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Use of a GIS-Based Model of Habitat Cores and Landscape Corridors for the Virginia Department of Transportation's Project Planning and Environmental Scoping

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BRIDGET M. DONALDSON
Research Scientist
Virginia Transportation Research Council

JOSEPH T. WEBER
GIS Projects Manager/Conservation Biologist
Virginia Department of Conservation and Recreation

Virginia Transportation Research Council, 530 Edgemont Road,
Charlottesville, VA 22903-2454, www.vtrc.net, (434) 293-1900

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16. Abstract

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The Virginia Department of Conservation and Recreation's Natural Heritage Program is creating a GIS tool, the Virginia Natural Landscape Assessment (VANLA), that identifies large patches of natural land cover (habitat cores) and the habitat linkages connecting these areas (landscape corridors). This analysis can be integrated into the Virginia Department of Transportation's (VDOT) existing GIS applications for access by staff involved with transportation planning and environmental scoping activities.

Analyzing a proposed project in the early stages of project development would allow VDOT to identify important natural resource areas and habitat corridors to avoid or for which mitigation may be appropriate or necessary. This can result in fewer project delays, promote collaboration between VDOT and state natural resource and regulatory agencies, and meet the directives of the new habitat conservation provision in SAFETEA-LU, the federal transportation legislation. In addition, basing particular project decisions on a project's location relative to a habitat corridor can decrease the risk of costly animal-vehicle collisions.

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FINAL REPORT

USE OF A GIS-BASED MODEL OF HABITAT CORES AND LANDSCAPE CORRIDORS FOR THE VIRGINIA DEPARTMENT OF TRANSPORTATION'S PROJECT PLANNING AND ENVIRONMENTAL SCOPING

Bridget M. Donaldson
Research Scientist
Virginia Transportation Research Council

Joseph T. Weber
GIS Projects Manager/Conservation Biologist
Virginia Department of Conservation and Recreation

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ABSTRACT

As important habitats are being lost to human development, transportation agencies are facing increased expectations that their road projects avoid or minimize further habitat destruction and adverse effects on wildlife populations. Wildlife linkage or landscape corridor analyses are being conducted in an increasing number of states, and more transportation agencies are using this information during the planning of proposed road projects.

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Research Scientist
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Joseph T. Weber
GIS Projects Manager/Conservation Biologist
Virginia Department of Conservation and Recreation

INTRODUCTION

Habitat Fragmentation and Landscape Corridors

Transportation agencies across the United States are under increasing pressure to minimize or avoid impacts of transportation projects on important wildlife habitat. With new road construction and lane additions, habitat fragmentation is becoming more pronounced and its effects are increasingly evident. Roads divide landscapes into discrete patches or fragments. This decrease in habitat connectivity results in impacts to both driver safety and wildlife. Roads are impenetrable barriers to some species, isolating populations and threatening their viability. Other species regularly attempt to cross roads to access other habitat. Animal-vehicle collisions are a common result, posing a serious threat to drivers and the populations of some species (Iuell et al., 2003; Forman et al., 2003).

Habitat destruction and fragmentation are the greatest threats to biodiversity in Virginia. Conversion of natural land covers to suburban and urban land uses is the primary mechanism by which habitat is lost permanently in Virginia (Virginia Department of Game and Inland Fisheries [VDGIF], 2005). Large, unfragmented patches of habitat are less numerous as land development and road construction increase. Fragmentation of large patches of natural cover disproportionately removes high-quality interior habitat and increases the amount of edge habitat, a type of habitat that occurs at the boundary between two habitat types. Interior species, including black bears and various songbird species, are susceptible to edge effects. Edge effects include disturbance from humans, predation from opportunistic and generally more common wildlife species, and differences in conditions such as wind velocity, temperature, light, and relative humidity. Large patches of natural cover have benefits that exceed the benefits of the same total area of natural cover distributed among smaller patches. Large patches are important not only in terms of wildlife and plant habitat, but also in terms of open space, recreation, groundwater recharge, maintenance of water quality, carbon sequestration, climate regulation, crop pollination, erosion control, sediment retention, and protection from storm and flood damage (Costanza et al., 1997).

Species in fragmented landscapes are affected by the degree to which they are isolated in the fragments. The degree of isolation is dependent not only on the distance to other patches, but also on the land cover surrounding the isolated patch. If the surroundings of a patch are harsh to a species, that species will be unlikely to travel to another patch. Isolation because of habitat fragmentation affects the natal dispersal movement of many species, movement associated with migration and breeding activity, and long-term movement in response to environmental changes. This has led to serious declines in the populations of many species. Isolated populations face an increased probability of inbreeding as genetic exchange between them decreases, thereby increasing the risk of eventual extirpation, or local extinction (Forman et al., 2003; Foresman, 2004). Extirpation of local populations can also result for seemingly healthy populations because of catastrophic weather events, sudden disease outbreaks, excessive predation, nest failure, and other causes. Once there is an extirpation, isolated patches are less likely to be recolonized naturally.

If the surrounding land cover is at least marginally suitable and the distance is not too great, then species might cross it to reach other patches. This often entails crossing roads. Some animals, such as spotted salamanders and semi-aquatic turtle species, travel in mass migrations to ponds and wetlands each year. Crossing roads to reach aquatic habitat can result in critical impacts to their populations. Although the populations of other species may not be harmed by vehicle collisions, some collisions can cause considerable human injury and property damage. Deer-vehicle collisions (DVC) in Virginia have resulted in an estimated 38,000 to 43,000 vehicle collisions in *each* of the last 4 years (M. White, unpublished data, 2006). At the 2006 average reported property damage cost of $2,800 per DVC (M. White, unpublished data, 2006), these collisions can cost Virginia taxpayers $120.4 million in property damage in 1 year alone

Landscape corridors are valuable conservation tools (Bier and Noss, 1998) that can attenuate the negative consequences of fragmentation, such as patch isolation, and help conserve wildlife populations that are subdivided among different patches. Landscape corridors have been shown to increase the exchange of animals among patches and to facilitate dispersal of pollens and seeds (Tewksbury et al., 2002). The results of a study by Damschen et al. (2006) support the use of corridors in biodiversity conservation. They found that habitat patches connected by corridors retain more native plant species than do isolated patches, that this difference increases over time, and that corridors do not promote invasion by exotic species. Important considerations of landscape corridors include length and width. Corridor width is positively correlated with abundance and species richness of birds, mammals, and invertebrates (Lindenmayer and Franklin, 2002).

Landscape corridors can be used to connect large patches of natural land in fragmented landscapes to form a network of natural lands. Because corridors are used as a means of regular travel by wildlife, reviewing the location of identified landscape corridors relative to a proposed road project or to the transportation network as a whole can be particularly useful for transportation agencies. In transportation project planning, this can be a highly effective means of planning avoidance measures or mitigation methods to reduce the effects of habitat fragmentation or the likelihood of animal-vehicle collisions.

Federal and State Perspectives

VDGIF recently submitted a report mandated by the U.S. Congress, *Virginia's Wildlife Action Plan,* that provided information on the status of the Commonwealth's wildlife species and habitat (VDGIF, 2005). The report stated that Virginia is headed toward a wildlife crisis, with 925 species identified as in decline. The plan, for which the Virginia Department of Transportation (VDOT) was a member of the external steering committee, mentioned highways as contributors to this species decline, because of their adverse effects concerning fragmentation, development, and aquatic habitat.

The U.S. government is encouraging state agencies to implement methods to manage such issues effectively. The 2005 Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) contains directives for designing projects and processes to reduce these impacts to wildlife habitat and driver safety. As part of the legislation, the U.S. Department of Transportation (USDOT) is charged with conducting a comprehensive study on the causes and impacts of wildlife-vehicle collisions (Section 119n). One of the highway improvement measures listed in the Highway Safety Section of the legislation (Subtitle D, Section 1401) is "the addition or retrofitting of structures or other measures to eliminate or reduce accidents involving vehicles and wildlife." An unprecedented provision also requires that transportation planners consider wildlife conservation during the planning process. Under Section 6001, SAFETEA-LU requires that preparation of transportation plans include (1) consultation with relevant state and local agencies responsible for conservation and natural resource protection, (2) consideration of available conservation plans or maps, and (3) a discussion of potential environmental mitigation activities and potential areas to carry out these activities.

The USDOT and the Federal Highway Administration (FHWA) support this type of cooperative ecosystem approach to planning transportation projects. A newly released document by USDOT and endorsed by FHWA entitled *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects* (Brown, 2006) guides transportation agencies in "making infrastructure more sensitive to wildlife and ecosystems through greater interagency cooperative conservation"

Virginia transportation and conservation professionals also recognize the importance of integrating ecosystem analyses with transportation. A main benefit of this approach is that it allows for planning early for conservation measures, as mitigation activities are substantially more expensive when conducted after the completion of road designs or construction. As part of an ongoing study, the authors of NCHRP 25-27, *Evaluation of the Use and Effectiveness of Wildlife Crossings* (Bissonette, unpublished data), distributed a survey to prioritize transportation and wildlife issues in each state. The survey was taken by 12 environmental professionals in Virginia, including staff from VDOT's Environmental Division. Virginia's first priority in the topic of transportation and wildlife, as ranked by these professionals, is to "incorporate wildlife needs early in the DOT programming, planning, and design process." The second priority is to "use conservation plans and connectivity analyses to inform the transportation programming/planning/design process on where mitigation is needed and where it may be carried out" (Bissonette, unpublished data).

Virginia Natural Landscape Assessment and Its Application to VDOT

An analysis conducted by the Virginia Department of Conservation and Recreation's Division of Natural Heritage (DCR-DNH) may provide an ideal opportunity for VDOT to comply with SAFETEA-LU directives, USDOT guidelines, and the needs of Virginia transportation and environmental professionals. This analysis, entitled the Virginia Natural Landscape Assessment (VANLA) uses a geographic information system (GIS) to identify large patches of natural land cover (habitat cores) and the natural linkages connecting these areas (landscape corridors). Figure 1 illustrates a VANLA-modeled landscape corridor and the habitat cores it connects. The project is intended for use in conservation planning by state agencies, local governments, and non-governmental organizations (NGOs). If incorporated into VDOT's GIS applications, the data can be easily accessed by VDOT employees during the project planning process. This can provide VDOT the means to plan ahead for potential measures to avoid sensitive areas or to mitigate when necessary, thereby reducing impacts to important habitat and reducing the likelihood of animal-vehicle collisions.

VDOT's current process in the environmental scoping and review of a project follows the requirements of the State Environmental Review Process (SERP) and the National Environmental Policy Act (NEPA). Under these regulations, VDOT uses environmental data

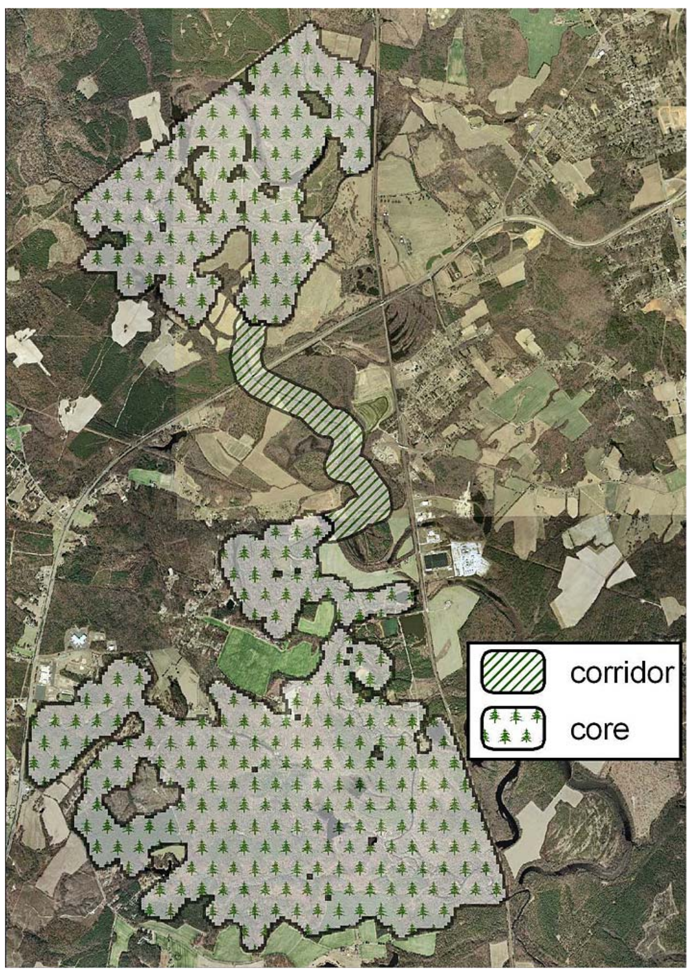

Figure 1. GIS Image Depicting Two Habitat Cores Connected By Landscape Corridor

provided by various natural resource agencies in Virginia to determine the potential effects of a proposed road project on the natural resources of the area. The SERP process is intended to allow other agencies to provide input as early as possible so the VDOT project manager and designer have time to avoid or minimize potential impacts in the design process. Nevertheless, it is sometimes difficult to provide proposed project information to natural resource and regulatory agencies during the environmental scoping process (and prior to the design process). If these agencies request or require avoidance or mitigation measures after the completion of VDOT's project designs, however, significant project costs and delays can result. Because data depicting large blocks of significant habitat and their connecting landscape corridors are not currently available to VDOT staff, it is difficult for them to assess potential habitat fragmentation issues or impacts on landscape corridors during the project scoping stage. Moving forward with projects without considering these effects can not only lead to costly mitigation activities after the completion of road designs and construction, it may also increase the likelihood of animal-vehicle collisions on particular road segments.

PURPOSE AND SCOPE

The purpose of this study was to provide VDOT an environmental tool that can be used for early identification of core habitat areas and the landscape/wildlife corridors connecting these habitats. The public and state regulatory agencies are increasingly concerned with the preservation of Virginia's remaining resources. Projects are often planned, designed, and funded before important habitat considerations are taken into account, which can lead to expensive delays and lawsuits. Providing VDOT this statewide habitat data will not only promote environmental stewardship and stress collaborative agency participation, it will also allow for a more timely, predictable, and cost-efficient approval process.

The GIS model (VANLA) created by DCR-DNH would be available in digital map form for use during the project planning stage before a project is designed and funded. When a proposed project is shown to intersect or interfere with an identified important habitat core or corridor, a variety of mitigation options offered in a toolkit by Donaldson (2006) could be considered.

METHODS

Four tasks were conducted to achieve the study objectives:

1. Review other states' analyses of habitat cores or habitat connectivity in relation to the transportation network.

2. Describe the methods for developing VANLA habitat cores and landscape corridors.

3. Determine VANLA's applicability to transportation planning and environmental scoping.

4. Determine the means for making VANLA data easily accessible to VDOT staff.

Review of Statewide Habitat Analyses

Corridor or linkage analyses, which include the identification of natural corridors necessary to support the movement and reproductive needs of wildlife populations, are being conducted in an increasing number of states. These analyses, most of which utilize GIS techniques, can be applied to transportation systems to identify mitigation opportunities in areas where wildlife corridors intersect with existing or planned roads.

Information on these statewide analyses was gathered from the literature, presentations and proceedings from transportation conferences (including those of the Transportation Research Board and the International Conference on Ecology and Transportation), and websites of departments of transportations (DOTs). Though not a comprehensive list, the examples of corridor analyses that were gathered were those in which the state transportation agency played a large role in the project support and development.

Methods for Developing the Virginia Natural Landscape Assessment

Overview

DCR-DNH is developing a project to identify a network of natural lands. This project, VANLA, is the main ecological component of the Virginia Conservation Lands Needs Assessment (VCLNA), the overarching project that models and maps various types of priority lands for conservation. VANLA is a landscape-scale GIS analysis for identifying, prioritizing, and linking natural lands in Virginia. This work was guided initially by ecological assessments conducted for other states and regions, most notably the Maryland Green Infrastructure Assessment (Weber, 2003) and the Chesapeake Bay Resource Lands Assessment (Chesapeake Bay Program, 2005). Using land cover data derived from satellite imagery, VANLA identifies unfragmented ecological units called cores. Cores are large patches of one or more natural land covers with at least 100 acres of interior cover. Large, medium, and small cores, as well as a smaller feature type called habitat fragments that may be important in the more urban localities, have been identified and mapped. Cores provide habitat for a wide range of species, from species dependent upon interior forests to generalist species that use many different ecological communities. Since marsh, dune, and beach land covers were included in this analysis, cores also provide habitat for species that use these habitats. In addition to wildlife and plant habitats, cores also provide the open space, recreation, and ecological-service benefits.

A network of landscape corridors that connects the highest priority cores is also under development. The landscape corridor analysis is complete along Virginia’s coastal zone, and the corridor analysis for the rest of the state is planned for completion in 2007. A final report that describes VANLA methodology in detail is planned for completion in spring 2007. VANLA products, and other products of VCLNA, are intended to be used by the Virginia Land Conservation Foundation, state and federal agencies, land trusts, and other conservation partners for land and resource conservation and habitat restoration. These products also will be made available to localities for use in local and regional planning efforts.

Study Area

The study area includes the entire Commonwealth of Virginia and a 20-mile buffer around the state. This large buffer was selected to prevent truncation of cores and corridors that cross the state boundary and to facilitate edge matching to similar projects conducted in adjacent states.

Land Cover

The VANLA land cover layer was created by modifying and combining classified Landsat Thematic Mapper satellite imagery from various sources. Weber's final VANLA report (unpublished data) will provide more information about VANLA land cover.

Cores Development

The VANLA land cover was used to develop VANLA cores, which are defined in this analysis as patches of natural cover containing at least 100 acres of interior cover. Interior cover begins 100 m inward from the patch edge. This 100-m buffer constitutes the abiotic transition zone following the "three-tree-height" rule (Harris, 1984), since fully mature forests in Virginia reach maximum height around 33 m. Harris (1984) also discusses a threshold thickness of being more on the order of six tree heights, but an abiotic transition zone of this width was considered too restrictive for areas of Virginia that are already overly fragmented. Problems pertaining to insufficient buffer thickness for some species can be addressed with subsequent analyses of the cores.

The first step in the core development process was to assemble a fragmentation layer that included spatial data for power lines, pipelines, railroads, and roads. This layer was used to fragment the VANLA land cover, thus making a better approximation of the fragmentation in the landscape. Anthropogenic land covers were excluded from the analysis at this point by extracting from the fragmented land cover layer only the following classes and then classifying them as natural cover: deciduous forests, evergreen forests, mixed forests, deciduous wooded wetlands, evergreen wooded wetlands, emergent herbaceous wetlands, mixed wetlands, undeveloped beaches/dunes, and maritime grasses. One pixel width of near-shore open water was added back from the fragmented land cover to the natural cover layer to prevent narrow stretches of open water less than 60 m across (two pixel widths) from splitting a core into two or more smaller cores. The interior areas of the patches in the natural cover layer were identified by using distance analysis to calculate the 100-m abiotic transition zone of each patch. Interior areas greater than or equal to 10 acres were then identified; all patches not meeting this criterion were excluded from further analysis. The abiotic transition zone used to identify interior areas was added back to the remaining interior areas. These patches were then classified into large cores if they had at least 10,000 acres of interior cover, medium cores if they had 1,000 to 9,999 acres of interior cover, small cores if they had 100 to 999 acres of interior cover, and habitat fragments if they had 10 to 99 acres of interior cover. The habitat fragments feature type resulted from a pilot study for VANLA completed in 2004 (Weber and Carter-Lovejoy, 2004), which revealed that the 100-acre minimum interior size for cores was too restrictive for some urban localities. These features may contain natural heritage resources (rare plant and animal species and exemplary natural communities) and have utility for recreation, open space, and stormwater management, but they are too small or narrow to provide many of the other benefits of cores.

Core Prioritization Attributes

To date, analyses were performed to add at least 45 prioritization attributes to the cores and habitat fragments layer (see the Appendix). These attributes can be categorized under the general headings of rare species and habitats, species diversity surrogates, core characteristics and landscape context, and water quality. The prioritization attributes can be used by planners either on an attribute-by-attribute basis or in the development of models combining several attributes in efforts to identify those cores that have the characteristics and provide the benefits of greatest interest to them. DCR-DNH also plans to develop an ecological composite model that will use the principle ecological parameters to develop a single prioritization attribute for ecological significance.

Landscape Corridors Development

Landscape corridors have been completed for the VANLA pilot study covering the coastal zone of Virginia (Weber and Carter-Lovejoy, 2004), and statewide completion is planned by July 2007. The landscape corridors methods described here were used for the pilot study and are expected to be similar to those applied to the entire state.

Landscape corridors are strips of natural cover that traverse the matrix of largely anthropogenic land covers to connect cores to each other. Corridor development required least-cost path analysis to identify the best corridor routes. Least-cost paths in this analysis were defined as the shortest distance through the most suitable land covers for wildlife use and movement. The first step in the process was to generate a corridor suitability layer. This was produced by using a model to combine various landscape parameters, including land cover, urban proximity, riparian forest, roads, slope, core priority, interior forest, and offshore water. The suitability layer represented impedances, the degree to which landscape features inhibit wildlife use and movement. The resulting layer was used to create a cost-distance layer representing the least-cost paths between cores. The lowest cost was achieved by traveling the shortest distance through the most suitable land covers and by avoiding harsh land covers such as urban and suburban developments. The least-cost paths identified the centers of each corridor. Corridors were further widened where they intersected lower-ranked cores, interior forests, and wetlands. These areas are called nodes, and they serve as patches of habitat that increase the functionality of a corridor.

VANLA's Applicability to VDOT Projects

VANLA methodology for cores and corridor development was analyzed for its relevance and applicability to VDOT project planning and environmental scoping. The VANLA data were assessed for their ability to screen effectively for sensitive areas in order to allow for more streamlined and efficient planning and scoping processes. VANLA methods were reviewed to verify that the VANLA cores may contain natural resources that VDOT is encouraged or required to avoid or protect. Online databases, including the National Transportation Library, Web of Science, and Transportation Research Board Research in Progress, were searched for information regarding the relevance of landscape corridors to wildlife movement and animal-vehicle collisions.

Making VANLA Data Available to VDOT

In order for the VANLA data to serve as an effective screening tool for VDOT staff, they would have to be easily accessible during transportation planning and environmental scoping activities. Discussions were held with VDOT GIS administrators and environmental staff to gather input on the feasibility of adding VANLA data to one of VDOT's GIS applications and to determine which application would best provide accessibility to the VANLA data. VDOT GIS staff were provided with a summary of the applicability of the VANLA data to VDOT transportation planners and environmental staff.

RESULTS

Review of Other Statewide Habitat Connectivity Analyses

As roads are constructed and widened to accommodate increasing traffic needs, transportation agencies are required to assess more thoroughly the potential effects on habitat earlier in the planning process. Statewide habitat connectivity analyses are ways in which state transportation and resource agencies are responding to these federal and state directives. Early planning can facilitate cost-effective efforts to conserve remaining habitat, reduce the likelihood of animal-vehicle collisions, and prevent costly mitigation activities or lawsuits resulting from a delayed response or inaction. The following are examples of corridor analyses in which the state transportation agency played a large role in developing and supporting the project. There was no single method for model development employed among states; each analysis was based on the application of unique techniques and variables. Although most analyses primarily involved GIS methods to model habitat connectivity, others relied more heavily on expert opinion.

The Florida DOT (FDOT) has been a leader in conducting and funding projects involving analyses of important ecological areas in relation to its transportation system. Under contract with FDOT, researchers from the University of Florida created a rule-based GIS model of landscape connectivity, which included an inventory and evaluation of specific ecological characteristics of identified priority highway segments (Schaefer and Smith, 2000). The effort included identification of a statewide greenway system that provided for recreation as well as habitat corridors for wildlife. Results were used to provide FDOT with recommendations for appropriate mitigation measures to protect critical environmental resources and reduce animal-vehicle collisions. Florida has also implemented an online environmental screening tool whereby potential effects of a transportation project on the natural resources of an area can be determined early in the project planning process.

The Alaska DOT similarly funded the design of a toolbox of environmental information to assess the effects of existing and proposed roads on habitat quality and connectivity (Dibari et al., 2004). The project used GIS data to inform transportation planners during the road design process and to promote designs that minimize the negative effects of roads on areas of concern and wildlife corridors.

The Arizona DOT (ADOT) was involved in a Missing Linkages Workshop in 2004, consisting of participants from various state agencies and organizations, to produce a statewide habitat inventory linkage map that shows core habitat areas and linkages (T. Brennan, personal communication, 2006). The purpose of the linkage map is for land protection measures, community planning, and mitigation activities such as wildlife crossings. Priority linkages will be integrated with ADOT's 5- and 20-year transportation plans.

Similarly, the Colorado Department of Transportation (CDOT) partnered with multiple state agencies and organizations to identify linkage zones to facilitate movement for wildlife in Colorado (Southern Rockies Ecosystem Project, 2005). Methods were based on integrating state expert opinion on animal habitat and computer modeling of habitat connectivity. Using these identified connectivity zones, CDOT has begun promoting wildlife crossings in their transportation plans and construction projects.

The Vermont Agency of Transportation (VTrans) and the Vermont Department of Fish and Wildlife collaborated to develop a GIS model to identify significant wildlife linkage habitat throughout the state (Austin et al., 2006). The data used include land cover and wildlife road mortality data. This analysis provides a planning tool that will assist VTrans in transportation planning and permitting.

Other states have conducted habitat connectivity analyses based on particular regions or specific highway segments planned for construction. As with most other state analyses, these projects have used GIS modeling to assess habitat corridors in relation to the transportation system. In Washington State, for example, the Snoqualmie pass along I-90 was analyzed in relation to habitat connectivity (Singleton and Lehmkuhl, 2006). Plans are underway for the construction of wildlife crossings to facilitate wildlife movement and reduce animal-vehicle collisions along the corridor.

Virginia Natural Landscape Assessment

The products from VANLA include the GIS data, reports, and digital map images. The GIS data currently include the cores shapefile (a GIS layer) that has been attributed with more than 45 prioritization themes (see the Appendix). This layer is expected to be finalized in 2007. Landscape corridors will be included with this dataset upon its completion in 2007, at which point plans can be made for VDOT and DCR-DNH to confer regarding VDOT's use of these data.

One form of a GIS deliverable is an ArcMap 9.1 document containing customized symbology in layer files that can be used for quick display of the different prioritization themes. The identify tool can be used to view the prioritization attributes of specific cores. Complex queries of the attribute table can be performed to select subsets of cores with the desired combinations of attributes. End users can develop decision tree analyses for these queries so that their methods of selection will be documented and repeatable. Finally, the prioritization attributes can be used as variables in models to generate customized prioritization scores to help identify cores with the best combinations of attributes that will help end users achieve their goals.

DCR-DNH also plans to make the data available via an Internet Mapping System (ArcIMS or comparable application). This will allow users access to the most current versions of the data and eliminate the need for GIS software on their own desktops.

VANLA's Applicability to VDOT Projects

The VANLA model was based on a suite of criteria that encompass the habitat requirements of a wide variety of terrestrial and aquatic species. The landscape corridors modeled by VANLA are therefore an effective way to connect wildlife habitats at an ecosystem level rather than focusing efforts on one or a few target species. Many of the VANLA corridors illustrate habitat convergency points (Foreman, 1995), whereby different habitat types converge and create a funnel effect across the landscape. Corridors act as a conduit for wildlife, which move either inside or alongside the corridor (Foreman, 1995). Because these corridors represent a high frequency of animal movement, there is an increased risk of animal-vehicle collisions where a corridor intersects a roadway (Figure 2).

Research supports this concept that animal-vehicle collisions are spatially aggregated and based on landscape elements that animals are likely to follow in their regular movements (Cain et al., 2003; Hubbard et al., 2000). One of the habitat types that was assigned a higher significance (i.e., assigned a value that represents the least impedance to wildlife movement) in VANLA's corridor development was riparian corridors. This landscape element is one that deer

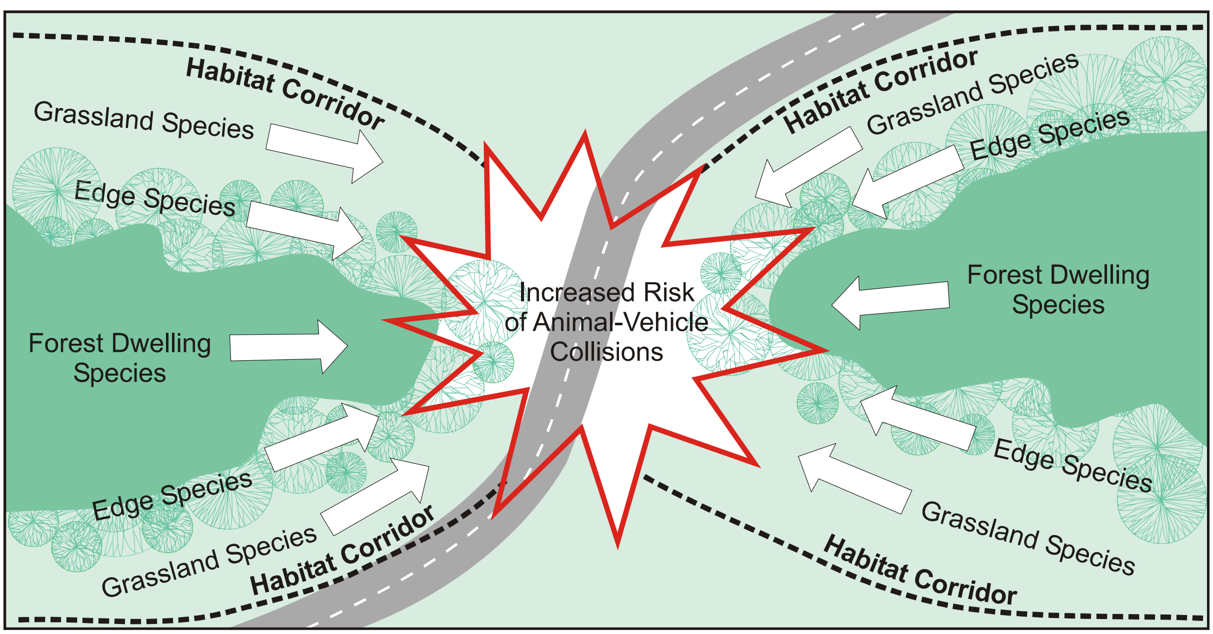

Figure 2. Landscape or Habitat Corridor That Illustrates a Convergency Point (as originally introduced in Donaldson [2006]). The location at which the corridor intersects with the road depicts a higher-risk area for animal-vehicle collisions.

and many other species follow in their daily and seasonal movements. High-frequency DVC areas are often located where roadways intersect with riparian travel corridors (Finder et al., 1999; Romin, 1994). The most effective location for considering avoidance measures or mitigation is therefore the area at which VANLA cores and corridors intersect a proposed or existing road. Donaldson (2006) provides a toolkit of mitigation options to consider in these circumstances.

Not only do the VANLA cores and corridors represent areas of increased wildlife movement, but these areas are more likely to contain natural resources that are required to be protected by Virginia regulatory agencies. The suite of core prioritization attributes include rare species and habitats, species diversity, and water quality. VDOT is commonly required to avoid or mitigate the impact on these elements during road projects. The VANLA data are therefore highly relevant to Virginia's transportation system. Whether planning a large-scale transportation network or simply widening a section of roadway, this model can be useful for transportation planners and environmental specialists in avoiding an area or considering mitigation alternatives where important natural resources may be affected. However, VANLA data should not be used as the sole source of environmental data. Users should contact the appropriate agencies to obtain specific information pertaining to rare species occurrences, drinking water protection zones, etc.

Providing VDOT Access to VANLA Data

VDOT is continually creating and enhancing access to information on transportation projects through Internet applications available on the desktop. GIS Integrator is one example of such a tool. This map-based graphical user interface links business and spatial data from various VDOT databases and allows VDOT users to query various types of information. Information including accidents, traffic volume, new construction, and other transportation data can be displayed for a given section of road or an entire road system throughout the state.

VDOT's Comprehensive Environmental Data and Reporting System (CEDAR) is a mapping tool that integrates with GIS Integrator. This environmental data management system came online in 2004 and consolidates more than 73 applications used by the environmental staff. The system allows VDOT employees to monitor compliance of environmental reporting on active construction and maintenance projects and document environmental decisions and commitments made by VDOT. GIS Integrator, which also displays some of the environmental data needed to review a project site, is accessible through CEDAR.

CEDAR or GIS Integrator would be an ideal means to display the VANLA cores and corridors data. Enhancements to CEDAR are underway to provide a more efficient environmental review process. The addition of VANLA would allow environmental staff and transportation planners early access to important habitat data that can assist them during the project scoping process. Further, because VANLA is a product of DCR, displaying this information on CEDAR would help streamline interagency actions and meet VDOT's goal of initiating interagency participation with environmental resource agencies. Discussions regarding

VANLA's integration into VDOT's GIS applications have been initiated, and further discussions will continue as DCR completes the analyses over the next year.

DISCUSSION

Habitat connectivity analyses are a predictive method of assessing where movement of wildlife is likely to occur. Superimposing this analysis with a transportation network provides a clearer view of where gray infrastructure breaks this connection, disrupting some habitat functions and potentially increasing the effects of habitat fragmentation and the risk of animal-vehicle collisions. DCR's VANLA is one such analysis that, in addition to illustrating habitat connectivity (corridors), depicts large areas of important habitat (cores). This is valuable information for VDOT transportation planners and environmental staff, as it illustrates areas that contain important natural resource elements (such as wetlands and rare species) and areas that likely pose an increased risk of animal-vehicle collisions. It will be important for users to keep in mind that VANLA is a landscape-scale analysis and the prioritization parameters used in VANLA were limited to statewide datasets. In analyzing projects at local scales, therefore, local data should be used to refine the VANLA data according to the local context.

VDOT has the means to integrate these data as a layer in its CEDAR applications, and discussions with VDOT's GIS staff to initiate this process have begun. Access to this tool by VDOT staff will place VDOT among a select group of states that have applied similar analyses and have consequently received numerous accolades from state and federal resource and transportation agencies. Other benefits to providing and using this tool include:

- providing VDOT with a valuable planning tool that promotes early assessment and proactive measures to avoid or mitigate potential environmental and safety effects of road projects

- facilitating VDOT's adherence to the conservation provision (Section 6001) in SAFETEA-LU

- demonstrating VDOT's commitment to safety and environmental stewardship

- promoting collaboration between VDOT and state natural resource and regulatory agencies.

CONCLUSIONS

- *Habitat corridor assessments are increasingly being conducted and applied to state transportation systems.* This provides transportation agencies information on which to make decisions regarding minimizing the impacts of future road projects on natural resources, wildlife movement, and animal-vehicle collisions.

- *VANLA would be highly useful for VDOT staff involved in transportation planning and environmental consultation and scoping activities.* This GIS tool incorporates multiple landscape and natural resource elements to model habitat cores and landscape corridors throughout the state.

- *VDOT's GIS Integrator and CEDAR applications are effective means to provide VDOT staff easy access to VANLA in order to analyze the location of proposed road projects relative to VANLA habitat cores and corridors.* Although VANLA cores are complete, corridors are planned for completion statewide by July 2007, and discussions regarding VANLA's potential integration into VDOT's GIS applications have been initiated.

- *Because animal-vehicle collisions are more likely to occur where wildlife corridors intersect with roads, avoiding corridors identified by VANLA or applying effective mitigation measures may decrease the risk of collisions in these areas.*

RECOMMENDATIONS

1. *VDOT's central office environmental staff and GIS Integrator and CEDAR administrators should continue discussions regarding integrating VANLA into VDOT's GIS applications*.

2. *If VANLA is incorporated into VDOT's GIS applications, DCR should work with VDOT CEDAR administrators to update any inaccuracies found in future field assessments and to complete annual data updates.*

3. *VDOT's Transportation and Mobility Planning Division and Environmental Division should use VANLA data during the long-range planning and environmental scoping processes to evaluate habitat core and corridor locations relative to proposed project areas.* Transportation planners should consider overlaying VANLA data with the long-range plan. Where feasible, habitat cores and landscape corridors should be avoided or mitigation should be planned if field assessments verify the area to be one with important natural resources, high animal movement, or a high number of animal-vehicle collisions.

4. *Where mitigation is warranted, VDOT's Environmental Division and appropriate VDOT division or district engineers should consult the Toolkit for Reducing Animal-Vehicle Collisions (Donaldson, 2006) for information on effective mitigation measures.*

COSTS AND BENEFITS ASSESSMENT

Currently, VDOT has no means to identify and analyze habitat cores and landscape corridors in relation to planned road projects. Project reviews from state natural resource and regulatory agencies frequently include recommendations or directives to avoid or mitigate important habitat areas for wildlife, yet these statements are commonly provided subsequent to

VDOT's project design process. At that stage, adherence would require substantial expenditures to redesign plans and could result in costly project delays. Using VANLA data that are accessible from any VDOT employee's desktop provides more control for VDOT staff in the ability to scope important wildlife habitat and corridors and plan for measures to avoid or mitigate projects that are likely to result in the loss of important habitat or increase the risk of animal-vehicle collisions. This can result in more efficient project deliveries, benefits to wildlife and driver safety, and substantial cost savings for VDOT by avoiding project delay or redesign efforts. Further, access and use of VANLA during planning and scoping activities benefit VDOT in terms of demonstrating its commitment to safety and environmental stewardship, complying with the conservation provision (Section 6001) in SAFETEA-LU, and promoting collaboration between VDOT and state natural resource and regulatory agencies.

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APPENDIX
VANLA CORES AND HABITAT SHAPEFILE ATTRIBUTES

FID: This field contains the internal feature number, a unique sequential number that is automatically generated by ArcGIS 9.1 software.
Shape: This field contains the feature geometry, the coordinates defining the features.
COREID: This field contains a unique numeric identifier for each VANLA Core or Habitat Fragment.
TYPE: This field identifies the type of VANLA feature.

Value	Definition
LC	Large Core: a core area with at least 10,000 acres of interior cover
MC	Medium Core: a core area with 1,000 to 9,999 acres of interior cover
SC	Small Core: a core area with 100 to 999 acres of interior cover
HF	Habitat Fragment: a patch of natural land cover with 10 to 99 acres of interior cover

Rare Species

The information presented here references a ranking system (B ranks, 1-5) of Natural Heritage Conservation Sites (CS) and Stream Conservation Units (SCU). Natural Heritage CS are areas that include the associated habitat of one or more occurrences of natural heritage resources as well as buffer zones and other land necessary for the element's conservation. When used in conjunction with a CS, B ranks indicate the biodiversity significance of that CS, based on the rarity, quality, and number of element occurrences (rare and endangered species populations and occurrences of exemplary or unique natural ecosystems and special wildlife habitats) it contains.

SCU identify stream reaches that contain aquatic natural heritage resources, including upstream and downstream buffer and tributaries associated with these reaches. When used in conjunction with a SCU, B ranks indicate the biodiversity significance of that SCU, based on the rarity, quality, and number of element occurrences it contains.

Conservation Site (CS) and Stream Conservation Units (SCU) Ranks
B1—Outstanding significance
B2—Very high significance
B3—High significance
B4—Moderate significance
B5—Of general biodiversity significance

EO_Count: This field contains the number of Natural Heritage Element Occurrences per VANLA Core or Habitat Fragment. These occurrences exclude records without dates, with dates prior to 1981, or with poor spatial precision (minutes or general precision).
CSAllAcre2: This field contains the acreage of all Natural Heritage CS per VANLA Core or Habitat Fragment.
CSAllPerc2: This field contains the percent area of all Natural Heritage CS per VANLA Core or Habitat Fragment.
CSB1B2Acre: This field contains the acreage of B1 and/or B2-ranked Natural Heritage CS per VANLA Core or Habitat Fragment. B1 and B2-ranked conservation sites were combined here

because there is some subjectivity involved in the determination of whether a site should be a B1 or B2. Both ranks indicate highly important sites.

CSB1B2Perc: This field contains the percent area of B1 and/or B2-ranked Natural Heritage CS per VANLA Core or Habitat Fragment. B1 and B2-ranked conservation sites were combined here because there is some subjectivity involved in the determination of whether a site should be a B1 or B2. Both ranks indicate highly important sites.

CSB1Acre: This field contains the acreage of B1-ranked Natural Heritage CS per VANLA Core or Habitat Fragment.

CSB1Perc: This field contains the percent area of B1-ranked Natural Heritage CS per VANLA Core or Habitat Fragment.

CSB2Acre: This field contains the acreage of B2-ranked Natural Heritage CS per VANLA Core or Habitat Fragment.

CSB2Perc: This field contains the percent area of B2-ranked Natural Heritage CS per VANLA Core or Habitat Fragment.

CSB3Acre: This field contains the acreage of B3-ranked Natural Heritage CS per VANLA Core or Habitat Fragment.

CSB3Perc: This field contains the percent area of B3-ranked Natural Heritage CS per VANLA Core or Habitat Fragment.

CSB4Acre: This field contains the acreage of B4-ranked Natural Heritage CS per VANLA Core or Habitat Fragment.

CSB4Perc: This field contains the percent area of B4-ranked Natural Heritage CS per VANLA Core or Habitat Fragment.

CSB5Acre: This field contains the acreage of B5-ranked Natural Heritage CS per VANLA Core or Habitat Fragment.

CSB5Perc: This field contains the percent area of B5-ranked Natural Heritage CS per VANLA Core or Habitat Fragment.

SCUAllAcre: This field contains the acreage of all Natural Heritage Stream Conservation Units per VANLA Core or Habitat Fragment.

SCUB12Acre: This field contains the acreage of B1 and/or B2-ranked Natural Heritage Stream Conservation Units per VANLA Core or Habitat Fragment.

SCUB1Acres: This field contains the acreage of B1-ranked Natural Heritage Stream Conservation Units per VANLA Core or Habitat Fragment.

SCUB2Acres: This field contains the acreage of B2-ranked Natural Heritage Stream Conservation Units per VANLA Core or Habitat Fragment.

SCUB3Acre: This field contains the acreage of B3-ranked Natural Heritage Stream Conservation Units per VANLA Core or Habitat Fragment.

SCUB4Acre: This field contains the acreage of B4-ranked Natural Heritage Stream Conservation Units per VANLA Core or Habitat Fragment.

SCUB5Acre: This field contains the acreage of B5-ranked Natural Heritage Stream Conservation Units per VANLA Core or Habitat Fragment.

Tier1EHMax: This field contains the maximum number of potential and confirmed habitats for Tier 1 species, the species of greatest conservation need in Virginia, per VANLA Core or Habitat Fragment. The source of these data is the Virginia Wildlife Action Plan developed by the Virginia Department of Game and Inland Fisheries. (*Note:* This attribute needs to be updated with newer information received in September 2006.)

Tier1EHAcr: This field contains the acreage of potential and confirmed habitats for Tier 1 species, the species of greatest conservation need in Virginia, per VANLA Core or Habitat Fragment. The source of these data is the Virginia Wildlife Action Plan developed by the Virginia Department of Game and Inland Fisheries.
Tier1EHPer: This field contains the percent area of potential and confirmed habitats for Tier 1 species, the species of greatest conservation need in Virginia, per VANLA Core or Habitat Fragment. The source of these data is the Virginia Wildlife Action Plan developed by the Virginia Department of Game and Inland Fisheries.

Species Diversity Surrogates

UMNWIVAR: This field contains the variety of unmodified wetlands per VANLA Core or Habitat Fragment. Unmodified wetlands are based on National Wetlands Inventory data from which farmed, diked, ditched, and otherwise modified wetlands were removed. Beaver impoundments, which are a natural form of modification, were left in the unmodified wetlands layer.
ElevSTD: This field contains the standard deviation of elevation values from the National Elevation Dataset per VANLA Core or Habitat Fragment.
ElevRange: This field contains the range of elevation values in meters from the National Elevation Dataset per VANLA Core or Habitat Fragment.
SRMax: This field contains the maximum value of potential species richness values of vertebrates and lepidopterans per VANLA Core or Habitat Fragment based of potential distribution maps developed by the Virginia GAP Analysis project (VA-GAP).
SRMean: This field contains the statistical mean of potential species richness values of vertebrates and lepidopterans per VANLA Core or Habitat Fragment based of potential distribution maps developed by VA-GAP.
SRMode: This field contains the statistical mode of potential species richness values of vertebrates and lepidopterans per VANLA Core or Habitat Fragment based of potential distribution maps developed by VA-GAP.
SRMedian: This field contains the statistical median of potential species richness values of vertebrates and lepidopterans per VANLA Core or Habitat Fragment based of potential distribution maps developed by VA-GAP.
TErichMax: This field contains the maximum value of potential species richness values of vertebrates and lepidopterans per VANLA Core or Habitat Fragment based of potential distribution maps for threatened and endangered species developed by VA-GAP.

Core Characteristics and Landscape Context

TotalAcres: This field contains the total acreage of each VANLA Core or Habitat Fragment.
TotAcreNew: This field contains the recalculation of total acreage to the tenth of an acre of each VANLA Core or Habitat Fragment.
InterAcres: This field contains the total acreage of interior cover of each VANLA Core or Habitat Fragment.
DEPTHINTER: This field contains the depth of interior of each VANLA Core or Habitat Fragment. This value represents the maximum distance in meters that can be achieved within a

core or habitat fragment. This parameter is useful for selecting and modeling cores that provide more protection for interior species.
P_A_Ratio: This field contains the perimeter to area ratio of each VANLA Core or Habitat Fragment. This ratio is influenced by patch shape and fragmentation. Lower values indicate cores that have less fragmentation and better shapes for protection of interior species.
Compactnes: This field contains the compactness ratio of each VANLA Core or Habitat Fragment. This ratio compares the area of a core to the area of a circle with the same perimeter as the core. Values approaching 1 represent cores that are circular, the best shape for protecting interior species, and values approaching 0 represent cores that are very long and narrow, the worst shape for protecting interior species.
RampDist: This field contains the distance to the nearest interstate highway ramp for each VANLA Core or Habitat Fragment. This value, expressed in meters, is a surrogate for remoteness.
IntersDist: This field contains the distance to the nearest intersection of a primary road with a secondary or urban road for each VANLA Core or Habitat Fragment. This value, expressed in meters, is a surrogate for remoteness.
THREAT: This field indicates the threat if not conserved of each VANLA Core or Habitat Fragment. The values indicate the potential land use change from the current use to an urban or suburban use. Values range from 1, lowest potential of conversion, to 8, greatest potential of conversion. The source of these data is the Virginia Vulnerability Model, VCLNA.

Water Quality

DrinkAcre: This field contains the acreage of high-priority groundwater and surface water protection zones per VANLA Core or Habitat Fragment. The source of these data is the Virginia Department of Health, Office of Drinking Water.
DrinkPerc: This field contains the percent area of high priority groundwater and surface water protection zones per VANLA Core or Habitat Fragment. The source of these data is the Virginia Department of Health, Office of Drinking Water.
UMNWIAcres: This field contains the acreage of unmodified wetlands per VANLA Core or Habitat Fragment. Unmodified wetlands are based on National Wetlands Inventory data from which farmed, diked, ditched, and otherwise modified wetlands were removed. Beaver impoundments, which are a natural form of modification, were left in the unmodified wetlands layer.
UMNWIPERC: This field contains the percent area of unmodified wetlands per VANLA Core or Habitat Fragment. Unmodified wetlands are based on National Wetlands Inventory data from which farmed, diked, ditched, and otherwise modified wetlands were removed. Beaver impoundments, which are a natural form of modification, were left in the unmodified wetlands layer.