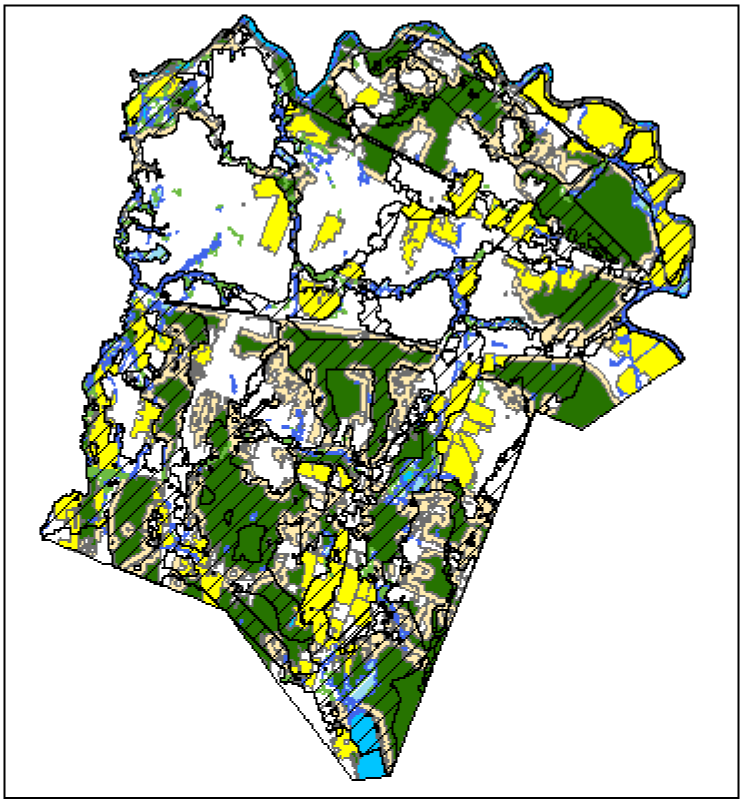
An Assessment of Wildlife Habitat in Williston, Vermont: Expanded Land-cover Mapping and Corridor Modeling



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Introduction

In July 2005, the University of Vermont Spatial Analysis Laboratory (SAL) completed a wildlife habitat assessment for the Town of Williston, developing a land-use\land-cover (LULC) map and modeling potential habitat for a suite of representative wildlife species (Capen et al. 2005). SAL personnel also performed extensive field work to assess habitat conditions for birds and mammals and to record species presence\absence. This assessment focused on selected parts of Town that contained the largest undeveloped areas of habitat for wildlife, delineated into seven wildlife units. In April 2010, the Town received a grant from the Lake Champlain Basin Program to expand the wildlife habitat assessment to the entirety of Williston's land area, with the ultimate of goal of incorporating this information into a wildlife habitat district overlay. The SAL was then contracted to: 1) complete LULC mapping for the entire Town using the best available imagery; 2) revise potential habitat maps for the previously-used set of representative species; and 3) identify possible landscape connections between important habitat blocks.

This report describes the methods that the SAL used to develop the expanded LULC map and derivative habitat descriptions; it should be considered an addendum to the final report for the 2005 project (hereafter noted as the 2005 Wildlife Habitat Report). In addition to the tasks listed above, the SAL also developed a simple habitat-prioritization scheme to highlight elements of the Williston landscape that are important to wildlife. This scheme can serve as a starting point for additional spatial analysis and field-based study. For use in current and future planning initiatives, all resulting geographic information system (GIS) maps and accompanying metadata will be submitted to the Town in digital format (Appendix A).

Methods and Results

LULC Mapping

The SAL has extensive experience with application of GIS technologies to natural resources assessments, and previously it had developed a protocol for mapping LULC in Vermont using publicly-available orthophotography and manual-interpretation mapping techniques. (http://www.uvm.edu/~joneildu/LULC/). This protocol has been successfully applied to a diversity of Vermont landscapes, including riparian corridors (Capen et al. 2006) and lakeshore zones (Capen et al. 2008, Merrell et al. 2009). Building on the partial 2005 map, we used the existing protocol to map LULC for the entire Town of Williston using 1:5,000 digital orthophotograph quadrangles (DOQs). These photographs are panchromatic, black-and-white images with 0.5-meter (1.64-foot) spatial resolution, obtained in early spring before foliage leaf-out. The DOQs covering Williston dated from spring 2007. We developed the following 14 LULC classes, as adapted from Anderson (1976): Urban-General; Urban-Transportation; Agriculture-General; Agriculture-Hay\Crop; Agriculture-Orchards; Barren; Brush\Transitional; Forest-Deciduous; Forest-Coniferous; Forest-Mixed; Water; Wetlands-Forested; Wetlands-Emergent; and Wetlands-Scrub\Shrub. Note that the Agriculture-General category was used when it was unclear whether an agricultural field is actively managed; some fields may be in an early transitional stage to brush or forest. When assigning individual features to LULC classes, we also examined National Agricultural Imagery Program (NAIP) orthophotographs, which are true-color images with 1-meter (3.281-feet) resolution a nominal scale of 1:40,000. Acquired in August 2009, these growing-season photographs provided an effective contrast to the black-and-white DOQs and helped refine initial LULC assignments. We also used NAIP photographs to update areas where land-use changes had occurred since the 2007 DOQs were acquired. Accordingly, the resulting Town-wide LULC map was considered current as of 2009, with a nominal scale of 1:5,000 (Figure 1). Note that all work was performed in ArcGIS (ESRI), state-of-the-art GIS software.

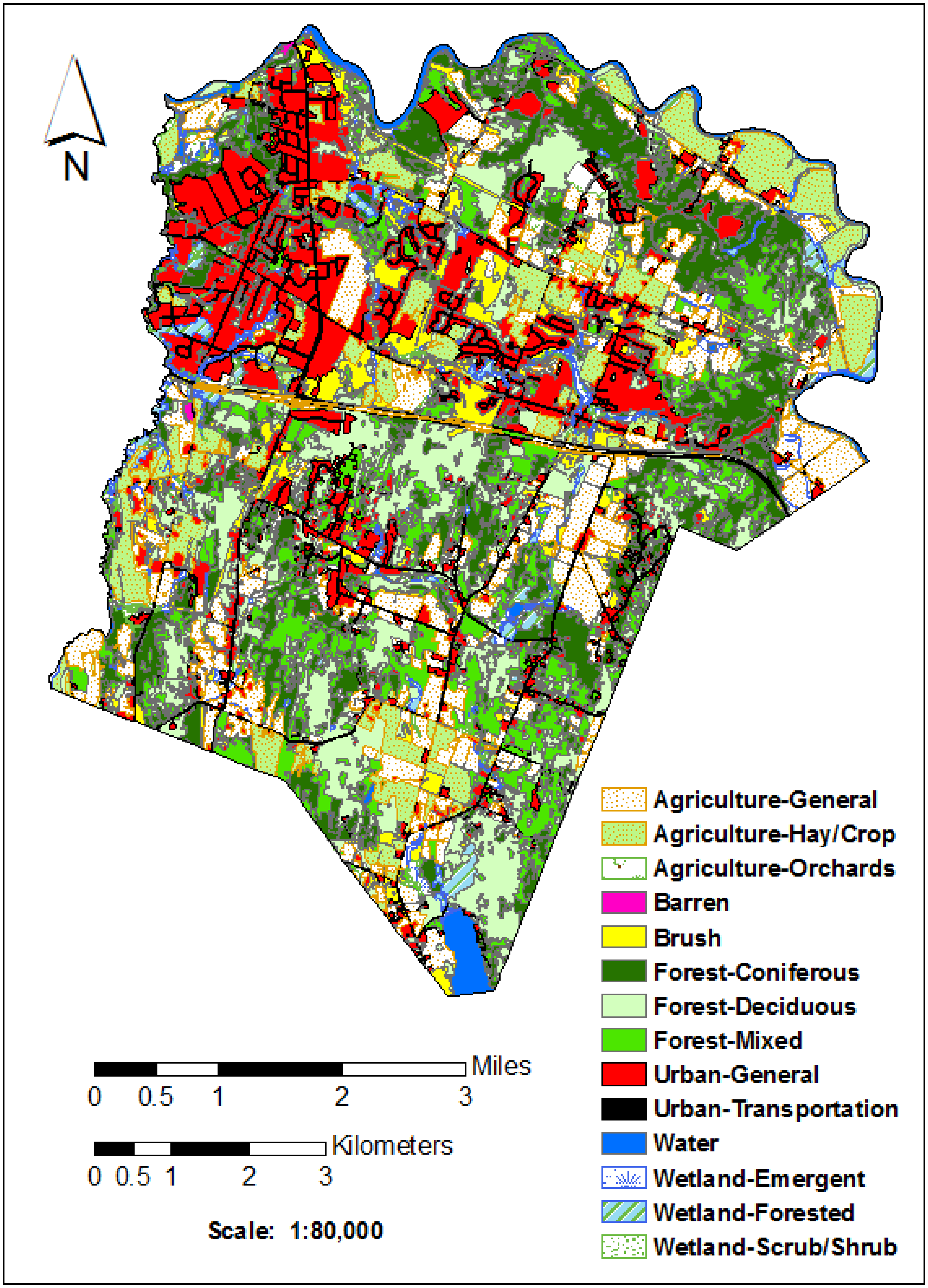

Figure 1. Land-use\land-cover (LULC) map for Williston, Vermont. This map has a nominal scale of 1:5,000 and is considered current as of 2009.

Although a quantitative accuracy assessment was not performed (a large set of random, field-based validation points would have been required), the LULC map was extensively reviewed for consistency and visual coherence and then modified as necessary. As an additional reference, we also compared polygons with difficult-to-interpret land cover to true-color oblique imagery (Pictometry Bird's Eye) available in Bing Maps (http://www.bing.com/maps).

Species-specific Habitat Modeling

Using the expanded LULC map, we revised the species-specific maps of potential habitat for 30 vertebrate wildlife species believed to occur in Williston (Appendix B). These mammals, birds, amphibians, and reptiles were selected for the 2005 Wildlife Habitat Report because they represent a range of habitat requirements and life histories. For this second iteration of habitat modeling, we also added two additional species, bobcat (*Lynx rufus*) and wood turtle (*Glyptemys insulpta*), because they were included in later corridor modeling. To create predicted Town-wide distributions for each species, we created simple habitat models that link known habitat preferences to the 14 classes in the LULC map. For example, the redback salamander (*Plethodon cinereus*) is usually found in upland forest LULC classes (i.e., Forest-Deciduous, Forest-Coniferous, and Forest-Mixed). For a subset of species with more specific habitat requirements, we then performed additional modeling to refine the predicted Town-wide distributions. The fisher (*Martes pennanti*), for example, will use a variety of forested and wetland land-cover types, but it prefers isolated coniferous forest. Accordingly, we identified all Williston land-cover polygons labeled as Coniferous Forest and then selected only those areas at least 100 meters (328.1 feet) from developed features (i.e., Urban-General and Urban-Transportation). The resulting map showed the predicted distribution of potential habitat for this species across the Williston landscape (Figure 2).

It is important to remember that the maps of potential habitat do not indicate where viable wildlife populations currently exist; systematic, multi-year field studies would be needed to map actual populations with statistical rigor. However, they do indicate the Williston land-cover types known to support each representative species in northwestern Vermont, and theoretically these features could provide breeding, foraging, or connecting habitat to self-sustaining populations, now or in the future. Such information is essential for developing meaningful town-planning initiatives that seek to conserve biological diversity and the wildlife habitats on which it depends. It also provides an assessment of baseline conditions for future studies of wildlife habitat, whether for individual species or for areas of high biological diversity (i.e., hotspots). For more information on species-specific predictive modeling based on LULC, see the 2005 Wildlife Habitat Report.

Corridor Modeling

Wildlife linkages are lands that maintain the ability of multiple species to move between wildland blocks or other patches of essential habitat. In modified landscapes, they can help mitigate the effects of habitat fragmentation on wildlife populations and biological diversity (Beier et al. 2008). One option for modeling wildlife linkages is Corridor Design (http://corridordesign.org), a set of tools developed for use with ArcGIS (Beier et al. 2007). Based on cost-distance modeling techniques, these tools are designed to identify and evaluate movement corridors between stable habitat blocks that support breeding populations of focal wildlife species. To identify potential routes of physical movement and genetic exchange, it combines information on multiple habitat factors, including preferred land-cover types, distance to critical habitat features (e.g., water), and landscape features that limit movement (e.g., roads). Unlike least-cost path analyses, which identify paths that are only pixel wide, Corridor Design produces corridors of varying widths (i.e., slices) that can be evaluated for their relevance and feasibility.

Corridor Design recommends using sets of focal species as an umbrella for a region's biological and ecological diversity, collectively encompassing the habitat needs for native species. If

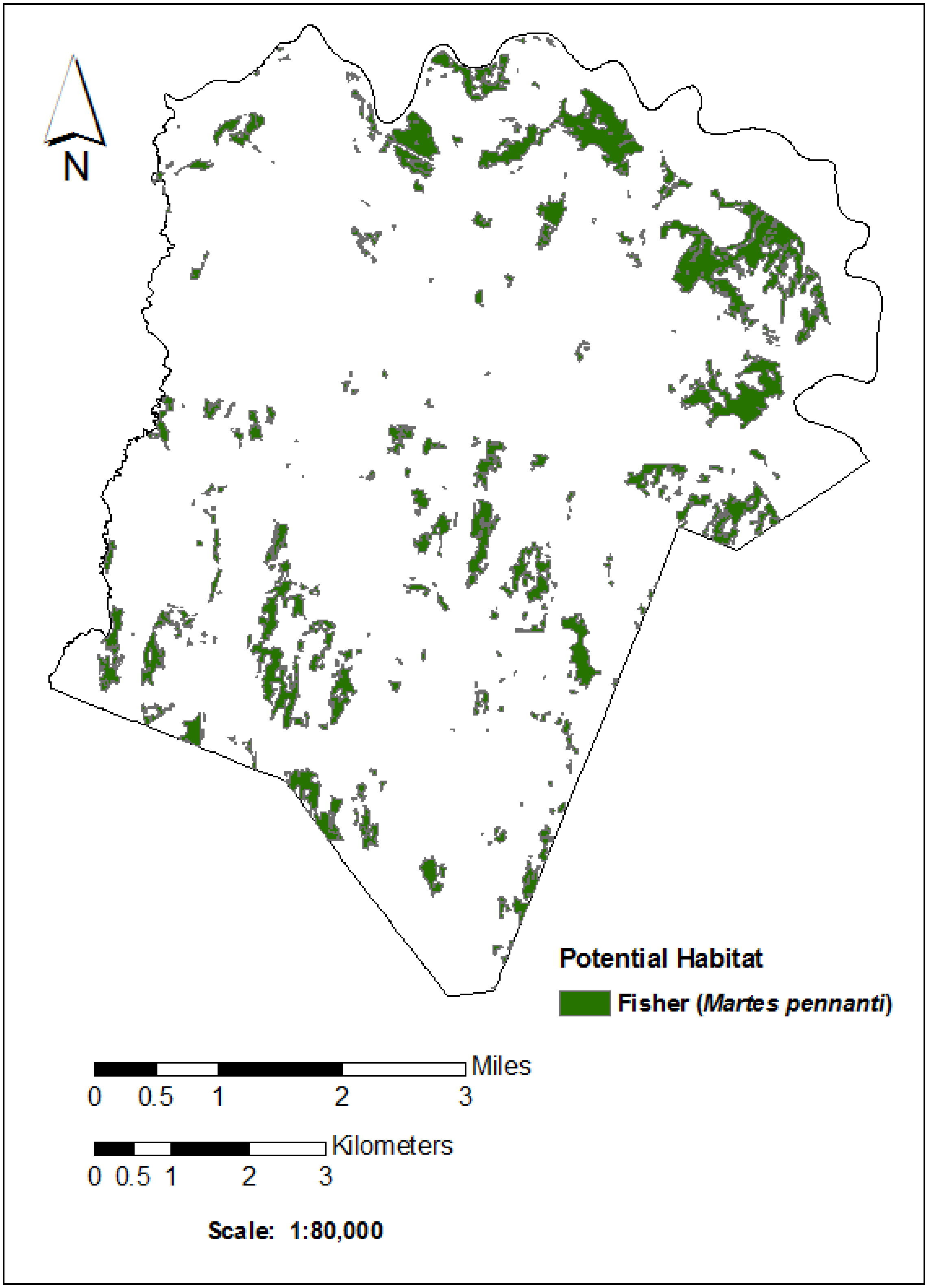

Figure 2. Potential habitat modeled for the Fisher (*Martes pennanti*) in Williston, Vermont. This map is based on the 2009 LULC map for Williston and species-specific habitat requirements.

possible, this set should include species that are: 1) area sensitive; 2) habitat specialists; 3) dispersal limited; 4) sensitive to barriers; 5) sensitive to metapopulation dynamics; and 6) ecological keystones (Beier et al. 2007). Accordingly, we selected 7 species that represent a diversity of habitat needs and behavioral characteristics: bobcat, fisher, mink (*Mustela vison*), four-toed salamander (*Hemidactylium scutatum*), wood frog (*Rana sylvatica*), smooth green snake (*Liochlorophis vernalis*), and wood turtle. For each species, we developed two habitat factor maps reflecting specific habitat requirements: 1) land cover (i.e., preferred habitat types); and 2) landscape permeability (i.e., the relative ease with which species move through or across specific land-cover types). The land-cover factor maps were based directly on the 14-class LULC map, but the landscape-permeability maps required additional refinement to adequately characterize the effect of roads on wildlife movement. We thus sub-divided the Urban-Transportation class into 6 sub-classes based on road type (e.g., interstate highway, state highway, town road) and traffic volume (i.e., Annual Average Daily Traffic data compiled by the Vermont Agency of Transportation). For some focal species, we also developed a third habitat factor map indicating proximity-based habitat requirements (i.e., use or avoidance of a specific land-cover type depending on the distance from that type). We then assigned suitability scores to each class in each habitat-factor map to quantify the relative value of individual landscape characteristics to each focal species (Appendices C1 through C7). As suggested by Corridor Design, we used a simple scoring system with values ranging from 0 (i.e., completely unacceptable as habitat or presenting an insuperable obstacle to movement) to 100 (i.e., preferred habitat for breeding, foraging, or movement).

A final preliminary step before running Corridor Design was choosing habitat blocks for each focal species; these are the landscape patches, as large and intact as possible, that theoretically provide the best habitat for an individual species. These are also the patches that should remain linked by one or more corridors to satisfy all facets of a species' life history and to ensure gene flow between geographically-disjunct metapopulations. For each species, we selected a set of large habitat blocks containing preferred habitat, preferably located along the periphery of the Town. By choosing blocks near the town boundary, we reduced the number of combinations that would be necessary to adequately characterize species-specific corridors (i.e., a modeled corridor linking distant habitat blocks will likely connect the suitable patches that occur between the selected blocks). When modeling the wood frog, for example, we selected the largest possible blocks along the Town's northern boundary, along the Winooski River, and along the southern boundary near Lake Iroquois (Figure 3).

In the subsequent modeling step, we ran Corridor Design on each logical pairing of two habitat blocks, producing separate corridor swaths connecting the blocks. There are no hard rules for evaluating corridors. As a rule-of-thumb, Corridor Design suggests a minimum width equal to two home range widths (Beier et al. 2007), but this rule was designed for large western landscapes and likely would be impractical at the scale of a Vermont municipality. However, Corridor Design also recognizes that some subjectivity is inevitable, requiring stakeholders to identify corridor slices that provide an adequate area and configuration for wildlife movement without capturing an unduly large proportion of the study area. After evaluating the range of corridor slices produced for each block pairing, which ranges from 0.1% to 10% (expressed as a percentage of the total study area), we determined that the 3% slices provided the best balance of function and practicality for the Williston landscape. For example, the primary corridors for mink were identified as the Winooski River, Muddy Brook, Allen Brook, and immediately adjacent areas, a result that would be expected for a species that prefers riparian zones (Figure 4).

Given this project's narrow scope, it was not possible to validate the species-specific models with extensive, systematic field surveys. To provide corroborating data on wildlife movements, however, Arrowwood Environmental LLC (Huntington, VT) was contracted by the Town to collect tracking observations for the fur-bearing mammals known to be active in Williston during the winter, including three of the focal species used in corridor modeling (bobcat, fisher, and mink). Based on Arrowwood's observations, which suggested that bobcat preferentially used riparian zones to move between habitat blocks during the winter of 2010-2011 (Parsons 2011), we

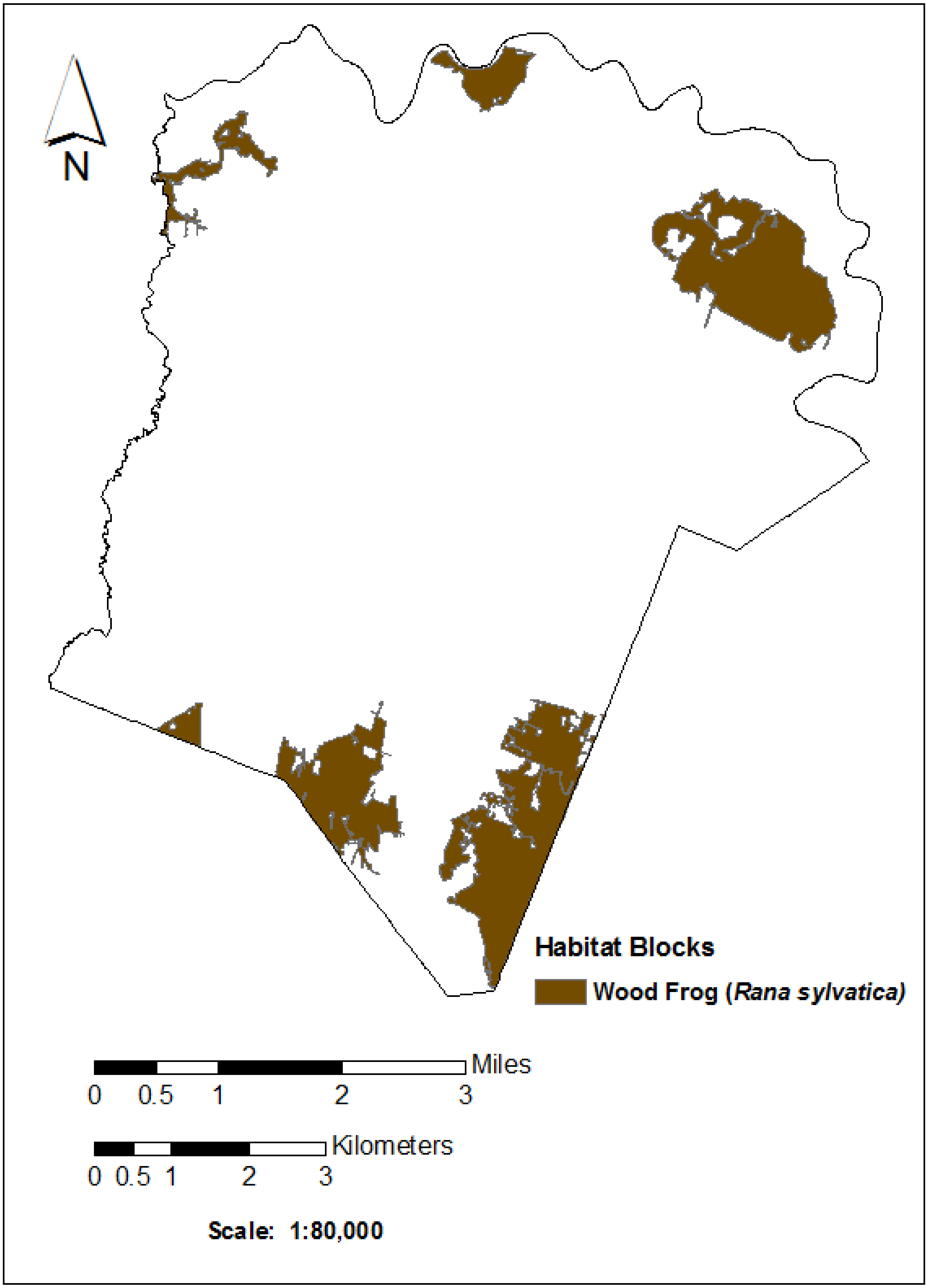

Figure 3. Habitat blocks selected for use in corridor modeling the Wood Frog (*Rana sylvatica*) in Williston, Vermont. The ArcGIS-based tool Corridor Design requires habitat blocks that serve as specific start and end points.

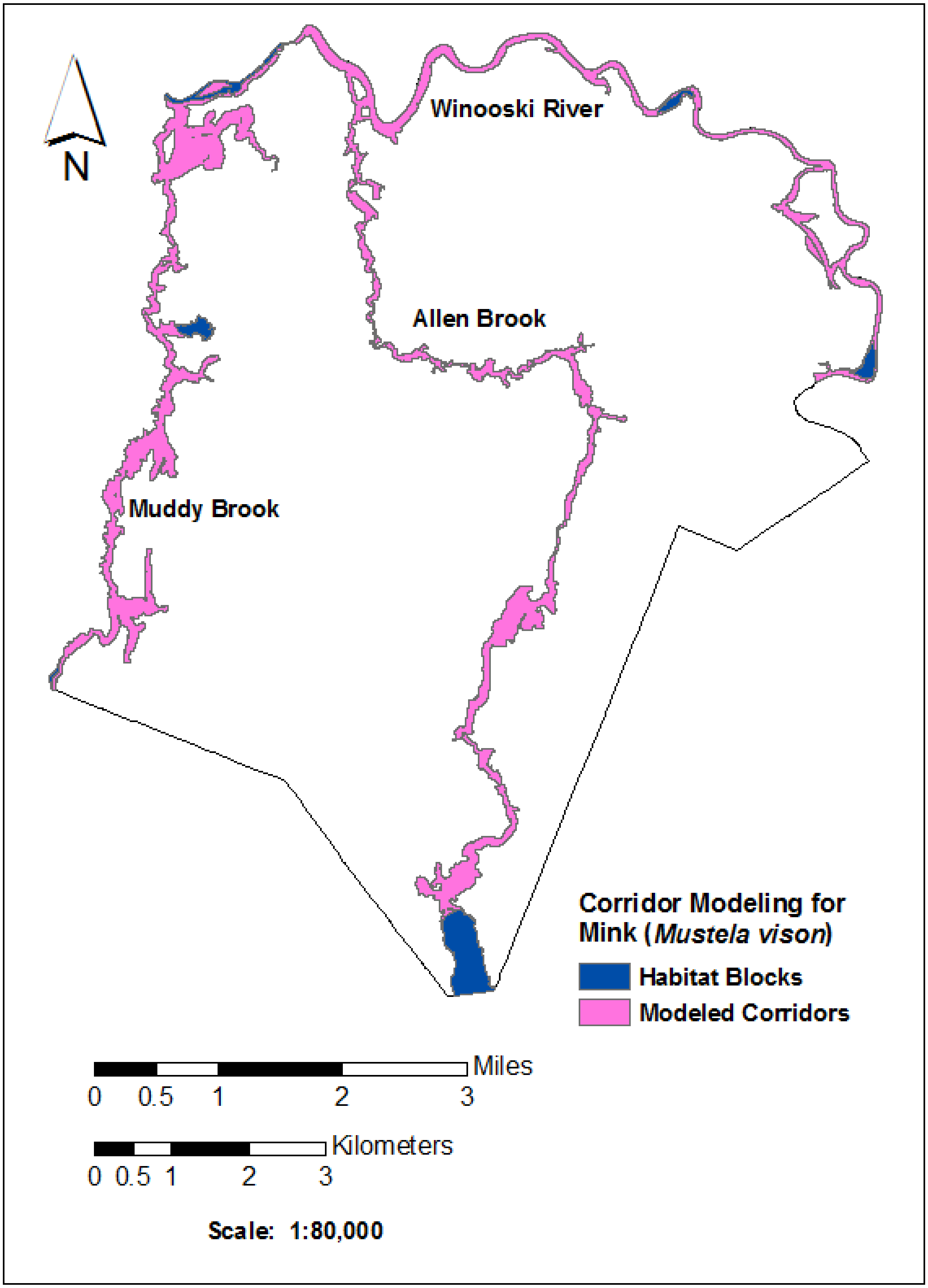

Figure 4. Modeled corridors for the Mink (*Mustela vison*) in Williston, Vermont. As expected for this species, its corridors encompass river and stream riparian zones.

revised the bobcat model (Appendix C1) to weight stream and river corridors more heavily (the original habitat parameters did not include a distance-to-rivers\streams habitat factor). A heavy snowpack 0.60 meters (2 feet) deep or greater was prevalent in Williston during the latter half of the 2010-2011 winter, so it is possible that bobcat will move through upland habitats more often in lighter snow years, but the distance-to-rivers\streams habitat factor is a reasonable and appropriate refinement given the available field data and supporting anecdotal evidence (Jeff Parsons, personal communication). See Parsons (2011) for more information on the 2010-2011 winter-tracking effort.

After revising the bobcat model, we combined all 3% slices for the 7 focal species into one layer and smoothed the corridors to provide a more coherent visual presentation (Figure 5). Note that some of the corridors appear artificially linear, especially where they cross large blocks of forest. This effect was created when the 3% slices were selected from the full set, effectively truncating the width of some corridors. These truncated corridors can be considered the most efficient (i.e., the most direct) path across otherwise appropriate habitat.

The combined map containing corridors for all focal species is the most important product for evaluating landscape linkages; it encompasses areas that are likely to support physical movement and genetic exchange for a cross-section of the Town's biological diversity. Not surprisingly, the modeled corridors contain ecosystems that are known to support high biodiversity: wetlands, riparian corridors, and large upland forest blocks. The corridor models are weighted in favor of these ecosystems, and their inclusion verifies the sensitivity of the selected modeling parameters and the Corridor Design approach in general. Yet, it is also informative to examine the modeled corridors that cross developed land-cover types. For example, one corridor segment parallels a section of the Interstate 89 median and another follows a utility right-of-way (Figure 6). These corridors were modeled for the smooth green snake, a species that relies on brush\transitional areas and agricultural land cover for essential habitat. While it is clear that an interstate median is not high-quality habitat, and mortality may be high for smooth green snakes attempting to cross four lanes of high-speed traffic, this species may have no choice but to traverse sub-optimal or even inhospitable habitat to satisfy its life-history needs. This observation emphasizes the reality that some modified landscapes are now essential to movement, especially agricultural lands, and it also underscores the need to consider special habitat features such as well-designed culverts and other wildlife crossings in long-term planning.

Although we could model corridors only for the land area of Williston, it is possible to consider linkages to habitat blocks in adjacent towns by comparing the combined corridor map to other land-cover maps covering Chittenden County. For example, when compared to the National Land Cover Dataset for 2001, a 30-meter (98.4-foot) resolution map derived from satellite imagery (http://www.mrlc.gov/), it is clear that Williston's primary corridors link to large forested blocks in Richmond in the southeast; Hinesburg and St. George in the south; and Jericho in the northeast, across the Winooski River (Figure 7). Habitat blocks in Williston also connect to Shelburne Pond and adjacent areas in the southwest via small forest patches, hedgerows, and wetlands. These connections emphasize the need for a regional approach to evaluating and conserving biological diversity.

Finally, it is important to note that the linkages represented in the combined corridor map are not the only locations in Williston that wildlife use to move between habitat blocks; indeed, some species will occasionally seek to traverse even the most highly-developed areas or the busiest roads. Nonetheless, these corridors indicate optimal routes across the Williston landscape given the town's land cover and the known habitat requirements for the focal species on which they were modeled. As such, they serve as another data point that the Town can use its land-use planning and conservation efforts.

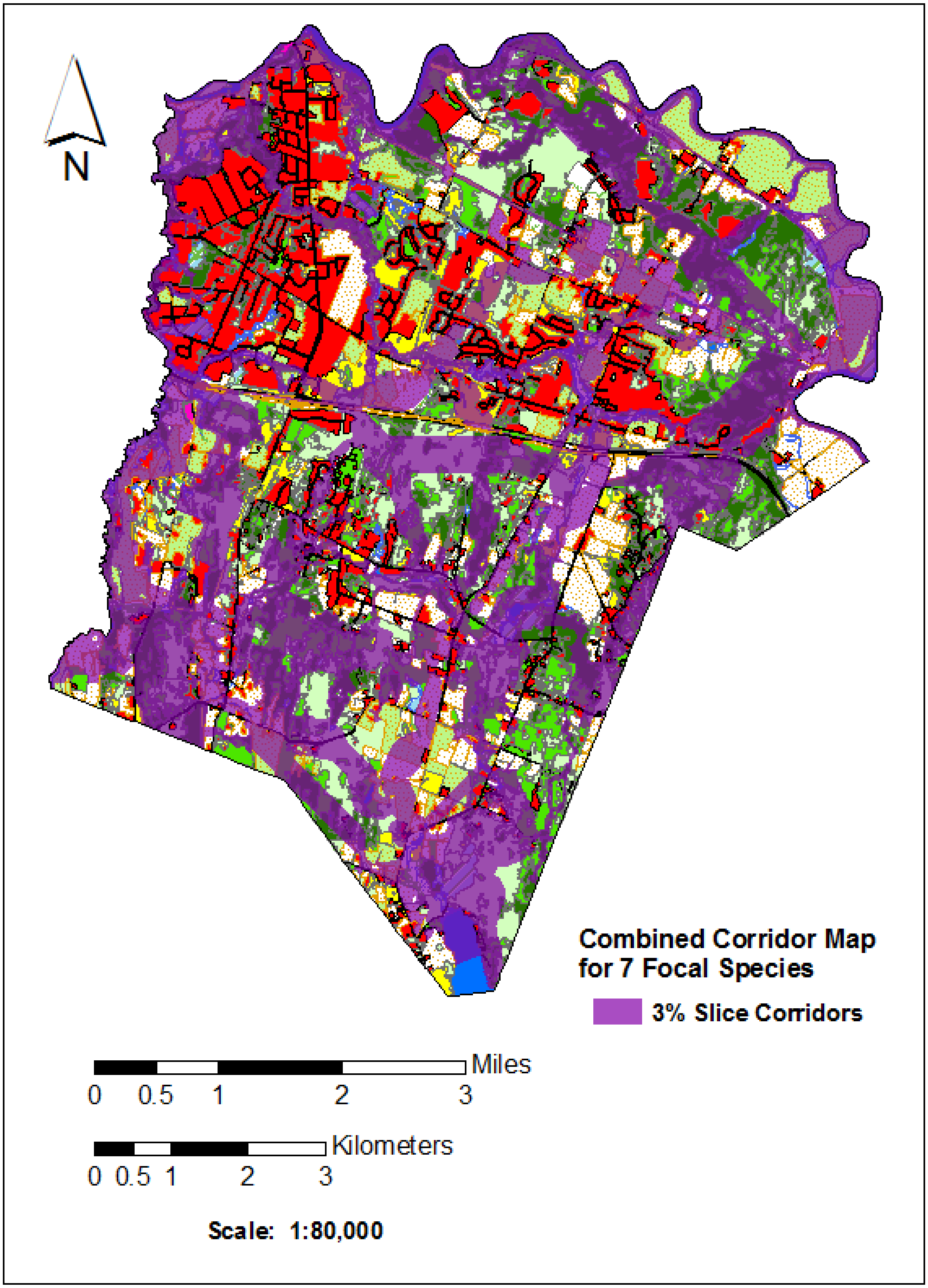

Figure 5. Combined corridor map for 7 focal species showing primary landscape linkages, Williston, Vermont.

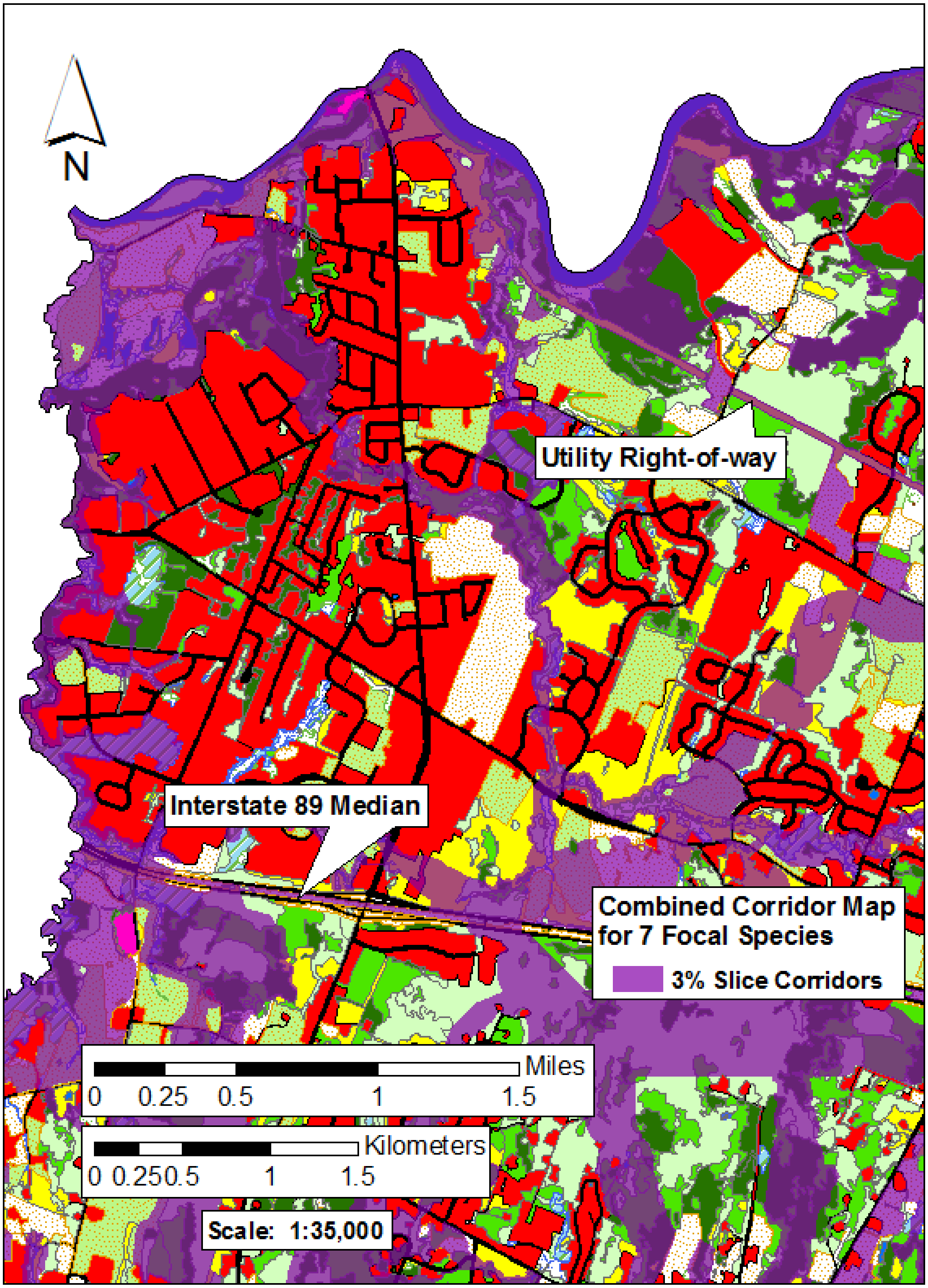

Figure 6. Modeled corridors that adhere closely to human-modified landscape features, Williston, Vermont. In this instance, corridors derived for the smooth green snake (*Liochlorophis vernalis*) parallel an interstate median and a utility right-of-way.

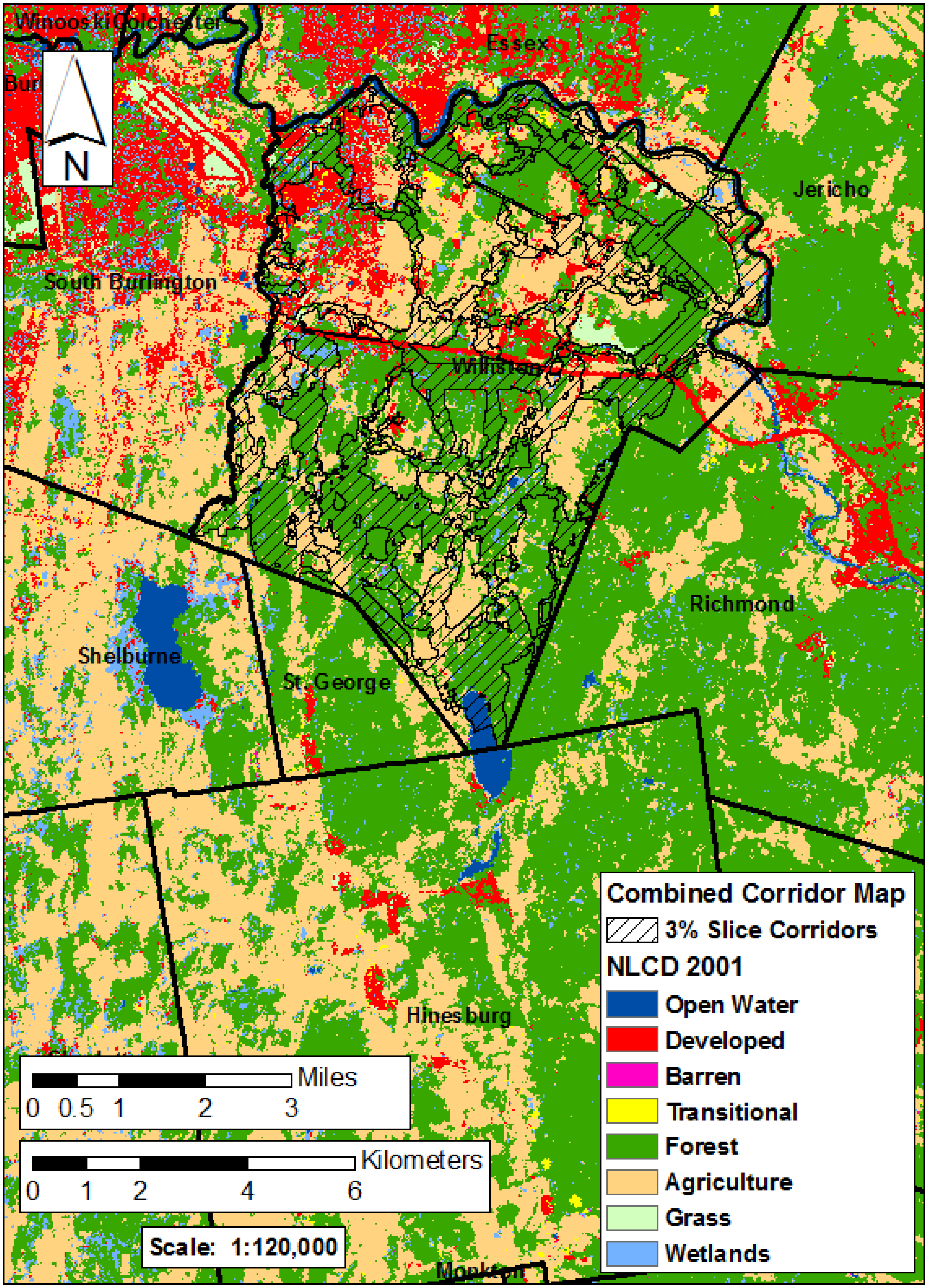

Figure 7. Regional context of modeled corridors in Williston, Vermont relative to the 30-meter (98.4-foot) resolution National Land Cover Dataset (NLCD) for 2001.

Habitat Prioritization

To distill the available wildlife habitat data into a manageable and interpretable subset, we developed a simple prioritization scheme for highlighting important landscape features in Williston. Many prioritization methods are possible, and we would not argue that the one chosen here is the most sensitive to biological diversity or appropriate for town planning. Rather, it is merely a starting point for discussion as the Town considers how best to incorporate wildlife habitat into its regulatory framework.

We first focused on forested land-cover classes, including forested wetlands. The conservation value of forests is obvious, for many reasons (e.g., ecological, aesthetic), but larger parcels are generally considered better for wildlife and more practical to conserve. Thus, we selected all forest patches greater than 30.4 hectares (75 acres), ignoring the smaller, more-widely scattered patches. These smaller patches may be very important ecologically, especially if they support rare or uncommon plants and animals, but an area threshold is a reasonable initial approach to Town-wide planning. We then sub-divided the combined forest class into two sub-categories based on proximity to developed features: Core Forest and Edge Forest. Forested areas at least 100 meters (328.1 feet) from the Urban-General and Urban-Transportation land-cover classes were categorized as Core Forest; all other forestlands were labeled as Edge Forest. This too is a reasonable and informative distinction because it is well known that some species prefer isolated, intact forests (e.g., scarlet tanager, *Piranga olivacea*) while others require forests close to fields or brush (e.g., chestnut-sided warbler, *Dendroica pensylvanica*).

Next, we extracted wetlands and open water from the LULC map, selecting all polygons regardless of size; no area threshold was used because these features are known to provide vital habitat to a wide array of terrestrial and aquatic wildlife species. They also provide important ecosystem services to human communities (e.g., water supply, flood control, recreation), and regulatory protections from Federal and State law theoretically make them enduring landscape elements that are unlikely to change in the short-term. For similar reasons, we also added streams from the 1:5,000 Vermont Hydrography Dataset; small streams depicted as lines rather than polygons were not included in the LULC map and thus had to be derived from other sources. As a final step, we added agricultural fields (Agriculture-General and Agriculture-Hay\Crop) greater than 8.1 ha (20 acres) in size. Although agricultural fields are human-maintained landscape features, they provide breeding and foraging habitat for some species (e.g., smooth green snake) and movement routes for many others. They are also valued for local food production and aesthetic values, and they are often the focus of public and private conservation efforts. Some grassland bird species (e.g., bobolink, *Dolichonyx oryzivorus*) will use hayfields smaller than the 8.1-ha threshold (UNH Cooperative Extension undated), but this threshold is the minimum field size eligible for inclusion in the Natural Resources Conservation Service's incentive program for grassland bird conservation (NRCS 2009) and is thus a practical starting point for prioritizing the conservation value of agricultural features.

When these landscape features are displayed together, they show the extent and distribution of Williston's primary undeveloped lands, the areas that are most likely to support intact wildlife habitats (Figure 8). By extension, they are also the areas likely to support the highest proportion of the Town's native biological diversity, potentially serving as population sources for other, less prominent habitat patches in Town or in adjacent municipalities. When the modeled corridors are superimposed on these landscape features, the two sets of landscape descriptors coincide closely, emphasizing the tendency for optimal corridors to cross undeveloped sites where interaction with humans are minimized. However, it is also clear that some corridors necessarily traverse busy roads, sub-optimal habitats, or isolated patches that are highly circumscribed by adjacent development; in highly urbanized sections of Town, wildlife have no alternative but to use the human landscape when attempting to access certain habitat patches. Accordingly, any plan for protecting and enhancing wildlife movement corridors must focus on the full breadth of land-cover types in Williston, including human-dominated ones. Although additional work would

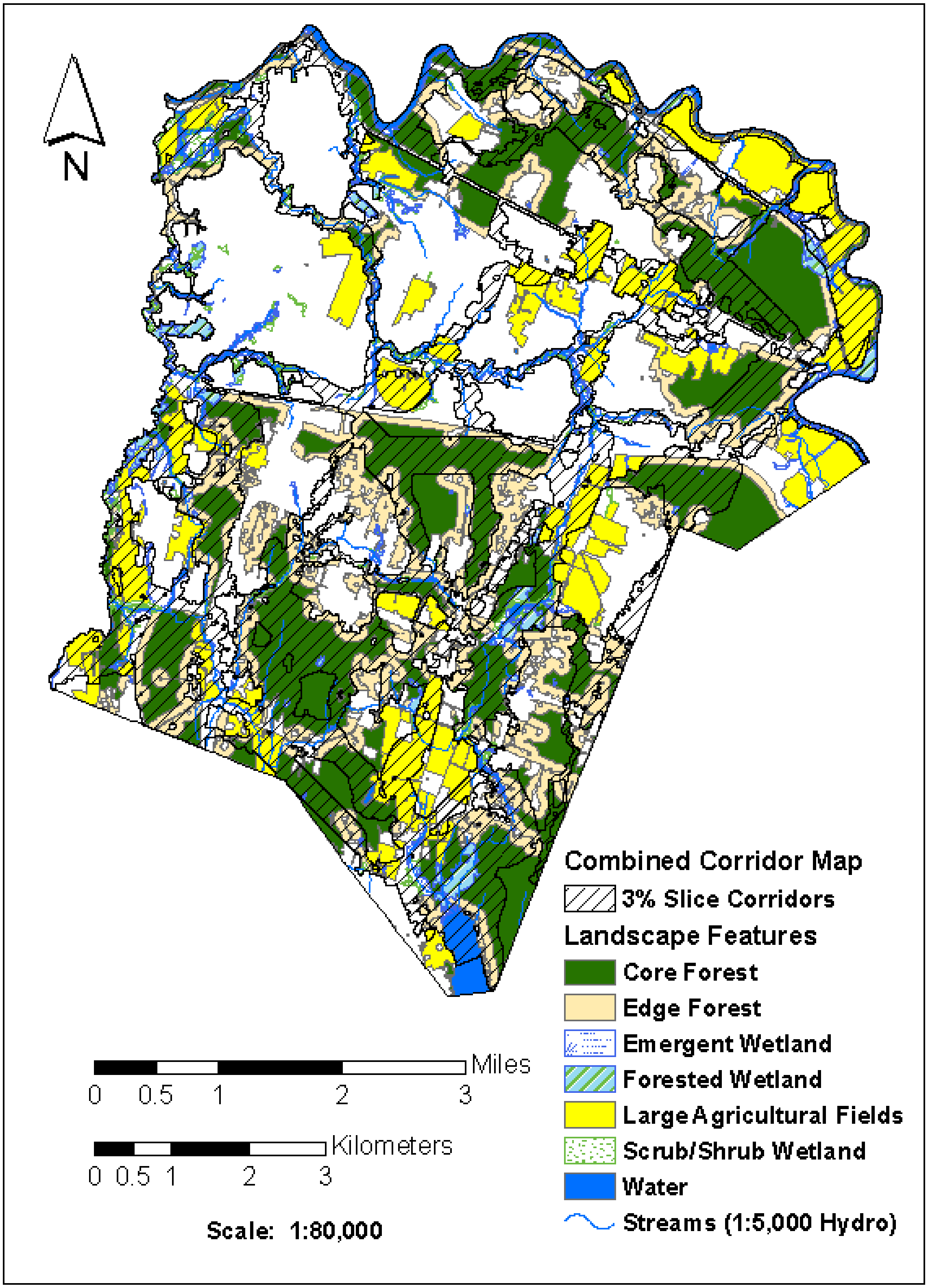

Figure 8. Notable wildlife habitat features in Williston, Vermont as identified by LULC, corridor modeling, and simple area thresholds.

no doubt be needed to refine conservation priorities beyond this simple assessment, it nonetheless provides an effective overview of the Town's most important habitat features and the linkages between them.

Conclusions

Williston's landscape is a complex mosaic of second-growth forest; actively-managed agricultural fields; old fields reverting to shrubs; wetlands and water; and urbanized zones where the Town's residential and commercial development is concentrated. This mosaic produces a similarly complex distribution of natural and human-modified habitats, and it is no small task to quantify the wildlife populations whose occurrence and spatial patterns reflect it. The datasets developed for this project help summarize that complexity and to simplify it, making it possible to predict where wildlife are most likely to occur and how they are likely to move across the landscape mosaic.

The comprehensive LULC map was the key initial data source; all subsequent habitat descriptions and analyses were derived from it. Now that this layer is complete, it can be used for a great variety of habitat-based analyses and land-use assessments, and it can also serve as a base map for landscape-change analyses as new orthophotography datasets are acquired and the original map is revised to reflect land-cover conversions (e.g., forest to developed uses, brush\transitional areas to forest). The derivative products, including core forest, potential habitat, and wildlife corridors, can also be updated as new land-cover data become available or additional field work is conducted to help refine estimated species-habitat relationships.

In the short-term, additional studies could focus on further validating the corridor models and refining them to better reflect the habitat preferences of Williston's wildlife populations. For example, a tree-canopy assessment for urbanized zones would help gauge wildlife movement through developed land uses. Given this project's limited scope, urban areas were generalized into single polygons, but a tree-canopy assessment would reveal small patches or even individual trees that might provide cover for wildlife navigating urban parcels. Many refinements to the habitat-prioritization scheme are also possible, including assessment of existing conservation lands, inclusion of relevant zoning restrictions (e.g., buffers for wetlands and riparian zones), and different area thresholds for forest patches and agricultural fields.

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Appendix A. Geographic information system (GIS) layers developed for Williston, Vermont as part of an updated wildlife habitat assessment, June 2011. All layers will be submitted to the Town in digital format* with accompanying descriptive metadata.

Layer	**Description**
Land use\land cover (LULC)	14-class LULC map delineating primary landscape elements, including forests, wetlands, agriculture, and developed features
Modified land use\land cover (Modified LULC)	LULC map modified to include transportation sub-classes necessary for categorizing landscape permeability in corridor modeling
Potential habitat for 32 representative species (32 separate layers)	Predicted distributions based on LULC and known or suspected species-habitat relationships; note that initial LULC-based maps for some species were refined with additional modeling
Species\habitat matrix (table)	List of vertebrate wildlife species expected to be found in Williston and the LULC types where they could occur; this database can be linked with the LULC map to predict the distribution of any species; note that this table includes all habitat types in which an individual species may occur, both preferred and marginal
Preferred habitat matrix for 32 representative species (table)	List of 32 species representing the range of potential habitats in Williston; this database can be linked with the LULC map to predict the distribution of any species; note that the species in this table are also present in the species\habitat matrix but only its preferred habitat types are included in this table, if applicable
Modeled corridors for 7 focal species (7 separate layers)	Predicted movement corridors for focal species based on LULC and other habitat factors; modeled using Corridor Design
Combined corridor map	Modeled corridors for all 7 focal species compiled into one map; this combined map encompasses a range of habitat requirements and life histories
Wildlife landscape features	Summary of landscape features important to wildlife, selected using simple prioritization rules: core and edge forests (combined area > 30.4 hectares or 75 acres), agricultural fields (area > 8.1 hectares or 20 acres), wetlands, open water
1:5,000 streams	Streams depicted as a single line, as delineated in the Vermont Hydrography Dataset; small streams were not included in the LULC map but are important habitat features

*ArcGIS geodatabase

Appendix B. Representative species used to develop maps of potential wildlife habitat, Williston, Vermont. These species reflect the diversity of habitats present in the Williston landscape.

Species	**Preferred Habitat**
Jefferson salamander (*Amystoma jeffersonianum*)	Deciduous forest close to seasonal wetlands
Spotted salamander (*Ambystoma maculatum*)	Forested wetland
Four-toed salamander (*Hemidactylium scutatum*)	Forested wetland
Redback salamander (*Plethodon cinereus*)	Deciduous forest
Wood frog (*Rana sylvatica*)	Forested wetland
Northern goshawk (*Accipter gentilis*)	Coniferous forest
Red-tailed hawk (*Buteo jamaicensis*)	Agriculture, brush\transitional near forest
American kestrel (*Falco sparverius*)	Grasslands; nests in tree cavities
Wild turkey (*Meleagris gallopavo*)	Deciduous forest with mast-producing trees
Great horned owl (*Bubo virginianus*)	Deciduous forest, esp. large, mixed patches
Pileated woodpecker (*Dryocopus pileatus*)	Deciduous forest with old, decaying trees
Willow flycatcher (*Empidonax traillii*)	Shrubland\transitional along wetland edges
Eastern kingbird (*Tyrannus tyrannus*)	Brush, agriculture, wetlands
Horned lark (*Eremophila alpestris*)	Grasslands with patches of bare ground
Common raven (*Corvus corax*)	Coniferous forest during nesting season
Red-breasted nuthatch (*Sitta canadensis*)	Coniferous forest
Marsh wren (*Cistothorus palustris*)	Emergent wetland
Blue-winged warbler (*Vermivora pinus*)	Shrubland\transitional
Chestnut-sided warbler (*Dendroica pensylvanica*)	Deciduous forest edges
Scarlet tanager (*Piranga olivacea*)	Deciduous forest, esp. large patches
Indigo bunting (*Passernia cyanea*)	Shrubland\transitional
Swamp sparrow (*Melospiza georgiana*)	Emergent wetlands
Bobolink (*Dolichonyx oryzivorus*)	Grasslands
American beaver (*Castor canadensis*)	Scrub\scrub wetland
Muskrat (*Ondatra zibethicus*)	Emergent wetland
Coyote (*Canis latrans*)	Forest, agriculture, brush\transitional
Red fox (*Vulpes vulpes*)	Forest, agriculture, brush near urban areas
Fisher (*Martes pennanti*)	Coniferous forest
Mink (*Mustela vison*)	Banks of rivers, streams, and ponds with cover
Bobcat (*Lynx rufus*)*	Forest, agriculture
Wood turtle (*Glyptemys insculpta*)*	Streams\rivers and adjacent forest
Smooth green snake (*Liochlorophis vernalis*)	Agriculture, brush\transitional

*Not in 2005 Wildlife Habitat Report; this species was added in the follow-up study because it was used in corridor modeling.

Appendix C1. Habitat parameters for the bobcat (*Lynx rufus*) used in corridor modeling, Williston, Vermont.

Habitat Factor	**Class**	**Score**
Land Cover	Agriculture-General	60
	Agriculture-Hay\Crop	60
	Agriculture-Orchard	60
	Barren	0
	Brush	60
	Forest-Coniferous	100
	Forest-Deciduous	100
	Forest-Mixed	100
	Urban-General	0
	Urban-Transportation	0
	Water	30
	Wetland-Emergent	30
	Wetland-Forested	60
	Wetland-Scrub\Shrub	30
Landscape Permeability	Agriculture-General	60
	Agriculture-Hay\Crop	60
	Agriculture-Orchard	60
	Barren	20
	Brush	60
	Forest-Coniferous	100
	Forest-Deciduous	100
	Forest-Mixed	100
	Urban-General	20
	Urban-Transportation (Interstate Highway)	20
	Urban-Transportation (U.S. & State Highway)	40
	Urban-Transportation (Town-High Volume)	50
	Urban-Transportation (Town-Low Volume)	60
	Urban-Transportation (Private Road)	80
	Urban-Transportation (Bridge & Major Culvert)	80
	Water	80
	Wetland-Emergent	80
	Wetland-Forested	100
	Wetland-Scrub\Shrub	80
*Distance to Rivers\Streams**	0-100 meters	100
	100-200 meters	75
	>200 meters	50

Factor Weights: Land Cover, 34%; Landscape Permeability, 33%; Distance to Rivers\Stream, 33%.

*This habitat factor was added after winter-tracking observations during the winter of 2010-2011 indicated that bobcat preferentially used river and stream corridors for movement.

Appendix C2. Habitat parameters for the fisher (*Martes pennanti*) used in corridor modeling, Williston, Vermont.

Habitat Factor	**Class**	**Score**
Land Cover	Agriculture-General	30
	Agriculture-Hay\Crop	30
	Agriculture-Orchard	30
	Barren	0
	Brush	60
	Forest-Coniferous	100
	Forest-Deciduous	60
	Forest-Mixed	60
	Urban-General	0
	Urban-Transportation	0
	Water	30
	Wetland-Emergent	30
	Wetland-Forested	60
	Wetland-Scrub\Shrub	30
Landscape Permeability	Agriculture-General	60
	Agriculture-Hay\Crop	60
	Agriculture-Orchard	60
	Barren	20
	Brush	60
	Forest-Coniferous	100
	Forest-Deciduous	100
	Forest-Mixed	100
	Urban-General	20
	Urban-Transportation (Interstate Highway)	20
	Urban-Transportation (U.S. & State Highway)	40
	Urban-Transportation (Town-High Volume)	50
	Urban-Transportation (Town-Low Volume)	60
	Urban-Transportation (Private Road)	80
	Urban-Transportation (Bridge & Major Culvert)	80
	Water	80
	Wetland-Emergent	80
	Wetland-Forested	100
	Wetland-Scrub\Shrub	80
Distance to Urban	0-25 meters	30
	25-100 meters	60
	>100 meters	100

Factor Weights: Land Cover, 34%; Landscape Permeability, 33%; Distance to Urban, 33%.

Appendix C3. Habitat parameters for the mink (*Mustela vison*) used in corridor modeling, Williston, Vermont.

Habitat Factor	**Class**	**Score**
Land Cover	Agriculture-General	30
	Agriculture-Hay\Crop	30
	Agriculture-Orchard	30
	Barren	0
	Brush	30
	Forest-Coniferous	60
	Forest-Deciduous	60
	Forest-Mixed	60
	Urban-General	0
	Urban-Transportation	0
	Water	100
	Wetland-Emergent	100
	Wetland-Forested	100
	Wetland-Scrub\Shrub	100
Landscape Permeability	Agriculture-General	60
	Agriculture-Hay\Crop	60
	Agriculture-Orchard	60
	Barren	20
	Brush	60
	Forest-Coniferous	80
	Forest-Deciduous	80
	Forest-Mixed	80
	Urban-General	20
	Urban-Transportation (Interstate Highway)	20
	Urban-Transportation (U.S. & State Highway)	40
	Urban-Transportation (Town-High Volume)	50
	Urban-Transportation (Town-Low Volume)	60
	Urban-Transportation (Private Road)	80
	Urban-Transportation (Bridge & Major Culvert)	80
	Water	100
	Wetland-Emergent	100
	Wetland-Forested	100
	Wetland-Scrub\Shrub	100
Distance to Water\Wetlands	0-50 meters	100
	50-150 meters	50
	>150 meters	0

Factor Weights: Land Cover, 34%; Landscape Permeability, 33%; Distance to Water\Wetlands, 33%.

Appendix C4. Habitat parameters for the four-toed salamander (*Hemidactylium scutatum*) used in corridor modeling, Williston, Vermont.

Habitat Factor	**Class**	**Score**
Land Cover	Agriculture-General	0
	Agriculture-Hay\Crop	0
	Agriculture-Orchard	0
	Barren	0
	Brush	30
	Forest-Coniferous	30
	Forest-Deciduous	60
	Forest-Mixed	60
	Urban-General	0
	Urban-Transportation	0
	Water	30
	Wetland-Emergent	100
	Wetland-Forested	60
	Wetland-Scrub\Shrub	100
Landscape Permeability	Agriculture-General	20
	Agriculture-Hay\Crop	20
	Agriculture-Orchard	20
	Barren	20
	Brush	20
	Forest-Coniferous	100
	Forest-Deciduous	100
	Forest-Mixed	100
	Urban-General	20
	Urban-Transportation (Interstate Highway)	0
	Urban-Transportation (U.S. & State Highway)	40
	Urban-Transportation (Town-High Volume)	50
	Urban-Transportation (Town-Low Volume)	60
	Urban-Transportation (Private Road)	80
	Urban-Transportation (Bridge & Major Culvert)	80
	Water	100
	Wetland-Emergent	100
	Wetland-Forested	100
	Wetland-Scrub\Shrub	100
Distance to Scrub\Shrub and Emergent Wetlands	0-50 meters	100
	50-200 meters	50
	>200 meters	0

Factor Weights: Land Cover, 34%; Landscape Permeability, 33%; Distance to Scrub\Shrub and Emergent Wetlands, 33%.

Appendix C5. Habitat parameters for the wood frog (*Rana sylvatica*) used in corridor modeling, Williston, Vermont.

Habitat Factor	**Class**	**Score**
Land Cover	Agriculture-General	0
	Agriculture-Hay\Crop	0
	Agriculture-Orchard	0
	Barren	0
	Brush	30
	Forest-Coniferous	100
	Forest-Deciduous	100
	Forest-Mixed	100
	Urban-General	0
	Urban-Transportation	0
	Water	30
	Wetland-Emergent	60
	Wetland-Forested	100
	Wetland-Scrub\Shrub	60
Landscape Permeability	Agriculture-General	20
	Agriculture-Hay\Crop	20
	Agriculture-Orchard	20
	Barren	20
	Brush	20
	Forest-Coniferous	100
	Forest-Deciduous	100
	Forest-Mixed	100
	Urban-General	20
	Urban-Transportation (Interstate Highway)	20
	Urban-Transportation (U.S. & State Highway)	40
	Urban-Transportation (Town-High Volume)	50
	Urban-Transportation (Town-Low Volume)	60
	Urban-Transportation (Private Road)	80
	Urban-Transportation (Bridge & Major Culvert)	80
	Water	100
	Wetland-Emergent	100
	Wetland-Forested	100
	Wetland-Scrub\Shrub	100

Factor Weights: Land Cover, 50%; Landscape Permeability, 50%.

Appendix C6. Habitat parameters for the smooth green snake (*Liochlorophis vernalis*) used in corridor modeling, Williston, Vermont.

Habitat Factor	**Class**	**Score**
Land Cover	Agriculture-General	100
	Agriculture-Hay\Crop	100
	Agriculture-Orchard	60
	Barren	0
	Brush	100
	Forest-Coniferous	30
	Forest-Deciduous	30
	Forest-Mixed	30
	Urban-General	0
	Urban-Transportation	0
	Water	30
	Wetland-Emergent	60
	Wetland-Forested	30
	Wetland-Scrub\Shrub	60
Landscape Permeability	Agriculture-General	100
	Agriculture-Hay\Crop	100
	Agriculture-Orchard	100
	Barren	20
	Brush	100
	Forest-Coniferous	80
	Forest-Deciduous	80
	Forest-Mixed	80
	Urban-General	20
	Urban-Transportation (Interstate Highway)	20
	Urban-Transportation (U.S. & State Highway)	40
	Urban-Transportation (Town-High Volume)	50
	Urban-Transportation (Town-Low Volume)	60
	Urban-Transportation (Private Road)	80
	Urban-Transportation (Bridge & Major Culvert)	80
	Water	100
	Wetland-Emergent	100
	Wetland-Forested	100
	Wetland-Scrub\Shrub	100

Factor Weights: Land Cover, 50%; Landscape Permeability, 50%.

Appendix C7. Habitat parameters for the wood turtle (*Glyptemys insculpta*) used in corridor modeling, Williston, Vermont.

Habitat Factor	**Class**	**Score**
Land Cover	Agriculture-General	30
	Agriculture-Hay\Crop	30
	Agriculture-Orchard	30
	Barren	0
	Brush	30
	Forest-Coniferous	60
	Forest-Deciduous	60
	Forest-Mixed	60
	Urban-General	0
	Urban-Transportation	0
	Water	100
	Wetland-Emergent	30
	Wetland-Forested	60
	Wetland-Scrub\Shrub	30
Landscape Permeability	Agriculture-General	60
	Agriculture-Hay\Crop	60
	Agriculture-Orchard	60
	Barren	20
	Brush	60
	Forest-Coniferous	80
	Forest-Deciduous	80
	Forest-Mixed	80
	Urban-General	20
	Urban-Transportation (Interstate Highway)	20
	Urban-Transportation (U.S. & State Highway)	40
	Urban-Transportation (Town-High Volume)	50
	Urban-Transportation (Town-Low Volume)	60
	Urban-Transportation (Private Road)	80
	Urban-Transportation (Bridge & Major Culvert)	80
	Water	100
	Wetland-Emergent	100
	Wetland-Forested	100
	Wetland-Scrub\Shrub	100
Distance to Rivers\Streams	0-150 meters	100
	150-300 meters	50
	>300 meters	0

Factor Weights: Land Cover, 34%; Landscape Permeability, 33%; Distance to Rivers\Streams, 33%.