vermont Valley, and most of the piedmont biophysical regions have very few large habitat blocks because of concentrated development in these areas, but these regions have high levels of biological diversity.

F5 Block Size
Low Rank
High Rank

F6 Interior Roads
(mi./sq. mi.)

Low Rank

High Rank

Roads (miles of road/square mile of habitat block)

Habitat blocks with higher densities of Class 4 and other narrow roads included within their boundaries rank lower than blocks with fewer interior roads. While Class 4 and other narrow roads identified on the E-911 data layer were not considered fragmenting features in the context of habitat block delineation for this model, these roads do create some habitat fragmentation that can have an adverse effect on ecological integrity of a block. In addition, Class 4 roads are public rights-of-way and may be the sites of future development – this is addressed as a potential threat to habitat blocks under the threats analysis.

Factor weight: 10%
Rationale: The presence of Class 4 and other narrow roads within a block reduces its contribution to the primary habitat block functions of providing interior forest habitat and maintaining ecological processes.
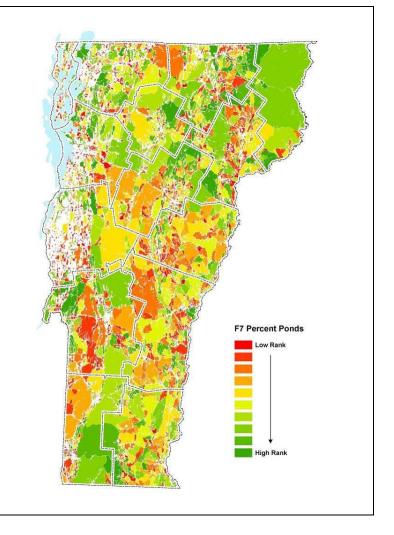
Note: It is interesting that although this factor is normalized to block area (it is presented as road density), small habitat blocks generally rank higher than large blocks. The explanation for this is simply that there are no roads within the smallest blocks. Although these smallest blocks include no roads they also provide less interior forest habitat value.
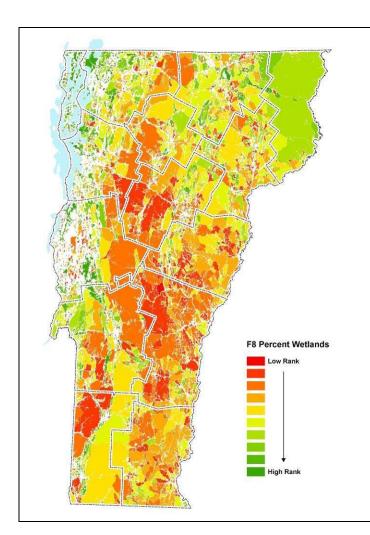
23

Percent Ponds

Habitat blocks are ranked by the ratio of pond surface area to overall block size. Habitat blocks that include a high percentage of ponds rank higher than habitat blocks without ponds. Lakes and ponds are very important habitat for many species of plants and animals and they are a relatively rare landscape feature compared to upland habitats.

Factor weight: 5%

Rationale: Ponds provide important habitat for many aquatic and wildlife species and are an important component of biological diversity. Their presence increases the conservation value of a block. However, the primary habitat block functions of providing interior forest habitat and maintaining ecological processes are typically not altered by the presence or absence of ponds.

F7 Percent Ponds
Low Rank
High Rank

F8 Percent Wetlands

Low Rank

High Rank

Percent Wetlands

Habitat blocks are ranked by the ratio of wetland area to overall block size. Habitat blocks that include a high percentage of wetlands rank higher than habitat blocks with a small percentage of wetlands. Wetlands are very important habitat for many species of plants and animals, provide good connectivity habitat, and are a relatively rare landscape feature compared to upland habitats.
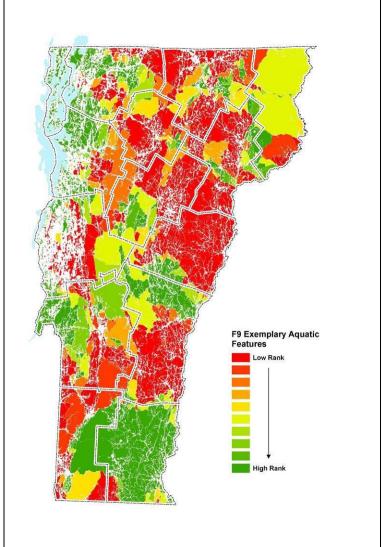
Factor weight: 5%
Rationale: Wetlands provide important habitat for many plant and animal species, provide many ecological functions, and are an important component of biological diversity. Their presence increases the conservation value of a block. However, the primary habitat block functions of providing interior forest habitat and maintaining ecological processes are typically not altered by the abundance of wetlands.
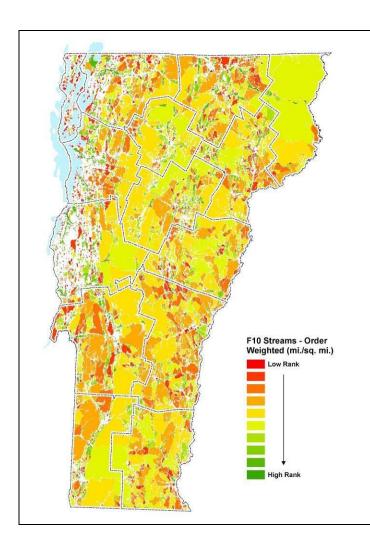
Exemplary Aquatic Features

Exemplary aquatic features are those that were identified as the best examples of each aquatic natural community type for the Vermont Biodiversity Project (Langdon et al. 1998). Habitat blocks are ranked by the percentage of block area that is in a watershed containing one or more exemplary aquatic features. For example, a block falling entirely within the Lewis Creek watershed (Lewis Creek is an exemplary aquatic feature) ranks higher than a block that has 20 percent of its area in the Lewis Creek watershed and 80% in Little Otter Creek watershed (not identified as an exemplary aquatic feature). This ranking does not consider the role habitat blocks play in all watersheds upstream of an exemplary aquatic feature, only those blocks that are in a watershed containing the water body.

Factor weight: 5%
Rationale: The exemplary aquatic features identify some of the best examples of each aquatic natural community type, but all aquatic features are important for maintaining aquatic biodiversity. The presence of exemplary aquatic features increases the conservation value of a block. However, the primary habitat block functions of providing interior forest habitat and maintaining ecological processes are typically not altered by the presence or absence of these features.

F9 Exemplary Aquatic Features

Low Rank

High Rank

F10 Streams - Order
Weighted (mi./sq. mi.)

Low Rank

High Rank

Rivers/Streams (miles of stream/square mile of habitat block)

To account for the high aquatic habitat value of streams and the connectivity benefits of riparian corridors, habitat blocks are ranked by the length and size of streams and rivers contained within them. Streams and rivers are weighted by stream order, so a block traversed by 0.5 mile of the Lamoille River ranks higher than an upper elevation block with 0.5 mile of first order streams.

Factor weight: 5%
Rationale: Rivers and streams provide important habitat for many aquatic and wildlife species and are an important component of biological diversity. Their presence increases the conservation value of a block. However, the primary habitat block functions of providing interior forest habitat and maintaining ecological processes are typically not altered by the density of streams and rivers.
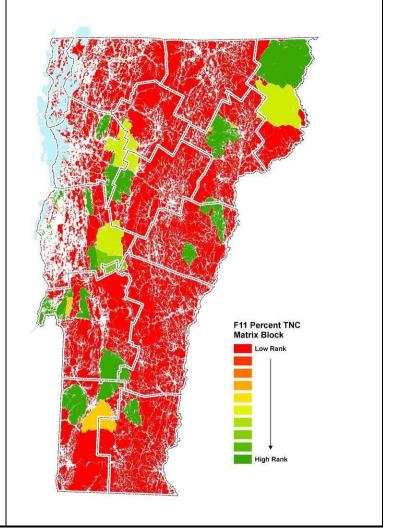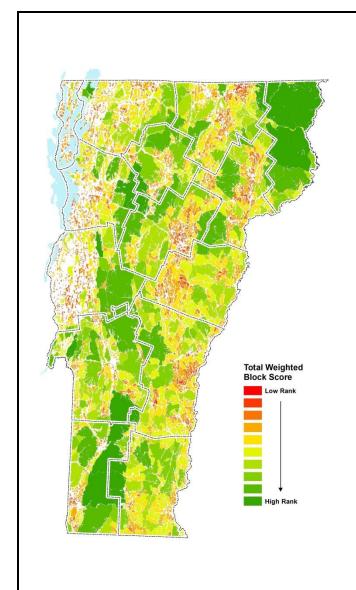
Percent TNC Matrix Block

Habitat blocks are ranked by the percent of a block that falls within a matrix block as identified by The Nature Conservancy (TNC) through their ecoregional planning process. TNC matrix blocks are large areas with minimal fragmentation by roads that were selected across ecoregions as the best locations for conservation of the "matrix" forest natural community types that are included in these blocks. Although only assigned a five percent weight toward the overall block scores, this factor identifies a few habitat blocks that are likely to have regional significance as they were identified as part of TNC's ecoregional planning. (See Anderson et al. 2006 for description of TNC matrix blocks for the Northern Appalachian ecoregion.)

Factor weight: 5%
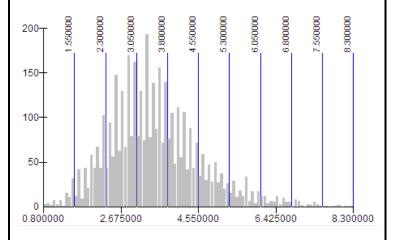Rationale: This factor adds a regional perspective to the analysis of Vermont's habitat blocks.

Note: Matrix forest natural communities are those that dominate the landscape and form the background in which other smaller scale communities occur. In Vermont, matrix forests include Northern Hardwood Forest and Montane Yellow Birch-Red Spruce Forest.

F11 Percent TNC Matrix Block
Low Rank
High Rank

Total Weighted Block Score

The 11 biological and physical landscape diversity factors were combined using the specified weights for each factor. This resulted in a total weighted score for each habitat block. Although this process favors large blocks, it is important to note that many small blocks also rank high for overall block quality and significance. Values range from a low of 0.8 to a high of 8.3, with an average of 3.49, as shown in the graph below.

The total weighted block score can also be presented in classes of values to simplify interpretation of the results. Both the "raw" weighted block score and the weighted blocks score separated into 10 equal interval classes are provided in the attribute table of the available GIS data.

Total Weighted Block Score

Low Rank

High Rank

Assessment of Potential Threat to Habitat Block

The 4,055 habitat blocks were also evaluated using five factors to assess the potential threat of the block being fragmented by future development. The factors relating to threat of fragmentation that were available or could be developed as statewide datasets were building density, average parcel size by town, human population change by town, percent of the habitat block conserved, and the density of Class 4 and other narrow roads in the block.
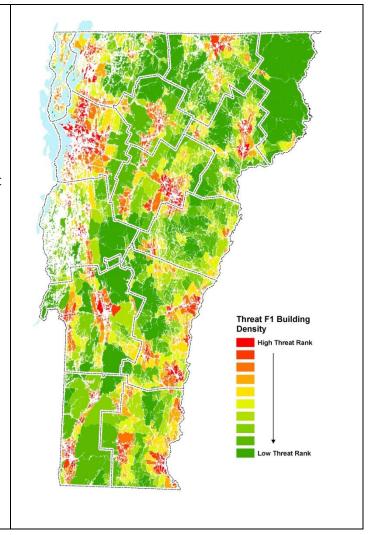
No specific time frame was assigned to this potential threat analysis. Since it is based on a limited number of factors and development patterns are likely to change in the future, it is recommended that potential threat be re-evaluated within ten years or as new tools become available.
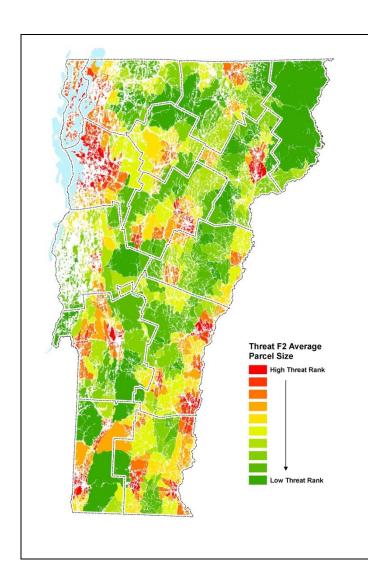
All of the five threat factors were considered equal in their potential contribution to habitat block fragmentation and all were weighted equally (20 percent) in determining the overall potential threat.

Building Density

Building density, derived from E911 data, was used as an indicator of development pressure on unfragmented habitat blocks. Habitat blocks adjacent to areas of high building density rank high for threat of fragmentation or development. The blocks with the highest threat ranks are adjacent to most urban areas and also areas of dense development, such as ski area.

Factor weight: 20%

Threat F1 Building Density

High Threat Rank

Low Threat Rank

Threat F2 Average Parcel Size

High Threat Rank

↓

Low Threat Rank

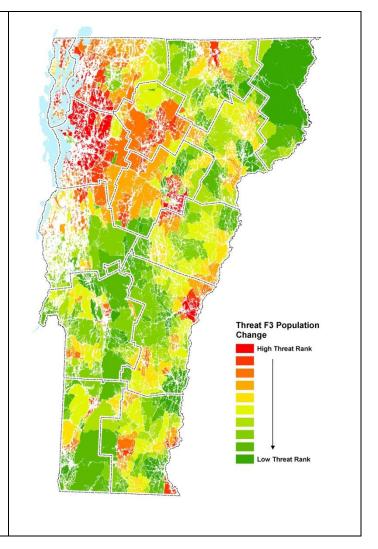## *Average Parcel Size*

Related to population growth and building density, average parcel size in a town is an indicator of development trends. Analysis of each town's Grand List showed that average parcel sizes range from a third of an acre in Rutland to over 5,800 acres in Averys Gore. Habitat blocks in towns with larger average parcel sizes rank low for potential threat.
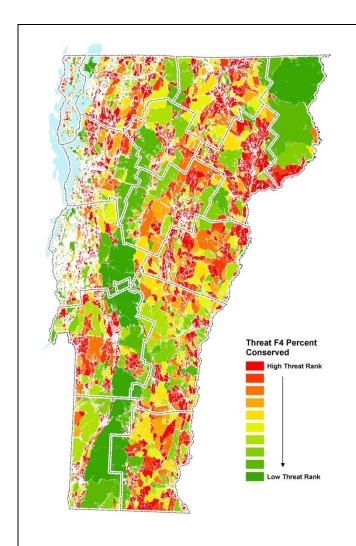
Factor weight: 20%

Population Change

The assumption is that an increase in population results in greater local development pressure on habitat blocks. Population growth per acre was calculated by town for the period 1990 to 2004. Population growth rates ranged widely, with a general trend of population declines in traditional population centers like Burlington, Rutland, Brattleboro and Bennington and population increases in so-called "bedroom communities" – areas within commuting distance of population centers, like Hinesburg, Hubbardton, Putney, and Shaftsbury. Habitat blocks in towns with high population growth rates rank high for potential threat; blocks in towns with low population growth rates rank low for potential threat.

Factor weight: 20%

Threat F3 Population Change

High Threat Rank

Low Threat Rank

Threat F4 Percent
Conserved

High Threat Rank

↓

Low Threat Rank

Percent Conserved

Roads, houses, other forms of development, and forest conversion for agriculture are the leading source of habitat fragmentation in Vermont. Most land that has been conserved by legal means will not be developed in the future, although some forms of development, such as ski areas and wind energy projects have occurred on public lands. Habitat blocks that contain a higher percentage of conserved lands are less threatened than those with little or no conserved lands. The conserved lands data used for this analysis are those available statewide and include federal land, state land, town land, and other land conserved by legal means. Unfortunately, land enrolled in the Use Value Appraisal Program was not used in this analysis, as it is currently not yet available for the entire state in a digital format.
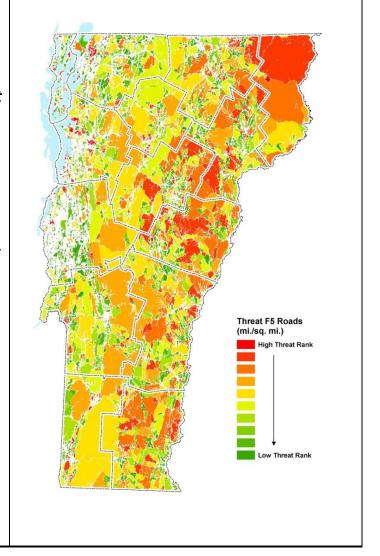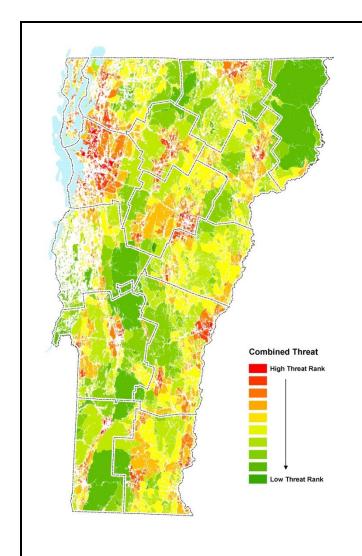
Factor weight: 20%

Roads (miles of road/square mile of habitat block)

This is the same factor that was used in the biological value assessment of habitat blocks. Here it is used as an indication of potential threat to the interior of a habitat block by future development. Habitat blocks with higher densities of Class 4 and other narrow roads included within their boundaries rank higher for threat than blocks with fewer interior roads.

Note: Some large habitat blocks, such as the Nulhegan Basin in northeastern Vermont, contain many small roads but the blocks are largely conserved (Silvio Conte National Wildlife Refuge and conservation easements). In these cases, the road density does not represent a threat of future development although it may represent a higher level of internal fragmentation.

Factor weight: 20%

Threat F5 Roads
(mi./sq. mi.)

High Threat Rank

Low Threat Rank

Combined Threat

High Threat Rank

Low Threat Rank

Combined Threat

The five factors used to assess the potential threat of habitat blocks being fragmented by future development were combined using the specified 20 percent weight for each factor. This produced the Combined Threat scores for all blocks. Rural areas, characterized by low population growth and large tracts of conserved land or "working" forest generally have the least threat of habitat fragmentation. The more intensive population growth found in the northern Champlain Valley, and the population growth, less conserved land, and greater road density found in portions of central Vermont and the southern Connecticut River valley result in higher potential block fragmentation threats in these areas.

Note: Development of ridgeline wind energy projects represents a relatively new and significant source of fragmentation in large habitat blocks. Most wind energy projects in Vermont have been proposed for relatively remote areas in which the associated habitat blocks have been ranked low for potential threat using this analysis.
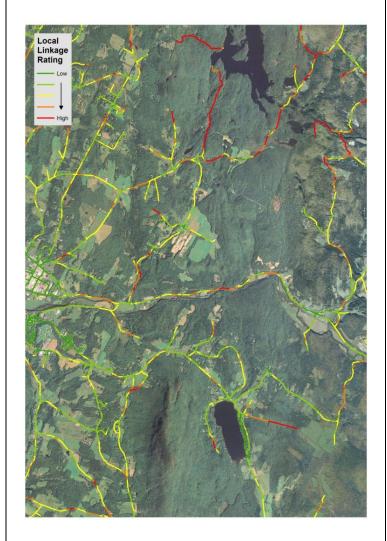
Wildlife Road Crossing Areas

A wildlife road crossing analysis was performed to identify likely road crossing areas for all roads in Vermont based on habitat characteristics adjacent to the road. This analysis relies on the cost grid, which is described on page 15.

The cost grid and this wildlife crossing analysis using the cost grid have intentionally been conducted considering the general needs of wildlife species and habitat connectivity and are not modeled to the needs of any particular wildlife species. The goal is to have the results apply to a wide range of animals that move across the landscape, but also reflect habitat connectivity that is relevant to a much broader range of plant and animal species migrations in the face of climate change or other environmental changes.

Local Wildlife Road Crossings

The cost grid was used to identify road segments where favorable habitat occurs on both sides of the road as a tool to help predict locally significant wildlife crossing areas (linkages). Forested uplands and forested wetlands are considered the most favorable habitats (least cost for wildlife movement) and road segments with these land cover types on both sides receive the highest linkage rating. Road segments with favorable habitat on only one side, and areas in or near developed areas receive lower linkage ratings. The most likely wildlife crossings (highest linkage ratings) are shown in red, orange, and yellow in the map to the right and can be thought of as road crossing "hot spots". The road segments with the lowest wildlife crossing ratings are shown in green. The map shows Green River Reservoir to the north, Elmore Pond to the south, Morrisville to the west and Route 15 running east-west along the Lamoille River across the center.

Note: The road segments with the highest rating for potential wildlife crossings are based on vegetation and habitat structure adjacent to the roads. Field verification is needed to determine if these highly rated road segments are actually functioning for wildlife crossing. However, field data has been collected to verify some road crossings and this effort is continuing in Vermont and adjacent state through efforts such as the Staying Connected Initiative.

Regionally Significant Wildlife Road Crossings

To identify regionally significant wildlife crossings (linkages) the cost distance between core areas greater than 2,000 acres was calculated. Road segments that have favorable habitat on both sides and are situated between large habitat blocks with significant core areas are rated high. This approach highlights those areas of the Vermont landscape with the highest habitat connectivity and de-emphasizes individual road crossing areas that may be very important at the local scale. The statewide view of the regionally significant road crossings closely matches the habitat blocks that are highest ranked for the "cost distance to core" factor. The recommendation is that consideration be given to both these local and regional scales of wildlife road crossings as both scales are critical to the long term conservation of habitat connectivity for all species. In some highly fragmented areas of the state, such as much of the Champlain Valley, only these locally-significant road crossings are all that remain as there are no large habitat blocks with greater than 2,000 acres of core.

Wildlife Corridors

Modeled wildlife corridors are not specifically a product of the habitat block project but are instead one of the important uses of the cost grid that was developed for the project. Identifying potential wildlife corridors using the cost grid requires ArcMap and Spatial Analyst software (ESRI Inc.)[2].

The cost grid was used to identify likely travel corridors between any two selected habitat blocks. To more accurately predict animal movement throughout the landscape, especially in areas where development has impeded free movement, a series of cost modifiers were developed. Those modifiers include: highway traffic volume, presence of ridgeline and riparian travel corridors, steep slopes, bridge crossings, and core areas.

Using Annual Average Daily Traffic data from the Vermont Agency of Transportation the state highways were classified into three categories and the cost for wildlife crossing them was scaled accordingly. Highways with high traffic volumes create, at a minimum, a barrier to animal movement and often times contribute to animal mortality. These areas have therefore been modified to have a higher cost than a highway with relatively low traffic volumes.
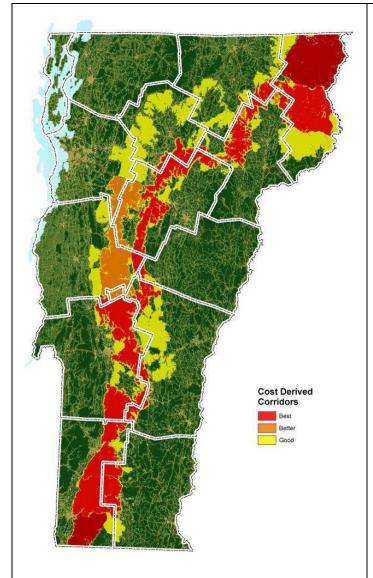
Wildlife biologists generally agree that wildlife tends to travel along certain linear features in the landscape, namely ridges and riparian corridors. Therefore, the cost along prominent ridges and river corridors was reduced, so that assuming all other costs were equal, predicted travel corridors would favor these linear features.

While steep slopes in a core area may limit movement by some wildlife species, the assumption was made that eventually most animals could negotiate steep terrain or circumnavigate it. Steep areas were considered only as they pertain to road crossings, trying to identify locations where very steep slopes or road cuts might restrict wildlife traveling between large habitat blocks. The steepest slopes were given a higher cost, resulting in these areas showing up as less favorable for wildlife crossing in the model.

Tracking experts and biologists have established that many kinds of wildlife utilize manmade highway infrastructure to facilitate road crossings. By decreasing the cost for the area immediately adjacent to a bridge on a state highway or town road, "weak spots" were created where an animal would be more likely to cross, even if it meant traveling some distance to get there.

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[2] For directions on using ArcMAP and Spatial Analyst to identify potential wildlife corridors with the cost grid, contact Eric Sorenson (eric.sorenson@state.vt.us).

For the purposes of delineating corridors for wildlife movement, two separate versions of the cost grid were developed. For one, the assumption was made that an animal could travel mostly unimpeded through core areas and therefore the travel cost within blocks was reduced to zero. A wildlife corridor model using this "no cost within block" assumption is shown in the map on the left. In this map, the two darkest red blocks were those selected as targets; the most favorable corridor between these two blocks is shown in red, with orange and yellow showing alternative corridors. Note the blocky quality of the model as a result of the entirety of blocks within the corridor being included in the model.

For the second version of the cost grid, the assumption was made that there is low cost for traveling within a habitat block, but the cost is not zero. This approach produces wildlife corridor models that are more linear in appearance and that favor ridgelines and riparian corridors. The map on the right shows this approach which produces slightly different results. The recommendation is to evaluate wildlife corridors using multiple model approaches and, most importantly, to confirm the accuracy of the model by on-the-ground observation of wildlife movement.

Note: The wildlife corridors identified through this GIS modeling process are based on the weighting of the cost grid and the additional modifications described in this section. Field verification is needed to determine if the potential corridors identified through this model are actually functioning for wildlife movement.

Application for Conservation Planning at Multiple Geographic Scales

For conservation planning purposes, the results of the habitat block project can be applied using GIS at multiple geographic scales: state, biophysical region, county, and town. At the statewide scale, the ranking of habitat blocks for their biological and physical diversity values can be applied directly for conservation planning, either by using the total weighted block score or any of the individual factor ratings that are included with the final GIS project (see the attribute table habitat block scores for individual factors or the final weighted score). At the biophysical, county, and town levels, those blocks that occur within that geographic area can be compared to determine which blocks are most significant for the area.

Maintaining or improving landscape habitat connectivity is recognized as a primary strategy for conserving biological diversity, especially in the face of a rapidly changing climate and an uncertain climate future. The results of the "cost distance to core" habitat block analysis, the results of the local and regional wildlife road crossing analyses, wildlife corridor models run between selected blocks, and especially on-the-ground observations of wildlife movement provide important insights into landscape connectivity in Vermont and should help in developing a statewide habitat connectivity strategy. All of these project results on landscape connectivity can also be applied at multiple scales: state, biophysical region, county, and town.

The results of the habitat block project were used directly in identifying high priority habitat blocks and a network of connected lands in the Agency of Natural Resources' BioFinder project.

Vermont Fish and Wildlife Department has provided suggested conservation strategies to be applied at the town level for habitat blocks ("contiguous forest") and connecting habitat (Austin et al. 2004). More specific conservation strategies are provided in "Community Strategies for Vermont's Forests and Wildlife: A Guide for Local Action" (VNRC 2013). The habitat block project results provide some of the first steps necessary for this local conservation planning: identification and prioritization of the habitat blocks and landscape connectivity.

Viewing and Using the Habitat Block Data

The habitat block assessments of biological and physical landscape diversity and potential threats are available on the Natural Resource Atlas (http://anrmaps.vermont.gov/websites/anra/). Habitat blocks are included within the "Fish and Wildlife" map layers on the Natural Resources Atlas. The results of the local and regional wildlife road crossing analyses are also available on the Natural Resources Atlas. A subset of high priority habitat blocks and a network of connected lands based in part on habitat block project results are also available and described as part of the Agency of Natural Resources' BioFinder project (http://biofinder.vermont.gov/).

GIS habitat block data is available to download and use in ArcMap from the Vermont Center for Geographic Information (VCGI) website (http://vcgi.vermont.gov/).

CONCLUSIONS AND RECOMMENDATIONS

This project identifies habitat blocks statewide and ranks them for their biological and physical landscape diversity values, ranks the blocks for the potential threat from future development, and provides tools for evaluating wildlife corridors and landscape connectivity. These project results can be applied directly for conservation planning at the state, biophysical region, county, and town levels.

The project results should be viewed as a first iteration of habitat block identification and ranking for Vermont. As new data becomes available on land cover/land use, roads and other development, and biological conditions on the land, revisions may be needed to this habitat block assessment. Similarly, as new analysis tools become available and as our collective understanding of interior forest habitat and landscape connectivity improve, future iterations of a habitat block analysis should take these factors into account.

The habitat blocks identified in this project represent very real land and water areas of contiguous forest and associated wetlands, ponds, streams, cliffs, and outcrops. There is a high likelihood that the larger and higher ranked habitat blocks provide interior forest habitat and other wildlife and ecological functions, even though many of these larger blocks have not been inventoried for these functions. In contrast, the wildlife road crossing areas and the tools for wildlife corridors and are based on GIS models and represent structural connectivity (the physical conditions on the ground), not necessarily functional connectivity (connections that are actually being used by wildlife). Although these models will be one more useful tool in assessing potential wildlife movement areas, on-the-ground verification of actual wildlife remains a critical step in the successful conservation of a functional network of connected lands and waters. However, field data has been collected to verify some road crossings and this effort is continuing in Vermont and adjacent states through efforts such as the Staying Connected Initiative.

Identification and long term conservation of a connected network of habitat blocks is one part of the larger goal of conserving Vermont's biological diversity. This connected network should be based on both habitat blocks and riparian corridors and should include viable populations of all of Vermont's rare native plant and animal species, representative examples of all of Vermont's terrestrial and aquatic natural community types, representation of the diversity in the physical landscape, and intact river and stream corridors. Maintaining a connected landscape of this type will not only allow continued movement and migration of wildlife now, but is the primary strategy to maintain biological diversity over the long term, especially in the face of a rapidly changing climate.

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