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CONSERVING WILDLIFE HABITATS WITH LANDSCAPE CORRIDORS IN THE SCHOODIC REGION OF MAINE, USA

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ABSTRACT

Humans have increasingly altered natural environments resulting in fragmentation and loss of wildlife habitat. This process has been especially noticeable on the east coast of the United States where most areas have experienced significant anthropogenic disturbances to ecosystems. However, with the exception of historic logging, the Schoodic region of Hancock County, Maine, has escaped mostly unscathed; but there are indications that development of this area is imminent. Therefore, to minimize the loss of wildlife habitats this study aims to identify essential habitats and map species presence in established conservation areas. The result is a practical approach to developing and conserving essential wildlife corridors within this region. Sampling sites were determined by a stratified random method using land cover types and property boundaries. Field observations (e.g., photo trapping, timed searches) and rapid habitat assessments along with electrical circuit theory (Circuitscape) and least-cost corridor models were used to determine where corridors should be placed.

Corridor selection was based on habitat suitability grids for nine carnivores and five herptiles which were created using an improved land cover layer. Optimal corridors were chosen to provide a continuous path of lowest resistance and highest conductance possible for each species. These corridors were then overlaid using map algebra to create corridors that included the needs of multiple species. Establishing a separate corridor path for each taxonomic group proved to be the best plan of action since the outputs of both the Circuitscape and least-cost corridor models showed the paths to be dissimilar. However, all corridors were similar in that they required two road crossings and relied heavily on the habitats in and around a property that is destined for future development. Securing these habitat corridors will reduce the effects of human encroachment on wildlife populations as development encroaches.

In comparing the two models I noticed that Circuitscape seems to be more sensitive to movement barriers such as roads, whereas the least-cost corridor model does not identify these barriers as strongly. I recommend that until the utility of Circuitscape is better understood conservationists should use a mixed method approach to corridor design by using a combination of both Circuitscape and the least-cost corridor models.

This study not only confirms the presence of multiple species and their habitat preferences, but it also provides an improved land cover layer, habitat suitability grids, and a comparison of two corridor models, which will all serve as a starting point for future work.

Keywords: habitat loss, connectivity, landscape ecology, fragmentation, wildlife conservation, habitat corridor, Schoodic Maine, Circuitscape, Least-cost

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Chapter 1

Introduction

Due to increasing human encroachment, the fragmentation and loss of wildlife habitat has caused a widespread decrease in biodiversity (Wilcove et al. 1986; Flather et al. 1994; Fahrig 2003). This process has been especially noticeable on the east coast of the United States which has experienced significant ecological disturbance over a long period of time (Williams 1982; Wilcove et al. 1986; Foster 1992; Lorimer 2001). However, there are still a few small relatively undeveloped areas in this region that various environmental organizations are scrambling to protect before further degradation occurs. One of these areas is the Schoodic region of Maine, which currently lacks significant human disturbances other than historic logging and a few small towns.

Preservation of the Schoodic peninsula has received much attention from local residents and conservationists due to a rising human population and imminent plans for development. Of special concern are plans for a controversial resort that would cover over 1,294 ha (3200 ac) of land in the Schoodic region (Walsh 2008), and completely surround an easement held by the Maine Coast Heritage Trust (MCHT). If approved, this type of large-scale development would disconnect the portion of ANP located on the peninsula from inland conservation areas. If habitat connectivity is not maintained, many species, especially those with large home ranges and high dispersal rates, would not only become isolated, but may also suffer from a potential decrease in gene flows (Schonewald-Cox et al. 1983; Aars and Ims 1999; Mech and Hallett 2001) and population viability (Beier and Noss 1998).

The Frenchman Bay Conservancy (FBC), a non-profit land trust based in Hancock, Maine is developing a strategic plan to guide conservation efforts and maintain wildlife habitat connectivity between Schoodic Point and Schoodic Mountain. Unlike many conservation plans that are created after the landscape is highly fragmented and are essentially a rescue effort, the FBC is striving to create a preventive conservation plan to ensure that connectivity persists as development encroaches. My research will assist the FBC in targeting essential upland and wetland wildlife habitats in the Schoodic region to set priorities for future purchases and easements in an effort to create one or more functional wildlife corridors that will connect multiple conservation lands across this landscape.

Background

To ensure that conservation efforts are most effective, Forman and Collinge (1997) recommended that a spatial plan be established before 40% of the natural landscape is disturbed. If plans are developed too late, fragmentation and loss of essential habitats can occur as a result of human settlements (Dale et al. 2000; Riitters et al. 2002; Fischer and Lindenmayer 2007). Habitat fragmentation and habitat loss are often inseparable and strongly related concepts that are commonly thought of as being synonyms, however, these terms have slightly different meanings (Goodwin and Fahrig 2002; Haila 2002; Lindenmayer and Fischer 2007). Habitat loss occurs as a result of fragmentation in 85% of cases and has been found to be the main cause of a species becoming listed as imperiled, threatened, or endangered (Flather et al. 1994; Wilcove et al. 1998; Cushman 2006).

In addition to habitat loss, fragmentation contributes to the loss of biodiversity by creating an increasing number of small, isolated habitat patches with varying interpatch distances

(Wilcove 1986; Fahrig 2003; Noss et al. 2006). When patches become small and isolated, gene pools have been shown to become less diverse (Schonewald-Cox et al. 1983; Keyghobadi 2007), and population size often decreases due to the inability of species to regenerate from neighboring populations through dispersal (Curtis 1956; Fahrig and Merriam 1985; Hudgens and Haddad 2003). Fragmentation also leads to an increase in edge habitats which can have negative effects on the numerous species that require large areas of interior habitat, but a positive effect on others (Yahner 1988; Fahrig 2003; Ries et al. 2004; Fischer 2007). Negative effects can range from increased predation and parasitism (Wilcove 1986; Fahrig 2003) to changes in access to resources (Ries et al. 2004). In contrast, positive effects have been shown for species that thrive on the edges of various habitats (Curtis 1956; Wilcove 1986). However, although some species might benefit from increased fragmentation, the negative effect of habitat loss almost always overrides any positive effects of fragmentation (Fahrig 2003).

Conservationists are concerned about fragmentation and loss of habitat because these processes can interfere with the natural dispersal patterns of many species. Dispersal is defined by Calabrese and Fagan (2004) as the “movement of individuals among populations”, and plays a large part in the maintenance of population health and size. The ease of species dispersal is commonly described by measures of landscape connectivity. This term was defined by Taylor et al. (1993) as “the degree to which the landscape facilitates or impedes movement among resource patches”. In the process of designing a long-term conservation management plan the amount of landscape connectivity should be one of the main considerations. For example, a landscape with low connectivity but large area and high habitat quality may not promote population persistence, whereas a very well connected landscape made up of smaller, lower quality habitat patches (Siitonen et al. 2002; Calabrese and Fagan 2004) may be more capable of supporting the needs of multiple species. However, the degree of connectivity of any landscape is highly dependent upon the needs and behaviors of the focal species, and will vary depending on the geographic region, environment, conservation goals and both the spatial and temporal scales at which the analysis is performed (Goodwin and Fahrig 2002; Haila 2002; Calabrese and Fagan 2004; Pascual-Hortal 2007).

One method that has been used to increase the degree of connectivity in fragmented habitats is to establish habitat corridors (Anderson and Danielson 1997; Beier and Noss 1998; Tewksbury et al. 2002; Chetkiewicz 2006). Corridors are bands of habitat that facilitate the movement of species between otherwise isolated patches of similar habitat types (Beier and Noss 1998; Bennett 2003). By providing a way for species to easily move from one habitat patch to another, corridors have been shown to maintain gene flow and population size, increase biodiversity, and support the reintroduction of otherwise locally extinct species (Fahrig and Merriam 1985; Saunders and Hobbs 1991; Tewksbury et al. 2002; Chetkiewicz 2006). However, corridors also have the potential to be detrimental to wildlife population viability by allowing the spread of diseases, predators, invasive species, and disturbances such as fire (Simberloff and Cox 1987; Simberloff et al. 1992; Hess 1994, Hudgens and Haddad 2003; Bailey 2007). The addition of corridors to a landscape also changes the shape and effective size of existing habitat patches, the effects of which are poorly studied (Tewksbury et al. 2002; Falcy and Estades 2007).

Since the concept of conservation corridors was first suggested by Wilson and Willis in 1975, the use of corridors in conservation planning has been heavily debated (Mann and Plummer 1995; Haddad 2008). This controversy has centered on the fact that many initial studies relied on instinct and theories and did not produce scientific evidence showing that species did in fact use corridors (Simberloff et al. 1992; Beier and Noss 1998; Tewksbury et al. 2002).

Although more recent studies have now shown that conservation corridors often have a positive effect on the survival of wildlife populations by increasing connectivity between existing conservation lands (Saunders and Hobbs 1991; Goetz et al. 2009; Gilbert-Norton 2010), these studies have often failed to include a wide range of species (Tewksbury et al. 2002; Haddad et al. 2003; Bailey 2007). Focusing on a single species or taxonomic group ignores the fact that a corridor could have either a negative or positive effect on a multitude of species throughout the landscape (Haddad et al. 2003; Beier et al. 2009). In addition, it is difficult to develop broad generalizations on corridor effects from such narrowly focused studies (Tewksbury et al. 2002).

In an effort to include more than one species in landscape connectivity studies, some researchers have chosen their focal species based on whether they are considered to be an “indicator”, “keystone” or “umbrella” species (Dale et al. 2002; Mace et al. 2006). Indicator species can tell us the status of a larger group of species and sometimes the habitat itself. Keystone species, such as the beaver (*Castor canadensis*), are species which are essential to the functioning of an ecosystem (Jones et al. 1994; Power et al. 1996). Umbrella species either have a large home range or require a variety of habitats thus coinciding with the needs of multiple species (Haila 2002; Roberge and Angelstam 2004; Beier et al. 2008). Typically large carnivores are identified as umbrella species for corridor designs because they are usually the first type of species to be negatively affected by decreased connectivity due to their large home range, solitary nature and use of multiple habitats (Singleton et al. 2002; Beier et al. 2008). However, Beier et al. cautions that large carnivores should not be the only focal species included in a study since they are most often habitat generalists and can survive in lower quality habitats (2008). Thus, a corridor designed solely for large carnivores or other umbrella species may not satisfy the requirements of important habitat specialists that require very specific types of habitat (Mace et al. 2006; Beier et al. 2008).

Since the introduction of Geographical Information Systems (GIS), a variety of spatial models have been used to measure landscape connectivity and design conservation corridors. Some examples of these models include least-cost path (Walker and Craighead 1997; Adriaensen et al. 2003; McRae 2006), friction analysis (Nikolakaki 2004), and electrical circuit theory (McRae and Beier 2007). However, regardless of which model is used there can be an infinite list of considerations to take into account when designing a corridor. First, a decision must be made for each focal species on which habitat types are most and least conducive to its movement and breeding success (Beier et al. 2008). These decisions are essential to the selection of the corridor because they heavily influence where the corridor will be placed and how well it will work in reality. Second, a determination must be made as to the width of the corridor to allow for optimal use by the focal species by providing sufficient interior habitat (Environmental Law Institute 2003). Beier et al. suggests that the minimum width of a corridor for a species that will inhabit the corridor rather than simply pass through it should be larger than the width of its typical home range (2008). Harrison (1992) adds complexity to the problem by proposing that that the length of the corridor may have an effect on the minimum sufficient width. However, a very wide corridor is often not financially practical or physically possible (e.g., when constrained to the width of a peninsula), thus compromises must be made to find the best feasible corridor while still providing increased connectivity (Beier et al. 2008). Finally, the cell size of the analysis grid must be chosen carefully (McRae 2008). If the cells are too large, important aspects and changes in the land cover may be over generalized. If the cells are too small, insignificant variations in land cover may cause the resulting corridor to avoid areas that may be suitable for movement in reality (Walker and Craighead 1997; Shah and McRae 2008).

Objectives

The Schoodic peninsula, with its relatively intact habitats, has become the main focus for the Frenchman Bay Conservancy and other conservation organizations striving to establish protected landscape corridors. The initiative of these organizations is to establish conservation corridors between Schoodic Point and Schoodic Mountain to allow for wildlife dispersal across the Schoodic peninsula. The main objective for this study was to pair principles of landscape ecology with GIS technology to identify potential wildlife corridors that will promote future connectivity between the previously mentioned conservation lands. These wildlife corridors are designed to provide habitat connectivity for a variety of both carnivores and herptiles and will act as a preliminary plan for a longer term project involving additional species and analyses. Furthermore, this project will provide preliminary data and establish a sampling design for future conservation work in the Schoodic region.

In the process of designing the wildlife corridor I also addressed a few other objectives. First, I created corridor maps for each individual species using two theoretically unique models. These species specific corridor maps will be essential for future studies, and as priorities evolve. Second, due to the lack of field studies on species distribution in this area, data on species presence collected during intensive summer fieldwork confirmed GAP model assumptions on species occurrence in a variety of habitats. Third, I created a land cover layer that uses the strengths of both the GAP land cover dataset and the National Land Cover Dataset (NLCD) to more correctly classify habitats based on my field observations and aerial photography. Lastly, by using two models for my analysis, I was able to conduct an evaluation of their strengths and weaknesses in an effort to create a starting point for the development of a standardized method for future studies. These methods could then be used outside of the Schoodic region with only some minor adjustments due to regional variations (e.g. flora, fauna, geology).

Chapter 2

Methods

Study Area

All sampling sites were located within Hancock County in the Schoodic region of eastern Maine (Figure 2.1). This region stretches along the Schoodic peninsula from Schoodic Point to Schoodic Mountain. Most of this area is undeveloped with limited roadways and only a few small towns (Figure 2.2). The largest town is Winter Harbor, which is located on the western side of the peninsula and has < 1,000 permanent residents (U.S. Census Bureau 2000). Most of Acadia National Park (ANP) is located on Mount Desert Island to the west of the Schoodic region; however, the mainland segment of ANP covers the southwestern corner of Schoodic peninsula. In addition to ANP lands, there are many other isolated conservation areas in the region, which are owned or managed by various private and government organizations. For example, the Frenchman Bay Conservancy (FBC) owns seven properties on the Schoodic peninsula totaling approximately 607 hectares (1500 acres), and has secured over 25 conservation easements.

Due to a glaciated past and its location in the transition between eastern deciduous and northern coniferous forests, the Schoodic region is comprised of many land cover types that host a diverse group of both wetland and upland wildlife species. According to the Maine Gap Analysis Project (GAP) report (Krohn 1998), 17 amphibians, 16 reptiles, and 54 mammals are reported across the state (Table 2.1), but little work has been done to confirm the presence of these species in the Schoodic region. Currently, five land mammals and seven reptiles (Table 2.2) are listed as state or federally threatened or endangered (Department of Inland Fisheries and Wildlife 1997).

Procedures

My methods consisted of both intensive field sampling (approximately 7.5 weeks, May 23rd – July 14th, 2009) and spatial analyses in a GIS environment. Field sampling tested for the presence of wildlife species in multiple habitats and rapid habitat assessments confirmed the individual species habitat preferences. GIS analyses supported the selection of sampling sites as well as the creation of potential habitat corridors between ANP lands on Schoodic point and other conservation lands surrounding Schoodic Mountain.

First, I obtained the following spatial datasets: 2001 National Land Cover Dataset (NLCD), 2007 National Agriculture Imagery Program (NAIP) orthoimagery, Maine GAP land cover and potential species distribution data layers, Hancock County e911 roads, National Wetlands Inventory (NWI), National Hydrography Dataset (NHD) and boundary layers for all FBC properties and other conservation areas (Table 2.3). These datasets provided the base layers on which to perform site selection and analysis throughout the project.

This study was limited to five FBC properties and one MCHT easement (Figure 2.2) due to time constraints and the difficulties associated with gaining access to private lands. To choose my sampling sites I used a stratified random method (Skalski 1994; Conroy and Nichols 1996) based on GAP land cover types that were within the boundaries of all sampling properties in the Schoodic region (Figure 2.2). Land cover types were used to stratify the random assignment of sampling sites to ensure that a wide variety of habitats were sampled, and to avoid multiple sampling locations from clustering in only a few of the more common habitat types.

To ensure that all properties were sampled equally, the acreage of each property was calculated in ArcMap 9.3.1 (ESRI 2009) using GIS boundary data provided by the FBC and

MCHT. The resulting acreage was then rounded to the nearest hundred for ease of assigning the number of sampling points per property. Photo traps (Covert II; DLC Trading Co, Lewisburg, KY) were placed at each of 10 sampling points (approximately one for every hundred acres) (Table 2.4) in a variety of randomly selected sites in varying habitats (Figures 2.3 and 2.4). Cameras were placed on existing animal trails or where recent animal activity had been spotted by field crews (Wemmer et al. 1996; Kays and Slauson 2008), and were mounted on trees or shrubs using a locking cable (Kays and Slauson 2008; Kelly and Holub 2008) approximately 1.0 -1.3 m above ground level to capture a wide range of species of varying body sizes (Figure 2.5). Each camera site was baited with a mixture of scents (e.g., beaver castor, skunk essence, predator attractant) to attract carnivores (Wemmer et al. 1996; Schlexer 2008). The scents were placed in plastic film canisters that were lightly stuffed with 2-3 cotton balls to slow evaporation, and 10-15 holes were placed evenly around the container for optimal scent dispersal (Schlexer 2008). One scented film canister was placed at each site and was secured to trees or shrubs with monofilament fishing line in a location that would lure the animal in front of the camera, but not startle it due to potential excessive movement (Schlexer 2008). Disposable gloves were worn while handing both bait and cameras to minimize human scents in and around the sampling sites (Moruzzi et al. 2002; Kays and Slauson 2008). In addition, cameras and scent lures were never both handled by the same crew member to avoid transferring scents onto the camera which would increase the possibility of large carnivores (e.g., Black Bears) destroying the equipment (Schlexer 2008).

Photo traps were relocated every two weeks and revisited approximately every three to five days to refresh scent lures, gather images, and check on equipment condition and position (Foresman and Pearson 1998; Kays and Slauson 2008). The resulting photos confirmed the presence of multiple species (Kays and Slauson 2008) with a focus on carnivores. Carnivores were chosen as focal species because they are the most area-sensitive, and are often considered “umbrella species” (Dale et al. 2000).

For wetland habitats, an assistant and I conducted time-constrained searches (Crump and Scott 1994; Brotherton et al. 2004) in 0.04 ha plots for all reptiles and amphibians (Table 2.1) at randomly generated locations. Within each search plot all cover items (e.g., logs, rocks, loose moss) were turned over and leaf litter was searched wherever possible (Crump and Scott 1994). Aquatic habitats were searched for egg masses and a 15 x 20 cm dip net was used to capture both larval and adult herptiles found in the water (Brotherton et al. 2004). Each search was constrained to half hour per person, for a total of one person hour of sampling and was performed twice at each sampling point (Barr and Babbitt 2001) with approximately one week between searches. In addition, field crews listened for anuran vocalizations (Zimmerman 1994; Brotherton et al. 2004) at the largest open water location on each property for one hour immediately prior to sunset. Using this survey method allowed for the confirmation of species presence in landscapes that were physically inaccessible due to deep water and/or a tall tree canopy (Zimmerman 1994). Each open water location was visited twice with at least two weeks between visits to account for seasonality and amphibian life cycles (Brotherton et al. 2004).

To characterize the habitats where species were found, I also performed a rapid habitat assessment (Scott, 1994) of the immediate area (40-m radius) surrounding each sampling point (Brooks et al. 2009). Habitat type (e.g., wetland, upland), successional stage, dominant vegetation types, percent tree canopy, shrubs, and herbaceous cover, possible stressors (e.g., foot trail, beaver dam, etc.), and approximate average dbh of all trees was recorded for each plot. Three photographs were taken at every sampling point for future reference. A GPS unit (Garmin eTrex version 3.30) was used to accurately map the actual location of each sampling point for the purpose of GIS analyses (Figures 2.3 and 2.4) and future studies.

Spatial Analysis

Once all field data was collected, I created GIS vector layers indicating which species were found at each sampling point and what type of habitat characterized the surrounding area of about 0.5 ha (40-m radius from center point of each sampling location). After comparing my habitat characterizations and general knowledge of the area (e.g., where developed areas, wetlands, and roads are located), with both the NLCD and GAP land cover datasets, I determined that neither of these datasets were sufficient for the purposes of my analyses. The NLCD layer was more recent then the GAP land cover layer (Table 2.3) and thus, more accurately depicted currently developed areas. The NLCD land cover classifications, however, were too broadly defined for assigning habitat quality rankings. Therefore, prior to beginning any analyses I created an improved land cover raster that combined the strengths of both existing land cover layers. First, I multiplied all GAP land cover values by 10,000, and then added the NLCD raster to this new GAP layer. Using a multiplication factor of 10,000 allowed me to keep the GAP and NLCD land cover classification values separated after they were added together so I could determine which portions of the two land cover grids differed in their classification assignments. By using NAIP, NWI, NHD, and Hancock County e911 road layers, in addition to my existing knowledge of the area, I was able to discern which classification was closer to reality on a case by case basis. Due to 2009 being an unusually wet year, I was forced to rely on the NWI data layer for wetland areas since my own observations may have been often influenced by the daily rainfall amounts. Finally, I reclassified the land cover raster based on these corrections. This procedure resulted in an improved land cover raster with 30-m resolution that contained updated information on developed areas, but also had narrow enough land cover classifications for the analyses. From this point forward any mention of a land cover raster dataset will be referring to this improved version. All raster datasets created throughout this analysis were projected into UTM Zone 19N at 30-m resolution.

I used both the least-cost corridor tool provided in ArcView 9.3.1 (ESRI 2009) and Circuitscape software (McRae and Shah 2009a) to determine corridor placement and for model comparison. The least-cost corridor tool is based on the least-cost path model which first creates a cost surface by assigning a “cost” value to each cell in a grid. This cost value is calculated by the width of the cell multiplied by a weighting factor which is based on habitat suitability for movement through the cell. Unlike a least-cost path model which only chooses a one cell wide path through a landscape, a least-cost corridor model uses two accumulative cost surfaces, one from each endpoint, to identify a corridor that is one or more cells wide. This corridor is considered to be the path of least resistance for a single species’ movement.

In contrast, Circuitscape is relatively new software that uses electrical circuit theory rather than traditional least-cost methods to model how species may randomly move across a landscape between two or more locations. This software has been used in only a few landscape connectivity studies (Lee-Yaw 2009; Poor 2010), but it is considered to be theoretically more robust (McRae and Beier 2007) than the traditional methods already being used in many studies (Adriaensen et al. 2003; Beier et al. 2006). The biggest advantage of Circuitscape over least-cost methods is that it has the ability to simultaneously consider all possible pathways across a landscape (McRae et al. 2008) rather than only being able to evaluate one pathway between two locations. The basic idea supporting the use of electrical circuit theory in ecological applications is that just as wider conductors allow more current to flow through them, a wider corridor will also allow for greater species movement. In addition, the further an electrical current has to travel, the more connectivity it will need to get to the destination. This is much like the needs of an organism that may have to travel from one point to another and must have well connected habitats that are conducive to its movement.

I chose to set the extent of all my analyses to span an area of approximately 25 by 36 km, which includes the entire Schoodic peninsula and adjacent areas. Expanding the analysis extent to include a larger area then just the Schoodic peninsula itself provided both models with the opportunity to choose alternative corridor routes that may need access to regions outside the study area (Beier et al. 2008). All conservation lands located near Schoodic Mountain in the north and the ANP lands on Schoodic point on the southern end of the study area were chosen as endpoint regions for potential wildlife corridors.

Due to time constraints and the limited scope of this study, I chose to focus on 14 species out of 87 mammal, reptile, and amphibian species assumed to be found in the state of Maine. Five herptiles and nine carnivores were chosen for the corridor analyses based on their assumed ability to act as umbrella species (Table 2.5). For each focal species I scored the habitat quality of every land cover type found in my study region using whole integers from 0-5 based on the knowledge gained from fieldwork and GAP species habitat descriptions (Boone and Krohn 1998). Two main assumptions were made in the process of assigning these habitat quality scores. First, I assumed that habitat types where the species was found, or which were considered to be preferred by the species (Boone and Krohn 1998) are also preferred for movement through the region. Second, due to the lack of data on all vernal pools in the region, it was necessary to assume that all forested areas could have vernal pools and thus, would be preferred by species that rely on this habitat type.

Before running either model it was necessary to create a habitat suitability grid for each species based on the habitat quality scores assigned previously. For input into Circuitscape, high habitat quality values corresponded to habitats where species presence was confirmed during field work or habitats that GAP species descriptions indicated as being most preferred. Low habitat quality values represented areas where the species would rarely be found, or which formed a barrier to dispersal (Table 2.6). However, for the least-cost path corridor analysis it was necessary to invert these rankings since the least-cost model was based on cell resistances whereas the Circuitscape model was based on cell conductances. These rankings were then used to reclassify the land cover raster to create a habitat suitability grid for each of the 14 focal species which were used as the main inputs for both the Circuitscape and least-cost corridor models (Walker and Craighead 1997; Goetz et al. 2009).

Corridor Selection

To find the best suited corridors, habitat suitability grids for each species were exported from ArcView 9.3 using the Circuitscape export tool, and then the Circuitscape model was run using the pairwise option based on conductances with 8 neighbors considered per cell. The resulting Circuitscape cumulative conductance grids were imported back into ArcView 9.3 and multiplied by 100,000 to move the decimal place far enough to the right on each conductance value for compatibility with the software and ease of analysis. The least-cost corridor model was run using the Corridor tool in ArcView 9.3 and was based on resistances also provided by the habitat suitability grids. The outputs from both the Corridor tool and Circuitscape were then visually analyzed using various data classification methods (natural breaks, equal interval, standard deviations, etc). I determined that a quantile classification method worked best to identify corridors as suggested by McRae and Shah (2009b). Regardless of taxa group, all Circuitscape models and least-cost models revealed the best continuous corridor paths when displayed using a 3-class and 5-class quantile classification scheme respectively. The best corridor path was identified by selecting the highest 33.3% of conductances in the Circuitscape models and the lowest 20% of resistances in the least-cost models.

To overlay multiple species' corridor grids, I first assigned a number (1-3 or 1-5) to the quantile classification bins. Then, I used map algebra to add the grids together by taxa group. I did this separately for each model type to be able to compare differences in each method's output, and then combined the output of both models separated by taxa group. Finally, corridor paths for all focal species and from both models were combined to determine where to best place the final theoretical wildlife habitat linkage that would benefit the greatest number of both upland and wetland dependent species. The best three corridor paths were chosen for the final map output and ranked as optimal, good, and fair to provide some flexibility for the design of the corridor.

Table 2.1. List of Amphibians, Reptiles, and Mammals expected to be found in Maine (Krohn 1998).

Amphibians	Mink (Mustela vison)
Blue-spotted Salamander (Ambystoma laterale, laterale x jeffersonium)	Striped Skunk (Mephitis mephitis)
Spotted Salamander (Ambystoma maculatum)	Northern River Otter (Lutra canadensis)
Eastern Newt (Notophthalmus viridescens)	Lynx (Lynx canadensis)
Northern Dusky Salamander (Desmognathus fuscus)	Bobcat (Lynx rufus)
Northern Two-lined Salamander (Eurycea bislineata)	**Mammals** *Other*
Spring Salamander (Gyrinophilus porphyriticus)	Moose (Alces alces)
Four-toed Salamander (Hemidactylium scutatum)	White-tailed Deer (Odocoileus virginianus)
Northern Redback Salamander (Plethedon cinereus)	Common Porcupine (Erethizon dorsatum)
American Toad (Bufo americanus)	Woodland Jumping Mouse (Napaeozapus insignis)
Gray Treefrog (Hyla versicolor)	Meadow Jumping Mouse (Zapus hudsonius)
Spring Peeper (Hyla crucifer)	Deer Mouse (Peromyscus maniculatus)
Bullfrog (Rana catesbeiana)	White-footed Mouse (Peromyscus leucopus)
Green Frog (Rana clamitans)	Southern Red-backed Vole (Clethrionomys gapperi)
Pickerel Frog (Rana palustris)	Meadow Vole (Microtus pennsylvanicus)
Northern Leopard Frog (Rana pipiens)	Rock Vole (Microtus chrotorrhinus)
Mink Frog (Rana septentrionalis)	Woodland Vole (Microtus pinetorum)
Wood Frog (Rana sylvatica)	Muskrat (Ondatra zibethicus)
Reptiles	Southern Bog Lemming (Synaptomys cooperi)
Common Snapping Turtle (Chelydra serpentina)	Northern Bog Lemming (Synaptomys borealis)
Common Musk Turtle (Sternotherus odoratus)	American Beaver (Castor canadensis)
Painted Turtle (Chrysemys picta)	Eastern Chipmunk (Tamias striatus)
Spotted Turtle (Clemys guttata)	Woodchuck (Marmota monax)
Wood Turtle (Clemmys insculpta)	Eastern Gray Squirrel (Sciurus carolinensis)
Blanding’s Turtle (Emydoidea blandingii)	Red Squirrel (Tamiasciurus hudsonicus)
Eastern Box Turtle (Terrapene carolina)	Southern Flying Squirrel (Glaucomys volans)
Racer (Coluber constrictor)	Northern Flying Squirrel (Glaucomys sabrinus)
Ringnecked Snake (Diadophis punctatus)	New England Cottontail (Sylvilagus transitionalis)
Milk Snake (Lampropeltis triangulum)	Snowshoe Hare (Lepus americanus)
Northern Water Snake (Nerodia sipedon)	Masked Shrew (Sorex cinereus)
Smooth Green Snake (Opheodrys vernalis)	Water Shrew (Sorex palustris)
Brown Snake (Storeria dekayi)	Smoky Shrew (Sorex fumeus)
Redbelly Snake (Storeria occipitomaculata)	Long-tailed Shrew (Sorex dispar)
Eastern Ribbon Snake (Thamnophis sauritus)	Pygmy Shrew (Sorex hoyi)
Common Garter Snake (Thamnophis sirtalis)	Northern Short-tailed Shrew (Blarina brevicauda)
Mammals	Star-nosed Mole (Condylura cristata)
Carnivores	Hairy-tailed Mole (Parascalops breweri)
Coyote (Canis latrans)	Virginia Opossum (Didelphis virginiana)
Red Fox (Vulpes vulpes)	Little Brown Myotis (Myotis lucifugus)
Common Gray Fox (Urocyon cinereoargenteus)	Northern Myotis (Myotis septentrionalis)
Black Bear (Ursus americanus)	Eastern Small-footed Myotis (Myotis leibii)
Common Raccoon (Procyon lotor)	Silver-haired Bat (Lasionycteris noctivagans)
American Marten (Martes americana)	Eastern Pipistrelle (Pipistrellus subflavus)
Fisher (Martes pennanti)	Big Brown Bat (Eptesicus fuscus)
Ermine (Mustela erminea)	Eastern Red Bat (Lasiurus borealis)
Long-tailed Weasel (Mustela frenata)	Hoary Bat (Lasiurus cinereus)

Table 2.2. List of land mammals and reptiles in Maine that are state or federally endangered or threatened (Department of Inland Fisheries and Wildlife 1997).

Land Mammals	**Reptiles**
Canada Lynx (*Lynx canadensis*) – FT	*Snakes*
Eastern Cougar (*Felis concolor couguar*) – FE	Black Racer (*Coluber constrictor*) – SE
Gray Wolf (*Canis lupus*) – FE	*Turtles*
New England Cottontail (*Sylvilagus transitionalis*) – SE	Atlantic Ridley (*Lepidochelys kempi*) – FE
Northern Bog Lemming (*Synaptomys borealis*) - ST	Blanding's Turtle (*Emys blandingii*) – SE
	Box Turtle (*Terrapene carolina*) – SE
	Leatherback (*Dermochelys coriacea*) – FE
	Loggerhead (*Caretta caretta*) – FT
	Spotted Turtle (*Clemmys guttata*) – ST
Key: ST-State threatened, FT – Federally threatened, SE – State endangered, FE - Federally endangered	

Table 2.3. List of spatial data used in sampling site selection and analysis for Schoodic region of Maine.

Raster Format			
Name	***Date published***	***Resolution***	***Publisher***
GAP Land Cover (statewide)	1998 (1993 data)	30m	Maine GAP
Potential Habitat for all wildlife in Maine (statewide)	1998	90m	Maine GAP
Hancock Co., Maine NAIP Aerial Orthoimagery	2007	1m	National Agriculture Imagery Program
National Land Cover Dataset (Land Cover/Tree Canopy/Impervious)	2003 (2001 data)	30m	USGS
Vector Format			
Name	***Date published***	***Scale***	***Publisher***
Frenchman Bay Conservancy property boundaries	As of May 2009	No metadata	FBC
State/County Boundaries for Maine	2002	1:24,000	Maine Office of GIS
Conservation Lands ownership (statewide)	2006	1:24,000	Maine Office of GIS
Birch Harbor Pond Property boundary (MCHT easement)	recent	(from GPS survey)	Maine Coast Heritage Trust (MCHT)
National Hydrography Dataset (NHD)	1999 (2009 update)	varies	USGS
National Wetlands Inventory	2009	1:24,000	USFWS
Hancock Co., Maine e911 Roads	2008	1:24,000	Maine Office of GIS

Table 2.4. Distribution of photo traps among sampling properties based on acreage.

Property Name	**Hectares (Acreage)**	**Number of Cameras**
Corea	~231 (570)	6
Prentiss and Carlisle	~103 (254)	3
Little Tunk	~28 (68)	1
Schoodic Bog	~168 (415)	4
Birch Harbor	~149 (368)	4
Tucker Mountain	~40 (100)	2

Table 2.5. Species of Carnivores and herptiles chosen for GIS analysis.

Carnivores	**Herptiles**
Coyote (Canis latrans)	Spotted Salamander (Ambystoma maculatum)
Bobcat (Lynx rufus)	Northern Redback Salamander (Plethedon
Black Bear (Ursus americanus)	Northern Two-lined Salamander (Eurycea
Fisher (Martes pennanti)	Green Frog (Rana clamitans)
Long-tailed Weasel (Mustela frenata)	Painted Turtle (Chrysemys picta)
Ermine (Mustela erminea)	
Red Fox (Vulpes vulpes)	
Northern River Otter (Lutra canadensis)	
Mink (Mustela vison)	

Table 2.6. Habitat quality rankings used in Circuitscape and Least-cost path corridor analyses.

Circuitscape (conductances)		**Least-cost path corridor** (resistances)	
Ranking	**Description**	**Ranking**	**Description**
0	Never found in habitat, may create a total barrier (High Intensity Development, Urban, Salt Water, etc.)	0	Physically found in habitat
1	Rarely found in habitat	1	Optimal habitat according to GAP – most commonly found here
2	May transit through habitat	2	Suitable habitat according to GAP – often found here, but not optimal
3	Suitable habitat according to GAP – often found here, but not optimal	3	May transit through habitat
4	Optimal habitat according to GAP – most commonly found here	4	Rarely found in habitat
5	Physically found in habitat	5	Never found in habitat (High Intensity Development, Urban, Salt Water, etc.)

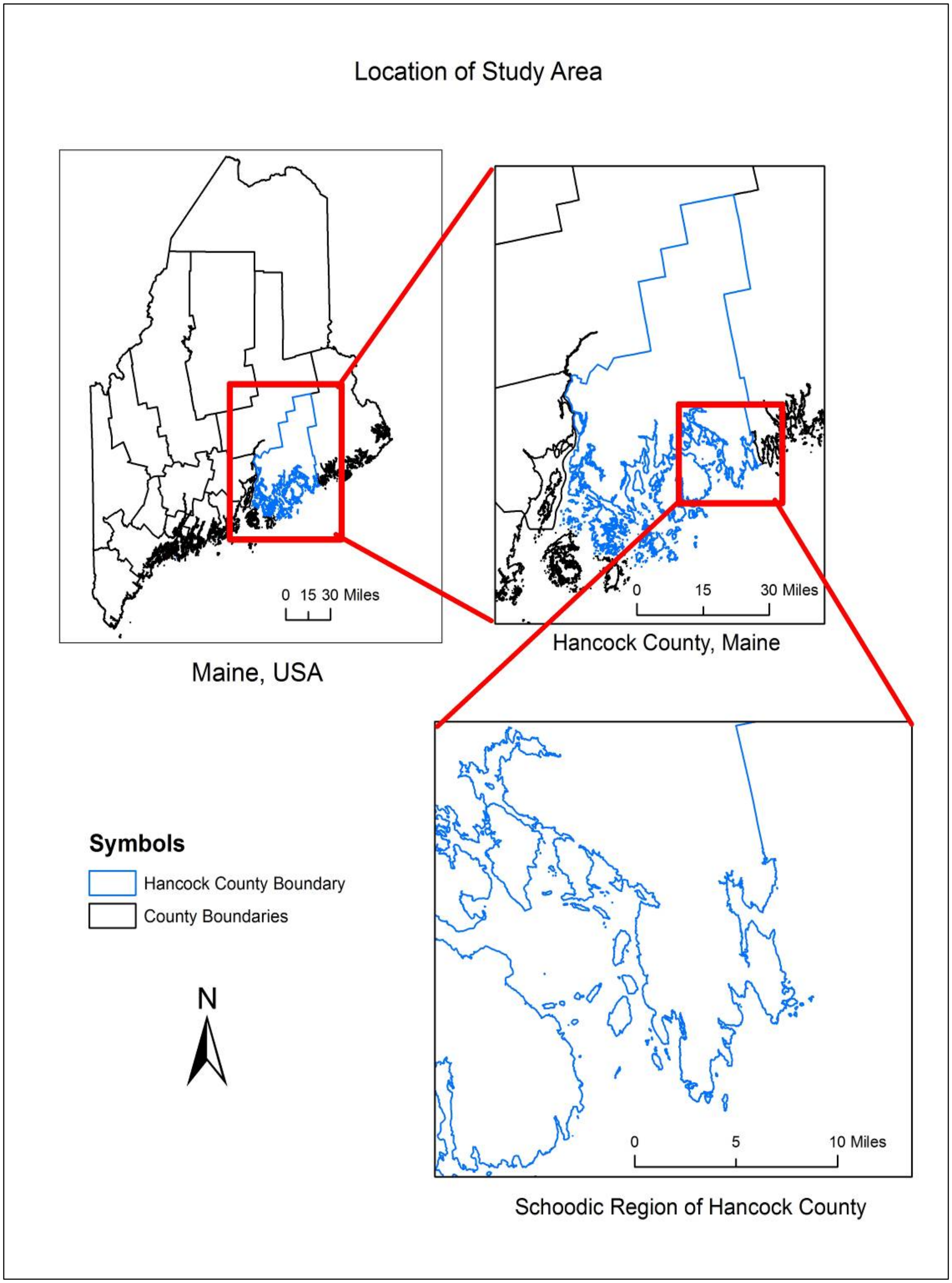

Figure 2.3. Image depicts the location of the Schoodic region in relation to the state of Maine.

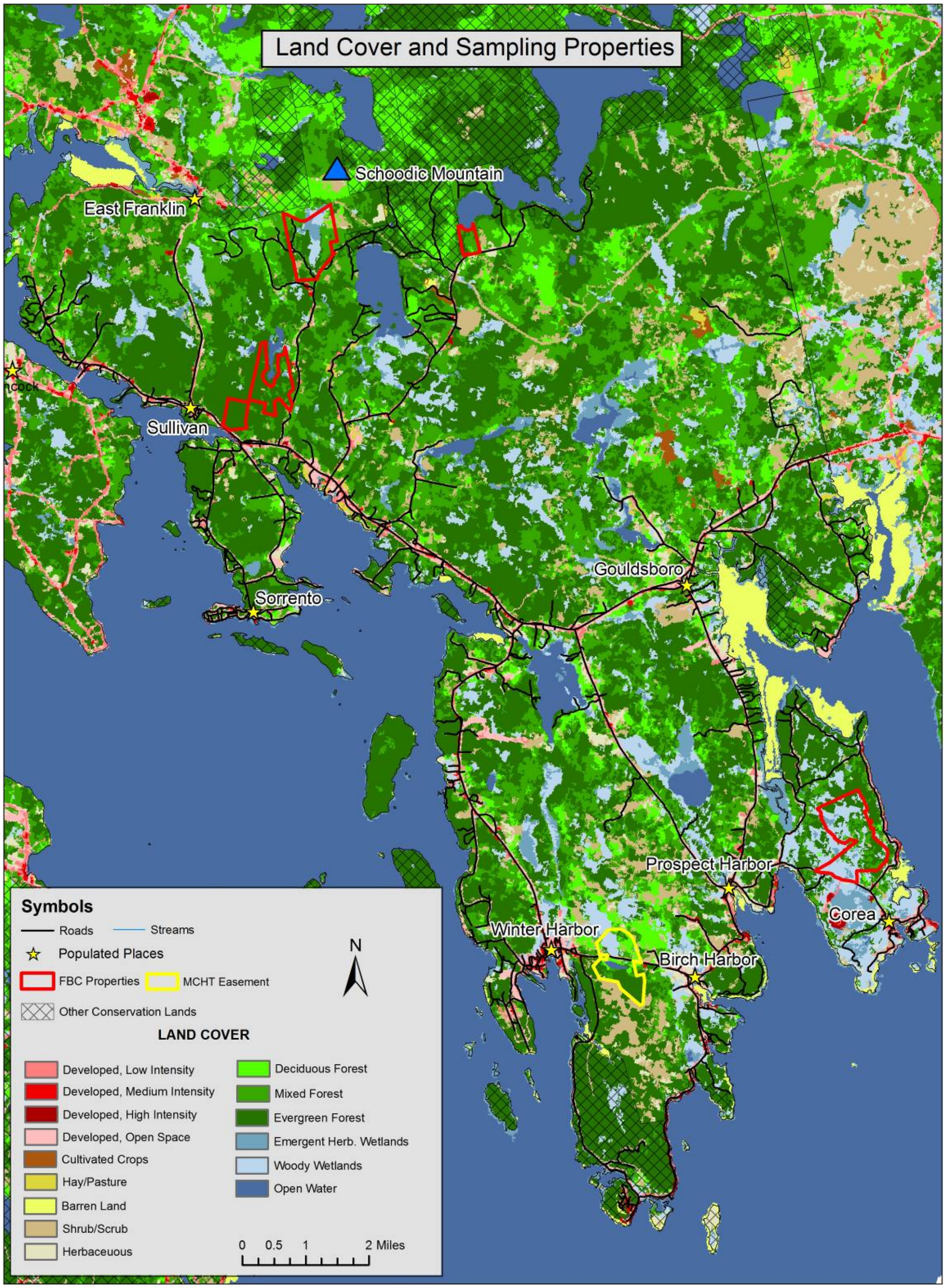

Figure 2.4. Image of Schoodic peninsula showing National Land Cover Data and properties sampled. Also indicates location of Schoodic Mountain in upper left corner and selected populated places.

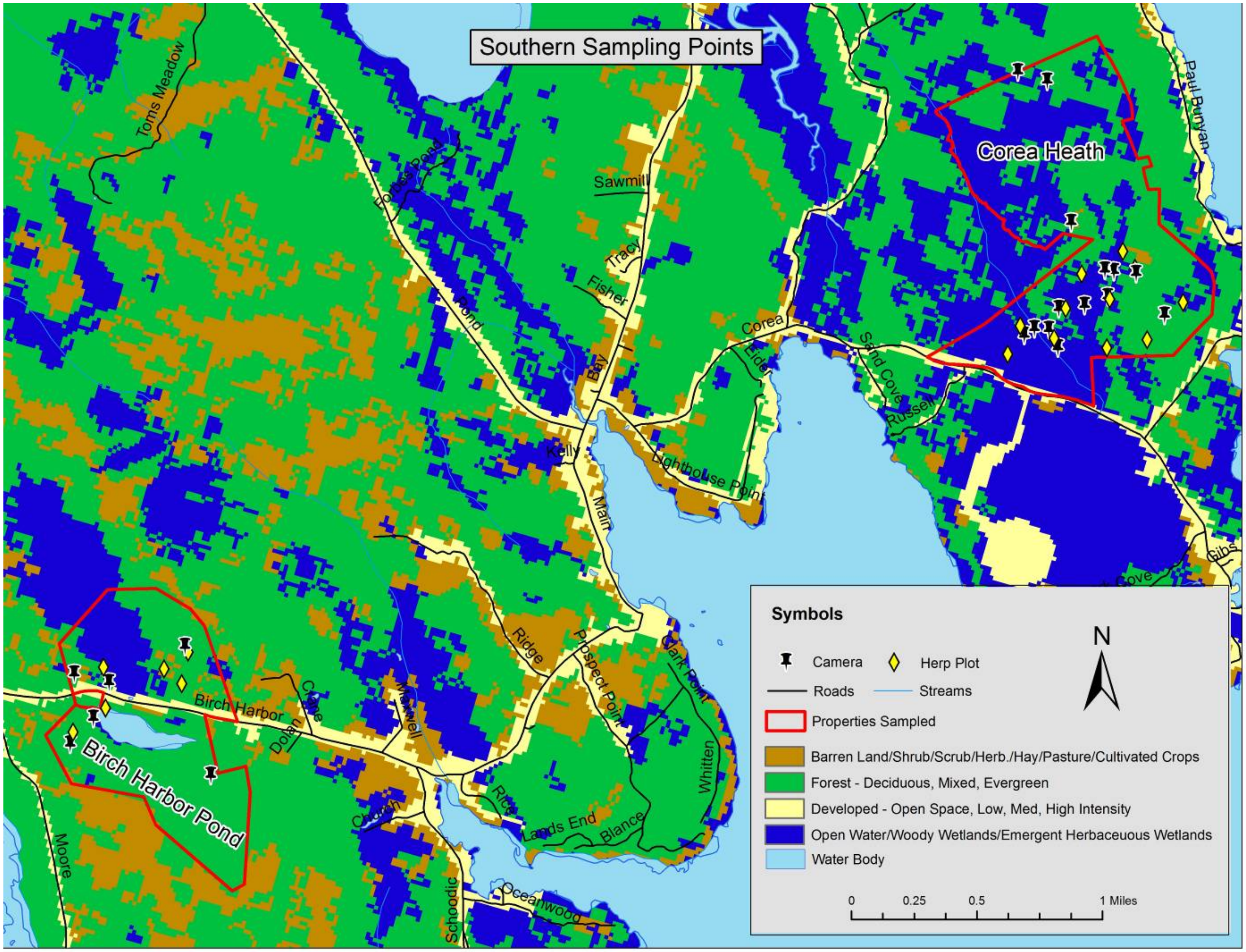

Figure 2.3. Map of sampling points within conservation lands in the southern portion of the study area.

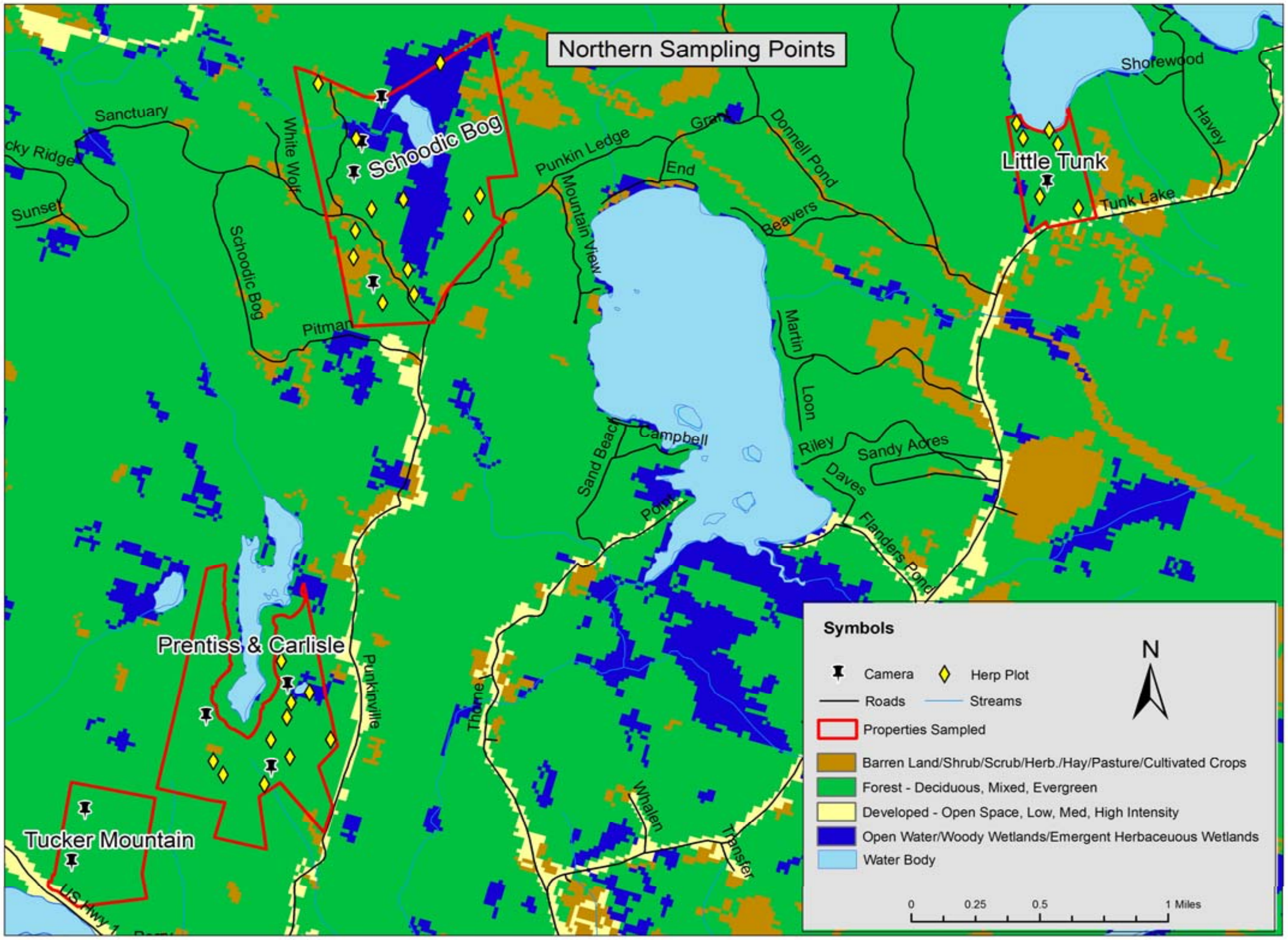

Figure 2.4. Map of sampling points within conservation lands in the northern portion of the study area.

Figure 2.5. Example of photo trap placed at sampling site.

Chapter 3

Results

Field Sampling

A total of 6 properties in the Schoodic region were sampled between May 23rd and July 14th, 2009. For the initial 2-week sampling period 5 photo traps were placed in only the Corea property due to delays in gaining access to other properties. During the remaining weeks all 10 photo traps were in constant operation on all 6 properties in 2-week rotational periods. If no photos were taken within this time period the camera was moved to another location. This resulted in a total of 30 photo trap sampling points and 385 trap days (Table 3.1). Each photo trap operated for a minimum of 2 weeks at each sampling point and was checked on every three days for the first two week period and every five days for the remaining weeks. Scent canisters were refreshed every five days or as needed. Out of 41 photos of individuals captured, the cameras detected 4 (10%) carnivores, 4 (10%) omnivores, 1 (2%) bird, 1 (2%) unidentified mammal, and 31 (76%) other mammals such as Moose and White-Tailed Deer. In addition to species detected by camera traps, a variety of mammals and herptiles were detected by direct observation (Table 3.2).

Over the course of the study period 45 search plots were sampled for herptiles (Table 3.3). Tucker Mountain was the only property not sampled for herptiles due to the lack of wetland habitats and hazardously steep terrain. Each search plot was visited twice, resulting in 90 total search efforts. Approximately 228 (43%) adult amphibians, 301 (57%) larvae, 6 reptiles (1%), 31 amphibian egg masses (Table 3.4) and 14 mammals (actual presence, scat, or tracks) were found within these plots. In addition, 5 species of frogs were detected during anuran vocalization surveys at open water locations on each property (Table 3.5).

At each camera site and herptile search plot I conducted a rapid habitat assessment to identify the general habitat type and then linked this data to the list of species that were found at each sampling site. Associating species presence with habitat type allowed me to confirm GAP model assumptions on habitat preference for multiple species. Habitats were classified based on percentages of herbaceous, shrub, and tree cover, hydrogeomorphic (HGM) wetland class, successional stage, surrounding successional stage, wetland type (if applicable), and presence of stressors such as trails and beaver impoundments. Out of 30 camera sites five (17%) of them were placed in wetland locations, with the remainder located in a variety of upland habitats. Herptile search plots were located mainly in wetland habitats with 17 (38%) of them in upland areas (Table 3.6). The exact location of each sampling site was recorded using a GPS unit for ease of mapping and comparing habitat assessment data with existing land cover datasets (Table 3.7).

Spatial Analysis

After all field data on habitat classifications was collected, I compared my data with both the NLCD and GAP land cover layers in a GIS environment. From this comparison I determined that neither dataset was accurate enough for my analysis since at least 20% of the existing land cover classifications did not match reality or were too generalized. To remedy this I created an improved 30-m, 36 class land cover layer that contained more recent data and was not overly generalized.

Out of 87 total herptile and mammal species assumed to be found in my study area, I chose nine carnivores and five herptiles on which to base corridor selection (Table 2.5). Both generalists and moderate habitat specialists were selected to ensure that essential habitats were not overlooked. Each habitat classification in the improved land cover layer was assigned a habitat quality ranking (Table 2.6) for each focal species. These rankings were then used to create 14 species specific habitat suitability grids (see Appendix A) which were the main inputs for both the least-cost corridor and Circuitscape models.

Both the least-cost corridor and Circuitscape models were run on each species' habitat suitability grid resulting in 14 unique corridor maps from each model, 28 maps total. I found that classifying Circuitscape outputs with a 3-class quantile scheme, and using a 5-class quantile scheme for the least-cost corridor outputs resulted in optimal well defined continuous corridors for all focal species. Optimal corridors are designated as such based on the fact that they provide the highest quality habitat for the species. The reason for the difference in the number of classes used for visual analysis and corridor selection can be attributed to the fact that Circuitscape models identify movement potential in multiple directions at once. Therefore, the resulting grid shows many pathways of greatest conductance which is almost too detailed and complex for the geographical extent of this study. In contrast, the least-cost corridor model only tests for movement in one direction along the path of least resistance resulting in a more direct, generalized corridor.

In the process of creating a final corridor grid, I created separate grids for each taxonomic group and model type to allow for corridor model and species type comparisons (see Appendix B). I then used map algebra to compile separate corridor grids for all herptiles and all carnivores which included the results of both models (Figure 3.1 and 3.2) and labeled the three best corridor paths as ‘Optimal’, ‘Good’ and ‘Fair’. Finally, I used map algebra again to add together both these grids into a final corridor map for all 14 focal species (Figure 3.3).

One big difference between the outputs of the two models is that the Circuitscape corridors tend to not continue through the entire region like the least-cost corridors do. Since this model is based on electrical circuit theory it would be difficult for the voltage to continue very far past an area that had very low conductance. Therefore, it seems that the Circuitscape model is more sensitive to movement barriers such as roads (especially Rt. 1) and development, both of which are present in the landscape directly before the corridor breaks off. In contrast, a least-cost corridor model which is based on cumulative resistances across a cost surface would be able to create a continuous corridor by “recovering” once it passed an area of greatest resistance and entered into large areas of least resistance. Additionally, the least-cost corridor model forces a continuous corridor through an area even if there are barriers by adding together the results from two cost distance analyses. One from point A to point B, and one from point B to point A.

After analyzing the final corridor paths, I determined that establishing a separate corridor path for each taxonomic group would be the best plan of action since the corridor paths identified by both models are obviously dissimilar. The corridor for carnivores (Figure 3.1) travels up the left side of the peninsula whereas the corridor for herptiles (Figure 3.2) travels more through the center of the peninsula. However, both corridor paths have two main similarities; not only do they require two road crossings (Pond Rd. and Route 1), but they also rely heavily on habitats found in and around the Birch Harbor property making this an essential area for habitat preservation. This is the privately-owned property planned for resort development.

Table 3.1. Summary of 2009 field sampling, including photo traps and herptile search plots.

Period	**1 (5/23/09-6/5/09)**	**2 (6/6/09-6/20/09)**	**3 (6/22/09-7/3/09)**	**4 (7/5/09-7/11/09)**	**Total**
Number of phototraps	5	10	10	10	5-10
Number of days	13	14	12	6	45
Total ”Trap Days”	65	140	120	60	385
Number of actual captures	11	5	16	9	41
Herptile plots (ea. visited twice)	6	16	12	11	45x2=90

Table 3.2. Summary of wildlife detected within sampling properties, including results from photo traps, herptile searches and general observations

Mammals	**Amphibians**	**Reptiles**
White-tailed Deer (Odocoileus virginianus)	Wood Frog (Rana sylvatica)	Smooth Green Snake (Opheodrys vernalis)
Moose (Alces alces)	Spring Peeper (Hyla crucifer)	Common Garter Snake (Thamnophis sirtalis)
Coyote (Canis latrans)	Gray Treefrog (Hyla versicolor)	Milk Snake (Lampropeltis triangulum)
Bobcat (Lynx rufus)	Bullfrog (Rana catesbeiana)	Common Snapping Turtle (Chelydra serpentina)
Black Bear (Ursus americanus)	Green Frog (Rana clamitans)	Painted Turtle (Chrysemys picta)
Raccoon (Procyon lotor)	Northern Leopard Frog (Rana pipiens)	
Red Squirrel (Tamiasciurus hudsonicus)	Pickerel Frog (Rana palustris)	
Common Porcupine (Erethizon dorsatum)	American Toad (Bufo americanus)	
Snowshoe Hare (Lepus americanus)	Eastern Newt (Notophthalmus viridescens)	
White-footed Mouse (Peromyscus leucopus)	Northern Redback Salamander (Plethedon cinereus)	
American Beaver (Castor canadensis)	Spotted Salamander (Ambystoma maculatum)	
Northern River Otter (Lutra canadensis)	Northern Two-lined Salamander (Eurycea bislineata)	

Table 3.3. Number of herptiles plots per sampling property (each plot was visited twice).

	# of plots - Period 1 (5/23/09-6/5/09)	# of plots Period 2 (6/6/09-6/20/09)	# of plots - Period 3 (6/22/09-7/3/09)	# of plots - Period 4 (7/5/09-7/11/09)	Total # of plots per property
Corea	6	0	6	0	12
Birch Harbor	0	0	6	0	6
Prentiss and Carlisle	0	5	0	5	10
Schoodic Bog	0	6	0	6	12
Little Tunk Preserve	0	5	0	0	5
Tucker Mountain	0	0	0	0	0
Total # of plots per round	6	16	12	11	45

Table 3.4. Number of individual herptiles and egg masses found in all sampling plots. Amount of individuals found in larval stage are estimates.

Species	Number found	Percentage of total
Red-back Salamanders (Adult)	99	18.71%
Northern Two-Lined Salamander (Adult)	2	0.38%
Red-spotted Newt (Adult)	5	16.13%
Spotted Salamander (Adult)	2	6.45%
Green Frog (Adult)	53	10.02%
Bullfrog (Adult)	23	4.35%
Wood Frog (Adult)	17	3.21%
Leopard Frog (Adult)	1	0.19%
Spring Peeper (Adult)	4	0.76%
Unknown Frog (Adult)	16	3.02%
Smooth Green Snake (Adult)	1	0.19%
Garter Snake (Adult)	5	0.95%
Wood Frog (Larval)	183	34.59%
Green Frog (Larval)	70	13.23%
Bullfrog (Larval)	33	6.24%
Unknown Salamander (Larval)	10	1.89%
Unknown Frog (Larval)	5	0.95%
Total	**529**	
Unknown Egg Masses	31	

Table 3.5. Summary of species heard at open water sites during anuran vocalization surveys.

Location	Bullfrogs	Green Frogs	Wood Frogs	Spring Peepers	Gray Tree Frogs
Corea	4	6	0	>20	>=8
Schoodic Bog	11	14	2	0	>15
Prentiss and Carlisle	0	5	0	0	4
Tunk Lake	8	0	0	0	>10
Birch Harbor Pond	0	4	0	0	0

Table 3.6. Habitat classifications of all sampling sites.

Name	Site Type	Date	Stressor	HGM Class	Herbaceous	Tree Canopy	Shrub/ Scrub	Plot Successional Stage	Buffer Successional Stage	Comments
CAM3_COREA	Camera	5/23/2009	none	Depression - bog	80%	50%	10%	Wetland - Palustrine Forested		
CAM5_COREA	Camera	5/23/2009	none	Upland	<10%	50%	80%	Upland	10-25 yr (pole)	Jack Pine stand
CAM6_COREA	Camera	5/23/2009	none	Depression - bog	10%	10%	80%	Wetland – Palustrine Scrub/Shrub	Brush or Scrub/Shrub	
CAM7_COREA	Camera	5/23/2009	none	Upland	20%	20%	10%	Upland	>50 yr (large mature tree)	
CAM8_COREA	Camera	5/23/2009	Beaver dam	Riverine - R2b	90%	10%	40%	Riverine Emergent	Brush or Scrub/Shrub	Beaver impounded
CAM1	Camera	6/7/2009	none	Upland	70%	60%	50%	Upland	5-10yr (sapling)	Mostly deciduous
CAM2	Camera	6/7/2009	none	Upland	<1%	70%	0%	Upland	25-50yr (small mature tree)	Mostly coniferous
CAM3	Camera	6/7/2009	none	Upland	10%	70%	10%	Upland	25-50yr (small mature tree)	Squirrel activity
CAM4	Camera	6/7/2009	none	Depressional - Intermittent stream	20%	10%	50%	Wetland - Palustrine Forested	10-25yr (pole)	Mostly Evergreen

Name	**Site Type**	**Date**	**Stressor**	**HGM Class**	**Herbaceous**	**Tree Canopy**	**Shrub/ Scrub**	**Plot Successional Stage**	**Buffer Successional Stage**	**Comments**
CAM5	Camera	6/8/2009	none	Upland	<1%	90%	0%	Upland	Upland - 10-25yr (pole)	Area had been logged, mixed forest, mostly con.
CAM6	Camera	6/8/2009	none	Upland	0%	90%	0%	Upland	Upland - 10-25yr (pole)	Area had been logged, coniferous
CAM7	Camera	6/8/2009	none	Upland	10%	0%	<1%	Upland	Upland - 0-5yr (seedling)	Coniferous
CAM8	Camera	6/8/2009	near old railroad	Upland	20%	90%	10%	Upland	Upland - 25-50yr (small mature tree)	Area had been logged, mostly deciduous, edge habitat
CAM9	Camera	6/8/2009	near old gravel road	Upland	0%	50%	0%	Upland	Upland - 10-25yr (pole)	Coniferous, some deciduous
CAM10	Camera	6/8/2009	none	Upland	<10%	70%	0%	Upland	Upland - 25-50yr (small mature tree)	Coniferous
CAM1H	Camera	6/22/2009	none	Upland	10%	60%	0%	Upland	Upland - 25-50yr (small mature tree)	Coniferous, mainly Arborvitae
CAM2H	Camera	6/22/2009	none	Upland	20%	<10%	30%	Upland	Upland - 25-50yr (small mature tree)	Mixed forest, some Jack Pine
CAM9H	Camera	6/22/2009	human/beaver impounded lake	Slope (into lake)	10%	10%	80%	Wetland - Palustrine Forested	5-10yr (sapling)	Mixed, mostly deciduous
CAM10H	Camera	6/22/2009	none	Upland	10%	50%	10%	Upland	Wetland - Palustrine Forested 10-25yr (pole)	Coniferous upland surrounded by forested wetland
CAM4C	Camera	6/22/2009	none	Upland	20%	70%	70%	Upland	Upland - 10-25yr (pole)	Mixed, some Jack Pine
CAM5C	Camera	6/22/2009	none	Upland	60%	80%	<10%	Upland	upland - 10-25yr (pole)	Deciduous , mainly Maples

Name	**Site Type**	**Date**	**Stressor**	**HGM Class**	**Herbaceous**	**Tree Canopy**	**Shrub/ Scrub**	**Plot Successional Stage**	**Buffer Successional Stage**	**Comments**
CAM7C	Camera	6/22/2009	none	Upland	90%	<1%	10%	Upland	upland - 10-25yr (pole), open water nearby	Mixed, with dead/dying Coniferous
FCAM1	Camera	7/3/2009	Logging road	Upland	40%	30%	20%	Upland	Wetland - Palustrine Forested? (hard to tell, raining for 4 wks) - 10-25yr (pole)	Deciduous, all Maple. Many seedling con.
FCAM9	Camera	7/3/2009	none	Upland	<10%	70%	0%	Upland	Upland - 25-50yr (small mature tree)	Coniferous, many Arborvitaes
FCAM3C	Camera	7/5/2009	none	Upland	10%	40%	40%	Upland	Upland - 10-25yr (pole)/25-50yr (small mature tree)	Mixed, mainly coniferous
FCAM4C	Camera	7/5/2009	none	Upland	0%	<1%	100%	Upland	Upland - Brush or scrub-shrub	Mixed, Jack pines predominating
FCAM5C	Camera	7/5/2009	none	Upland	70%	20%	30%	Upland	Upland 10-25yr(pole) on one side and Palustrine emergent wetland on other side	Mixed, mainly deciduous
FCAM6C	Camera	7/5/2009	none	Upland	30%	90%	20%	Upland	Upland - 5-10yr (sapling)	Deciduous, all maple (whitish gray trunks)
FCAM7C	Camera	7/5/2009	none	Upland	20%	40%	10%	Upland	Upland - 10-25yr (pole)	Coniferous, all deciduous are dead/dying
FCAM8C	Camera	7/5/2009	none	Upland	30	70%	0%	Upland	Upland - 10-25yr (pole)	Mixed, mainly coniferous
HERP1	Herp	5/23/2009	none	Depression - bog	80%	50%	10%	Wetland - Palustrine Forested	25-50 yr (small mature tree)	Pitcher plants present

Name	**Site Type**	**Date**	**Stressor**	**HGM Class**	**Herbaceous**	**Tree Canopy**	**Shrub/ Scrub**	**Plot Successional Stage**	**Buffer Successional Stage**	**Comments**
HERP2	Herp	5/25/2009	none	Riverine -R3c	60%	40%	10%	Wetland - Palustrine Forested (mostly deciduous)	10-25yr (pole)	Small stream through plot
HERP3	Herp	5/25/2009	none	Depression	10%	50%	0%	Wetland - Palustrine Forested (mostly coniferous/paper birch?)	25-50yr (small mature tree)	Many young coniferous and dead logs
HERP4	Herp	5/26/2009	none	Depression	20%	20%	30%	Wetland - Palustrine Forested (Deciduous, some coniferous)	upland - 10-25yr (pole)	Many young con.
HERP5	Herp	5/30/2009	old ATV trail	Slope Wetland - unidirectional flow	90%	<10%	30%	Palustrine emergent	10-25yr (pole)	Mostly shrubs/deciduous trees. Lots of grass
HERP6	Herp	5/27/2009	none	Depression	10%	50%	50%	Wetland - Palustrine Forested (Deciduous, some coniferous)	10-25yr (pole)	
HE113T	Herp	6/10/2009	none	Upland	0%	70%	0%	Wetland - Palustrine Forested	25-50yr (small mature tree)	Mixed forest with many coniferous seedlings
HER1T	Herp	6/10/2009	none	slope wetland	10%	90%	0%	Wetland - Palustrine Forested	25-50yr (small mature tree)	Mixed forest
HER4T	Herp	6/10/2009	human trampling	Lacustrine Fringing	70%	0%	0%	Lacustrine Emergent	Brush/scrub-shrub on shoreside	Fish present

Name	**Site Type**	**Date**	**Stressor**	**HGM Class**	**Herbaceous**	**Tree Canopy**	**Shrub/ Scrub**	**Plot Successional Stage**	**Buffer Successional Stage**	**Comments**
HER4TB	Herp	6/10/2009	none	Slope wetland	10%	90%	0%	Wetland - Palustrine Forested	10-25yr (pole)	Deciduous with a few coniferous
HER5T	Herp	6/10/2009	none	Slope wetland	10%	90%	0%	Wetland - Palustrine Forested	10-25yr (pole)	Mixed, mostly Arborvitae
HER23B	Herp	6/13/2009	none	Depression - bog	60%	30%	40%	Palustrine emergent	10-25yr (pole) - one side	Orchids and Pitcher plants present. Many blueberries
HER31B	Herp	6/13/2009	old logging road	Depression	50%	<1%	0%	Wetland - Palustrine Forested	0-5yr (seedling)	Mixed, mostly deciduous
HER24B	Herp	6/13/2009	none	Depression-bog	70%	<10%	10%	Palustrine emergent	Perrenial Herbaceous with 10-25yr (pole, dying)	Mostly arborvitae with grasses and blueberries
HER22B	Herp	6/13/2009	none	Depression, edge of bog open water	90%	0%	0%	Palustrine emergent	Annual Herbaceous	Mostly emergent grasses
HER40B	Herp	6/15/2009	old logging road	Slope wetland	80%	<10%	10%	Wetland - Palustrine Forested	5-10yr (sapling)	Mixed, mostly deciduous
HER50B	Herp	6/15/2009	Old railroad underwater	Depression - bog	50%	0%	50%	Palustrine emergent	Annual/Perennial Herbaceous (PEM/PAB)	Open water with emergent and aquatic bed
HER54P	Herp	6/15/2009	none	Depression - edge of kettle lake	20%	0	90%	Lacustrine emergent	Brush/scrub-shrub	Open water, was mainly coniferous at one time
HER55P	Herp	6/16/2009	none	Depression	<1%	90%	10%	Wetland - Palustrine Forested	10-25yr (pole)	Coniferous - mainly Arborvitae
HER10P	Herp	6/16/2009	small foot trail nearby	Slope	10%	60%	10%	Wetland - Palustrine Forested	10-25yr (pole)	Mixed forest

Name	**Site Type**	**Date**	**Stressor**	**HGM Class**	**Herbaceous**	**Tree Canopy**	**Shrub/ Scrub**	**Plot Successional Stage**	**Buffer Successional Stage**	**Comments**
HER61P	Herp	6/15/2009	small foot trail adjacent	Depression	<1%	50%	20%	Wetland - Palustrine Forested	Upland - 25-50yr (small mature tree)	Rock cliffs adjacent with animal holes. Mixed forest, mostly coniferous
HER62P	Herp	6/15/2009	small foot trail adjacent	depression	<10%	50%	60%	Wetland - Palustrine Forested	Upland - 25-50yr (small mature tree)	Mixed forest
HER9H	Herp	6/25/2009	human/beaver impounded	Upland	90%	0%	70%	Upland	upland - 5-10yr (sapling)	Mixed, oldest trees are coniferous
HER20H	Herp	6/25/2009	none	Upland	30%	60%	0%	Upland	Wetland - Palustrine Forested - 10-25yr (pole)	Mixed, mostly coniferous - deciduous is maple
HER13H	Herp	6/25/2009	logging clearing	Depression	<10%	60%	10%	Wetland - Palustrine Forested	Brush/Scrub-shrub with a few trees - 5-10yr (sapling)	Mixed, mostly coniferous
HER21H	Herp	6/26/2009	logging road	Depression	50%	60%	70%	Wetland - Palustrine Forested	Wetland - Palustrine Forested - 5-10yr (sapling)	Deciduous, maples and paper birch
HER6H	Herp	6/26/2009	none	Upland	80%	40%	10%	Upland	Upland - 10-25yr (pole)	Mixed, Deciduous is maple
HER8H	Herp	6/26/2009	none	Upland	10%	40%	0%	Upland	Upland - 10-25yr (pole)	Deciduous, mainly maple
HE101C	Herp	6/27/2009	none	Upland	10%	60%	0%	Upland	Upland - 25-50yr (pole)	Mixed, mostly coniferous, many arborvitae
HER83C	Herp	6/27/2009	none	Upland	10%	30%	80%	Upland	Upland - 10-25yr (pole)	Mixed, jack pine stand with paper birch

Name	**Site Type**	**Date**	**Stressor**	**HGM Class**	**Herbaceous**	**Tree Canopy**	**Shrub/ Scrub**	**Plot Successional Stage**	**Buffer Successional Stage**	**Comments**
HER75C	Herp	6/27/2009	none	Upland	60%	10%	70%	Upland	Wetland - Palustrine Forested - 10-25yr (pole)	Mixed, many ferns, deciduous is maple
HER81C	Herp	6/27/2009	none	Depression - bog	90%	0%	30%	Palustrine ScrubShrub/Palustrine Emergent	Annual Palustrine ScrubShrub/Palustrine Emergent	Blueberries and Grasses predominate
HE104C	Herp	6/27/2009	old ATV trail	Upland	90%	10%	10%	Upland	Shrub/ Wetland - Palustrine Forested , 10-25yr (pole)	Mixed, mostly maple
HER88C	Herp	6/27/2009	none	Slope wetland?	30%	20%	60%	Wetland - Palustrine Forested	Wetland - Palustrine Forested - 10-25yr (pole)	Deciduous
HER63	Herp	7/7/2009	None	Depression	10%	70%	0%	Wetland - Palustrine Forested	Wetland - Palustrine Forested - 10-25yr (pole)	Mixed, mainly coniferous
HER65	Herp	7/7/2009	None	Slope	10%	70%	0%	Wetland - Palustrine Forested	Upland - 10-25yr(pole)/25-50yr(small mature tree)	Mixed
HER64	Herp	7/7/2009	Foot trail	Slope (with stream)	10%	40%	30%	Wetland - Palustrine Forested	Upland - 10-25yr (pole)	Mixed, mostly deciduous
HER66	Herp	7/7/2009	None	Depression	10%	20%	60%	Wetland - Palustrine Forested	Upland - Scrub-shrub/5-10yr(sapling)	Coniferous
HER67	Herp	7/7/2009	none	Depression	10%	50%	10%	Wetland - Palustrine Forested	Upland - 25-50yr (small mature tree)	Mixed, mostly coniferous
HER93	Herp	7/8/2009	logging rd	Upland	60%	20%	0%	Upland	Upland - Grasses and 0-5yr (seedling)	Mixed

Name	**Site Type**	**Date**	**Stressor**	**HGM Class**	**Herbaceous**	**Tree Canopy**	**Shrub/ Scrub**	**Plot Successional Stage**	**Buffer Successional Stage**	**Comments**
HER95	Herp	7/8/2009	Logged	Depression	30%	70%	0%	Wetland - Palustrine Forested	Palustrine forested - 5-10yr (sapling)	Mixed, with small stand of coniferous
HER96	Herp	7/8/2009	None	Upland	10%	60%	0%	Upland	Upland - 25-50yr (small mature tree)	Coniferous
HER94	Herp	7/8/2009	None	Upland	30%	<1%	70%	Upland	upland - 5-10yr (sapling)	Mixed, mostly deciduous
HER92	Herp	7/8/2009	None	Slope	10%	20%	40%	Wetland - Palustrine Forested	Palustrine forested - 5-10yr (sapling)	Mixed, mostly coniferous
HER97	Herp	7/8/2009	Logged	Upland	0%	90%	0%	Upland	Upland towards rd, wetland other side - 10-25yr (pole)	Coniferous

Table 3.7. GPS locations for all sampling sites on the Schoodic peninsula.

Latitude	Longitude	Site Name	Property Name	Site Type
44.39497	-68.0675	CAM1H	BIRCH HARBOR	Camera
44.39443	-68.0647	CAM2H	BIRCH HARBOR	Camera
44.39239	-68.0659	CAM9H	BIRCH HARBOR	Camera
44.39092	-68.0679	CAM10H	BIRCH HARBOR	Camera
44.39648	-68.0585	FCAM1	BIRCH HARBOR	Camera
44.38902	-68.0565	FCAM9	BIRCH HARBOR	Camera
44.41605	-67.9838	CAM3_COREA	COREA	Camera
44.41388	-67.9906	CAM5_COREA	COREA	Camera
44.41556	-67.9857	CAM6_COREA	COREA	Camera
44.4154	-67.9878	CAM7_COREA	COREA	Camera
44.41425	-67.9898	CAM8_COREA	COREA	Camera
44.4175	-67.9833	CAM4C	COREA	Camera
44.41419	-67.9886	CAM5C	COREA	Camera
44.41313	-67.9879	CAM7C	COREA	Camera
44.41494	-67.9793	FCAM3C	COREA	Camera
44.41737	-67.9815	FCAM4C	COREA	Camera
44.41758	-67.984	FCAM5C	COREA	Camera
44.42036	-67.9867	FCAM6C	COREA	Camera
44.4291	-67.9909	FCAM7C	COREA	Camera
44.42854	-67.9885	FCAM8C	COREA	Camera
44.52618	-68.174	CAM2	PRENTISS & CARLISLE	Camera
44.52309	-68.1689	CAM3	PRENTISS & CARLISLE	Camera
44.52799	-68.1676	CAM4	PRENTISS & CARLISLE	Camera
44.55168	-68.1605	CAM5	SCHOODIC BOG	Camera
44.5582	-68.1619	CAM6	SCHOODIC BOG	Camera
44.56001	-68.1613	CAM7	SCHOODIC BOG	Camera
44.56267	-68.1597	CAM8	SCHOODIC BOG	Camera
44.52071	-68.1837	CAM9	TUCKER MTN	Camera
44.51764	-68.1847	CAM10	TUCKER MTN	Camera
44.55727	-68.1073	CAM1	LITTLE TUNK	Camera
44.39297	-68.065	HER9H	BIRCH HARBOR	Herp
44.3916	-68.0676	HER20H	BIRCH HARBOR	Herp
44.39533	-68.0651	HER13H	BIRCH HARBOR	Herp
44.39614	-68.0583	HER21H	BIRCH HARBOR	Herp
44.39518	-68.0602	HER6H	BIRCH HARBOR	Herp
44.39433	-68.0588	HER8H	BIRCH HARBOR	Herp
44.4159	-67.9837	HERP1	COREA	Herp
44.41441	-67.9909	HERP2	COREA	Herp
44.41539	-67.9873	HERP3	COREA	Herp
44.41309	-67.984	HERP4	COREA	Herp
44.41774	-67.984	HERP5	COREA	Herp
44.41278	-67.992	HERP6	COREA	Herp
44.41353	-67.9807	HE101C	COREA	Herp
44.41566	-67.9778	HER83C	COREA	Herp
44.41765	-67.9816	HER75C	COREA	Herp

Latitude	Longitude	Site Name	Property Name	Site Type
44.41864	-67.9826	HER81C	COREA	Herp
44.41737	-67.9859	HE104C	COREA	Herp
44.41368	-67.9882	HER88C	COREA	Herp
44.52754	-68.1659	HER54P	PRENTISS & CARLISLE	Herp
44.52351	-68.1735	HER55P	PRENTISS & CARLISLE	Herp
44.52695	-68.1673	HER10P	PRENTISS & CARLISLE	Herp
44.52609	-68.1677	HER61P	PRENTISS & CARLISLE	Herp
44.52475	-68.169	HER62P	PRENTISS & CARLISLE	Herp
44.52474	-68.1643	HER63	PRENTISS & CARLISLE	Herp
44.52942	-68.1681	HER65	PRENTISS & CARLISLE	Herp
44.52372	-68.1675	HER64	PRENTISS & CARLISLE	Herp
44.52213	-68.1695	HER66	PRENTISS & CARLISLE	Herp
44.52271	-68.1728	HER67	PRENTISS & CARLISLE	Herp
44.55251	-68.1578	HER23B	SCHOODIC BOG	Herp
44.55611	-68.1606	HER31B	SCHOODIC BOG	Herp
44.55664	-68.1581	HER24B	SCHOODIC BOG	Herp
44.5603	-68.1617	HER22B	SCHOODIC BOG	Herp
44.56357	-68.1647	HER40B	SCHOODIC BOG	Herp
44.56472	-68.1551	HER50B	SCHOODIC BOG	Herp
44.55567	-68.153	HER93	SCHOODIC BOG	Herp
44.55684	-68.152	HER95	SCHOODIC BOG	Herp
44.55485	-68.1619	HER96	SCHOODIC BOG	Herp
44.55328	-68.1621	HER94	SCHOODIC BOG	Herp
44.55057	-68.1598	HER92	SCHOODIC BOG	Herp
44.55107	-68.1573	HER97	SCHOODIC BOG	Herp
44.55993	-68.1092	HE113T	LITTLE TUNK	Herp
44.5608	-68.1097	HER1T	LITTLE TUNK	Herp
44.56038	-68.1071	HER4T	LITTLE TUNK	Herp
44.55956	-68.1064	HER4TB	LITTLE TUNK	Herp
44.55646	-68.1079	HER5T	LITTLE TUNK	Herp

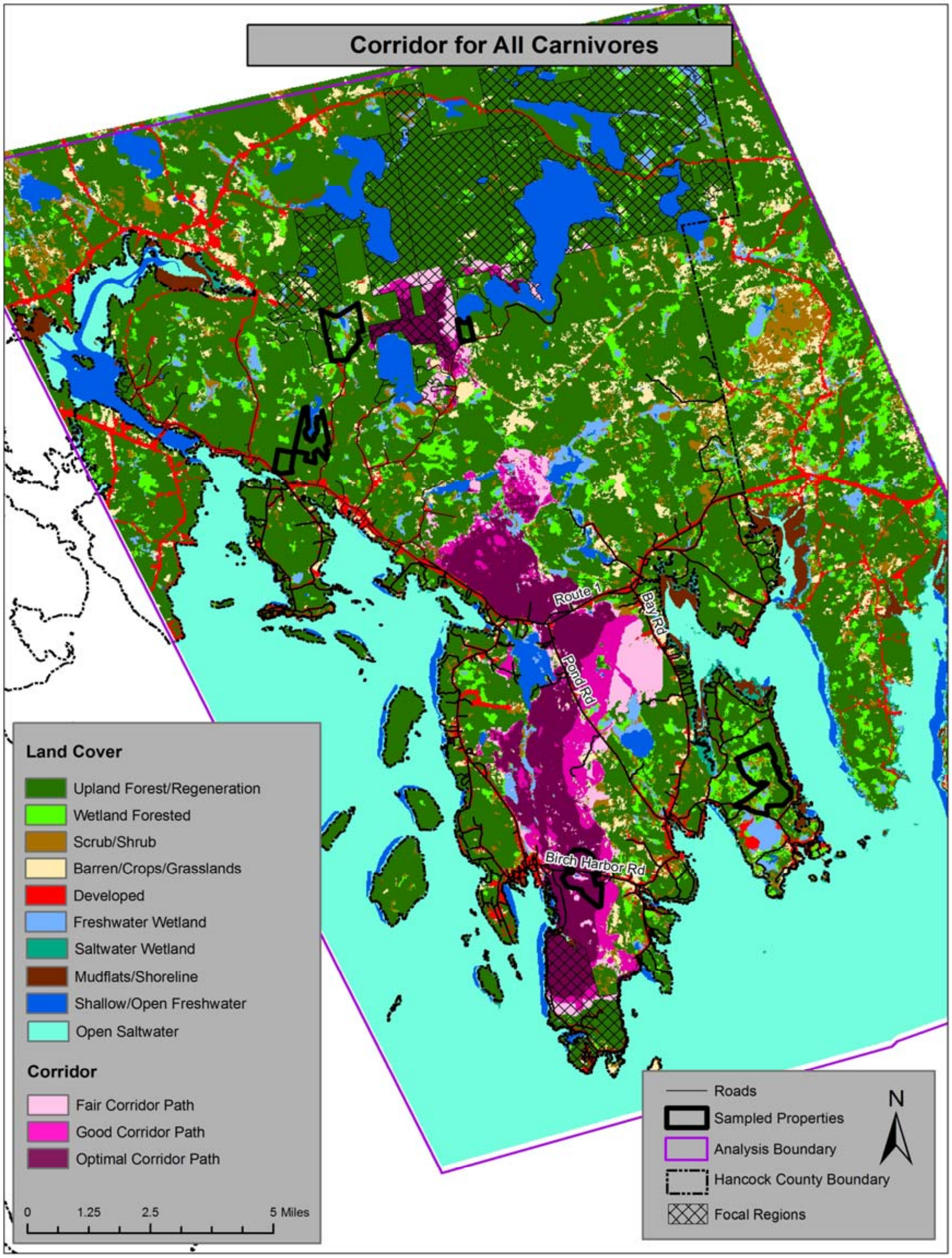

Figure 3.1. Map showing corridor path best suited to all carnivores on the Schoodic peninsula. Path was determined by overlaying the outputs of both the Circuitscape and Least-cost corridor models.

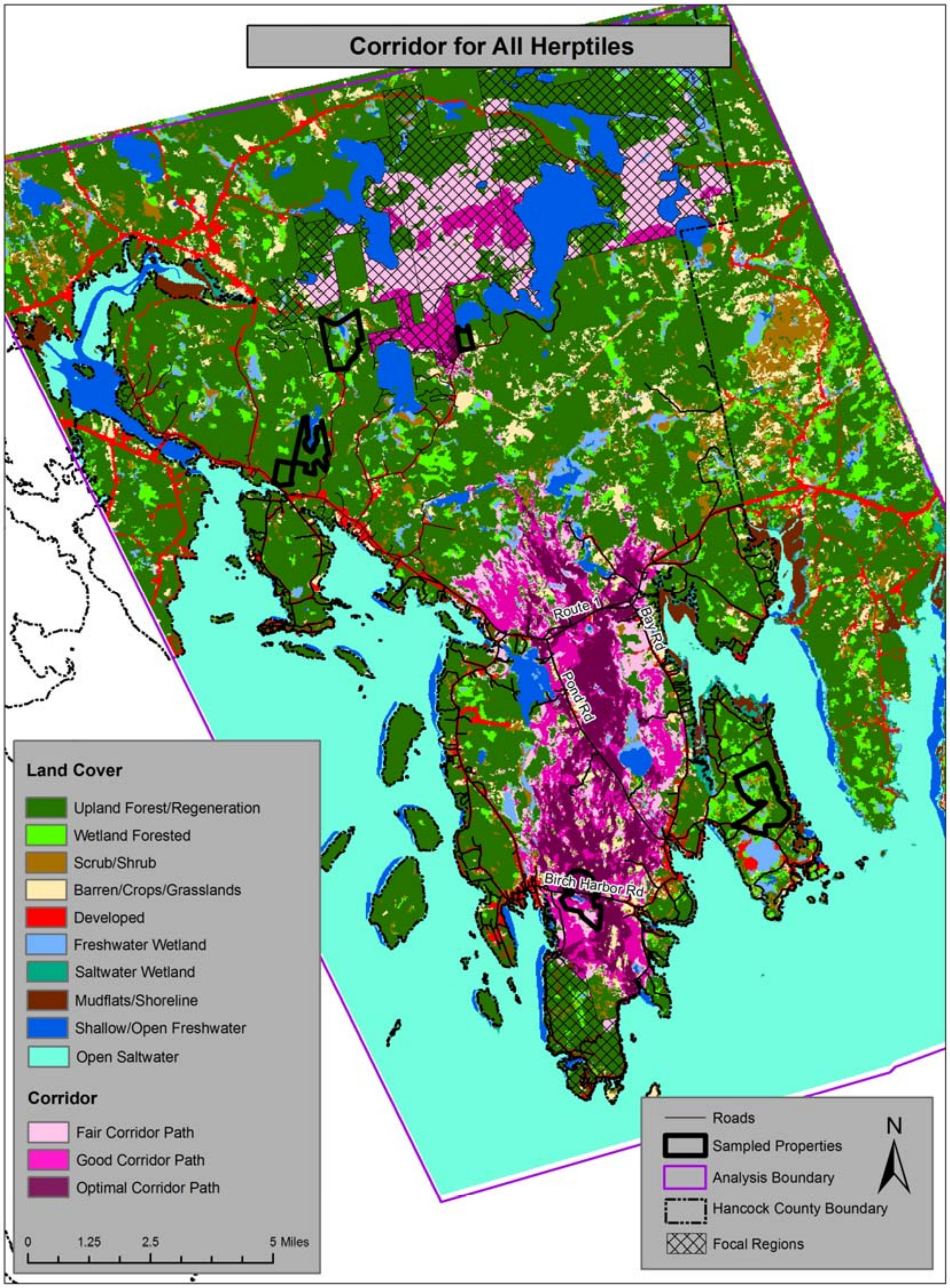

Figure 3.2. Map showing corridor path best suited to all herptiles on the Schoodic peninsula. Path was determined by overlaying the outputs of both the Circuitscape and Least-cost corridor models.

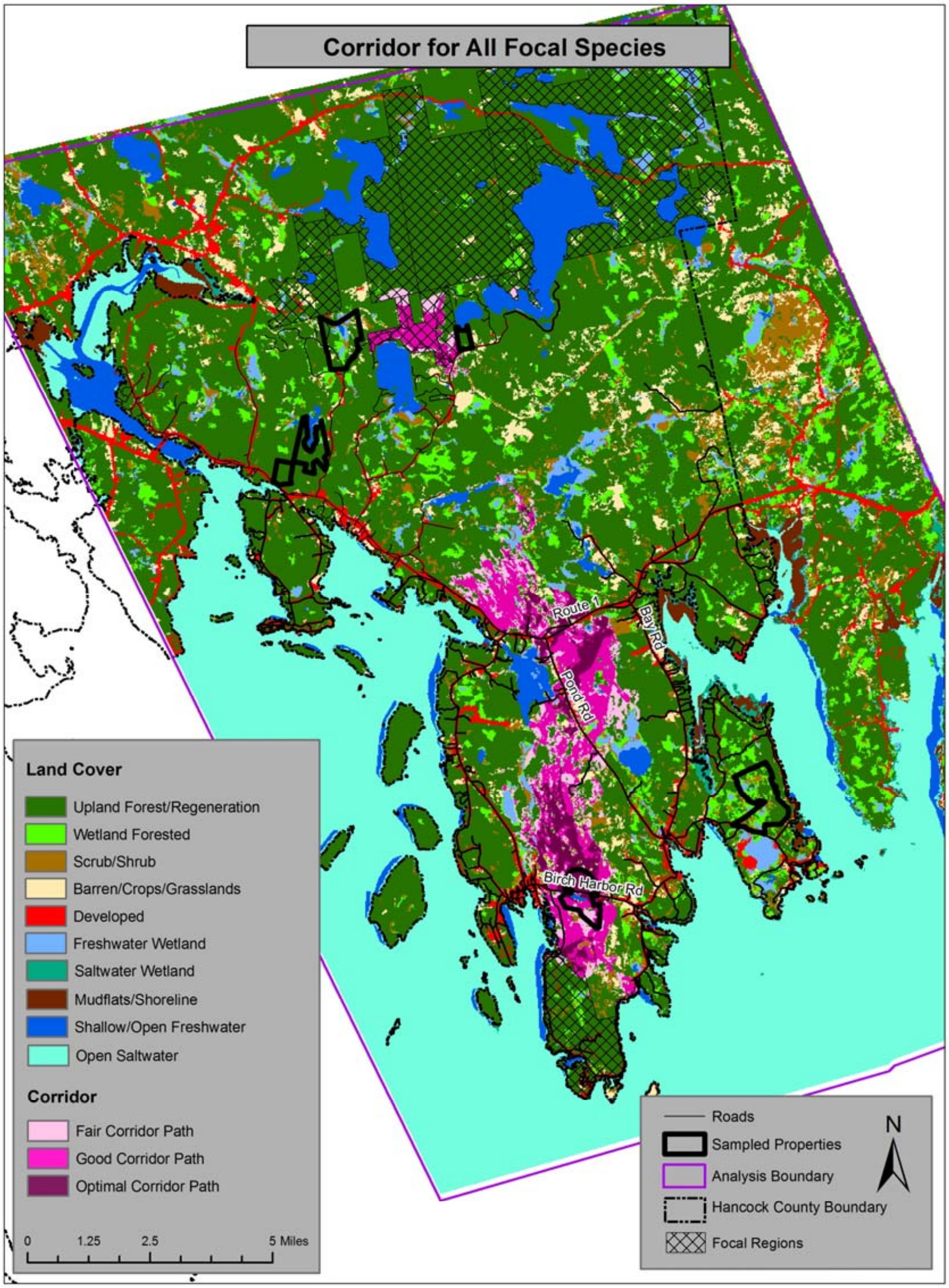

Figure 3.3. Map showing corridor path best suited to all focal species on the Schoodic peninsula. Path was determined by overlaying the outputs of both the Circuitscape and Least-cost corridor models.

Chapter 4

Discussion

Although the actual utility of wildlife corridors has been heavily debated, it is well known that all wildlife species naturally disperse at some point in their life cycle. Thus, it's only logical that when human development encroaches on the natural pathways of dispersal (i.e., fragmentation) the populations of many, if not all species will be isolated and negatively affected. Of course, an artificially created corridor through a highly developed area may not be very effective for the dispersal of many species, but by conserving a corridor through relatively undisturbed habitat I am confident that connectivity can be maintained throughout the region even after development has taken place. Essentially, by designing one or more corridors before development occurs I am attempting to work around the needs of the species rather than trying to force the animals into using what little habitat is left or is artificially created after the landscape is heavily fragmented.

However, it is important to keep in mind that each taxon disperses in different ways and has varying needs, so for corridors to be effective they must be designed for a wide range of species. Many plans to maintain connectivity fail because they tend to have a very narrow focus and only attempt to preserve the habitats for large carnivores, endangered species, or some of the more charismatic species that easily get stakeholder's attention. But by basing corridor selection for the Schoodic region on both herptiles and carnivores I believe that I have made a good first step towards creating a conservation plan that will benefit most, if not all the species found here. Future work will need to include a wider range of taxa such as birds, insects, and plants, among others.

Corridor Paths

The initial plan was to create a single corridor through the Schoodic region that would satisfy the needs of all focal species, and then make adjustments to the placement of that corridor as more studies were conducted in the future. However, after careful visual analysis of the final corridor maps I came to the conclusion that since herptiles and carnivores have different habitat requirements that only slightly overlap, it would more logical and effective to make two separate corridors. It is clear that although both herptiles and carnivores use a variety of habitat types, carnivores tend to prefer upland habitats whereas herptiles are typically wetland inhabitants. Thus, the placement of the carnivore corridor along the west side of the peninsula which has the most unbroken tracts of upland forest seems logical. Furthermore, the placement of the corridor for herptiles along the central and east side of the peninsula where more scrub/shrub and forested wetlands are found also seems like a reasonable result.

When comparing the placement of these corridors with field data on species presence it is apparent that the Birch Harbor property along Birch Harbor Rd. and the surrounding lands contain essential habitat for multiple species. Not only were Moose, Deer and Porcupine spotted here often, but large carnivores such as Coyotes, Black Bear, and Bobcat were captured by the photo traps on the Birch Harbor property. In addition, herptiles such as Spring Peepers, Wood Frogs, Leopard Frogs, Smooth Green Snakes, and Garter Snakes among others were also found on this property. Since the carnivore corridor travels directly through the middle of the Birch Harbor property, and the herptile corridor travels through and just to the east of it, preserving this land is the key to keeping the tip of the Schoodic peninsula from being isolated from the conservation areas around Schoodic Mountain. With development of these lands imminent, it is imperative that steps are taken to preserve as much of this area as possible.

One worrisome component of this landscape is the presence of roads which could have varying effects on the mobility of species through this region. Two state highways (195 - Pond Rd. and 186 - Birch Harbor Rd.) and one U.S. highway (Route 1) run through the region and have the potential to become serious barriers to movement especially with increased traffic as development encroaches. Currently, the two state highways are one lane each way with low speed limits; however, Route 1 usually has relatively heavy traffic during selected times, traveling at speeds often in excess of 50 mph. According to the 2008 MaineDOT Traffic Volume Count book the annual average daily traffic counts as of 2004 (count is done in 5-year cycles) are as follows: Pond Rd. - 1090, Birch Harbor Rd. - 2300, and Route 1 – 4090. Undoubtedly, Route 1 is the biggest threat to wildlife movement, with Birch Harbor Rd. being the next biggest threat especially since this road courses directly through the middle of the Birch Harbor property.

Roads are difficult barriers to overcome, and solutions can become costly, but may be necessary for a conservation corridor to be successful. Herptiles are the most affected by the presence of roads since they are slow moving and often have to travel between multiple habitats on an annual basis in order to complete their life cycle (Roe and Georges 2007). However, even though mammals generally have the ability to move relatively quicker and can move over road surfaces easily, they also often become victims of road traffic. Typically three structures are used to provide wildlife with a way to safely cross a road: underpasses (Foster and Humphrey 1995; Glista et al. 2009; van der Ree et al. 2009), overpasses (Olsson et al. 2008; Corlatti et al. 2009), and culverts (Yanes et al. 1995; Woltz et al. 2008). These structures have varying levels of success depending on design, placement, and other variables (McDonald and St. Clair 2004), but are often not sufficiently monitored after construction, thus there is little knowledge about how to implement these structures effectively (Clevenger and Waltho 2005). However, if placed and implemented correctly, culverts of varying sizes seem to be the most successful method of providing the widest variety of species with a safe way to cross a road. Therefore, I recommend that these structures be considered for Route 1 and Birch Harbor Rd. in an attempt to mitigate the current impact of these roads on wildlife survival.

Circuitscape versus Least-cost Corridor

Least-cost corridor, which is based on the popular least-cost path model has been used in many corridor design projects and continues to be the leading method used by conservationists. However, other methods have also been explored with the most recent of which being the use of electrical circuit theory models (Circuitscape) to create random walk paths through a landscape. Even though the use of Circuitscape is theoretically more robust then traditional least-cost path models, it is unclear whether it is superior in reality. Only rigorous testing in the field using both models for comparison can answer this dilemma.

Although it is difficult to compare these two models within the limited scope of this study, I did notice a few key differences in their outputs. First, since Circuitscape analyzes movement in multiple directions at once, the level of detail in the output tends to be very high. Usually very detailed outputs are beneficial, but in this case it could be a limiting factor due to the input data available and the large extent of the study. It may be better to use land cover layers with a much coarser resolution then 30-m to ignore small changes in vegetation cover that may not represent reality or may be irrelevant to the animal especially since land cover layers are created using algorithms along with best guesses and are thus prone to accuracy issues. If a fine resolution input layer is to be used it may be wise to focus the study on areas with a small extent to allow for more rigorous field proofing and the easier identification of features such as bottlenecks and barriers that may only be obvious at a more local scale.

Second, it appears that Circuitscape treats fragmenting objects in the landscape such as roads more as barriers to movement than the least-cost corridor model does. It is evident in the corridor maps created by each model (see Appendix B) that for both herptiles and carnivores the corridor path created by Circuitscape fades out after crossing Route 1 whereas the least-cost corridor model ignores the road and forces a continuous corridor. This reasoning is logical since according to electrical circuit theory the electrical current can travel a long distance only if there are sufficient connections along the way, and a barrier such as a road would reduce the current flow significantly. More analysis would have to be done to confirm this assumption since this pattern could also be due to the extent of the study and the inability of Circuitscape to create a corridor over a certain length. I recommend that until the utility of Circuitscape is proven conservationists should use a mixed method approach to corridor design by using a combination of both Circuitscape and the least-cost corridor models.

Corridor Model Improvements

The final corridor paths resulting from the analysis done within the scope of this project are preliminary and will need some adjustments before becoming finalized. I determined that the models used seem to be theoretically robust and complement each other, thus the accuracy of the output can only be improved by acquiring higher quality and supplementary data. There are a few major categories of data that are absent from this study and will need to be gathered to create a comprehensive conservation plan for the Schoodic peninsula.

First, steps must be taken to improve the land cover layer even further then attempted here. Intensive ground truthing and habitat assessments across the entire peninsula are essential to provide the models with a good base data layer. One very important dataset that is missing entirely is a comprehensive survey of all vernal pools in the region. These data are essential to identify potential habitats for species that depend on the existence of vernal pools for the persistence of their populations such as the Spotted Salamander. In this analysis I was forced to assume that all forested areas had the potential for vernal pools which may not be the case. Other grids such as canopy cover, impervious surfaces, and elevation should also be incorporated into the planning of these corridors. Little is known about potential movement barriers in this area such as fences or walls. Incorporating elevation into future studies is especially important for some species such as the Northern Dusky Salamander and the Northern Two-Lined Salamander which prefer high order mountain streams and most likely would not be found in most other types of wetlands.

Second, it will be necessary to gather data on whether species prefer the same habitats for movement as they do for breeding or everyday habitation. In this study it was assumed that habitats used for breeding are the favored habitats for animal movement, but this may not be the case. The best course of action may be to consult with wildlife biologists from the region to identify preferable habitats for each species rather than just relying on the highly generalized habitat descriptions provided by Maine GAP.

Finally, additional data on species presence and movement patterns throughout the region should be gathered. This study only focused on a few properties, most of which turned out to be outside the theoretical corridor; therefore, more studies on species presence should be conducted within the preliminary corridor boundaries with some additional attention focused on threatened and endangered species. The study of ecological phenomenon such as source/sink populations are also important to incorporated into a comprehensive conservation plan. In addition, radio telemetry and/or mark and recapture projects should be implemented to determine how far and how often organisms move through the Schoodic peninsula and how successful they are at crossing barriers such as fences and roads. A wildlife corridor generated by a computer model may look good, but it does not satisfy its goal unless it actually provides the species it is meant to protect with high quality resources and opportunities.

Chapter 5

Conclusion

With development of the Schoodic region (Hancock County, Maine) imminent, it is important to conserve as many continuous areas as possible. Strategic land use planning is a good first step towards preserving landscape connectivity and hence, biodiversity. The goal of this study was to provide the FBC with knowledge of which wildlife species are present in the region, and to create a starting point for planning a functional wildlife corridor and the prioritization of conservation activities. Ultimately, a wildlife corridor will connect the tip of Schoodic Point with the protected lands surrounding Schoodic Mountain and will ensure that currently conserved lands do not become physically and genetically isolated by human activities. This study confirmed the presence of multiple species and gathered data on their habitat preferences. To support corridor analysis, I developed an improved land cover layer using the strengths of both the NLCD and GAP land cover datasets. Using both the least-cost corridor and Circuitscape models allowed me to compare the two models and suggest improvements for future studies. Further work (e.g., bird sampling, radio tracking, source/sink populations) is needed to plan and confirm the most practical and essential corridors. Land use planners, who are usually responsible for developing these plans, often do not receive enough guidance from the scientific community concerning ecological problems (Environmental Law Institute, 2003). Therefore, it is important to remember that with the help of scientific research, planners can be more effective.

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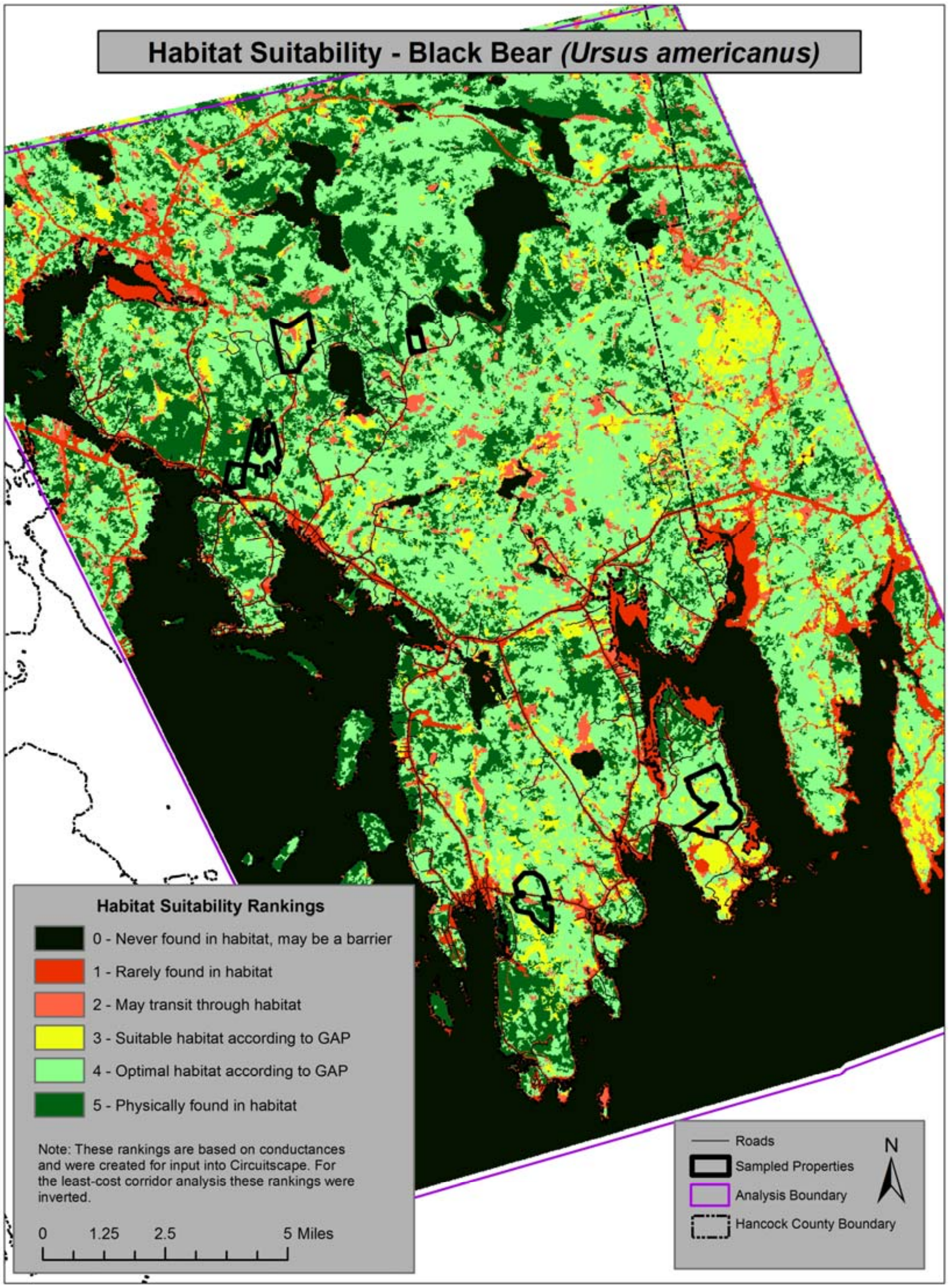
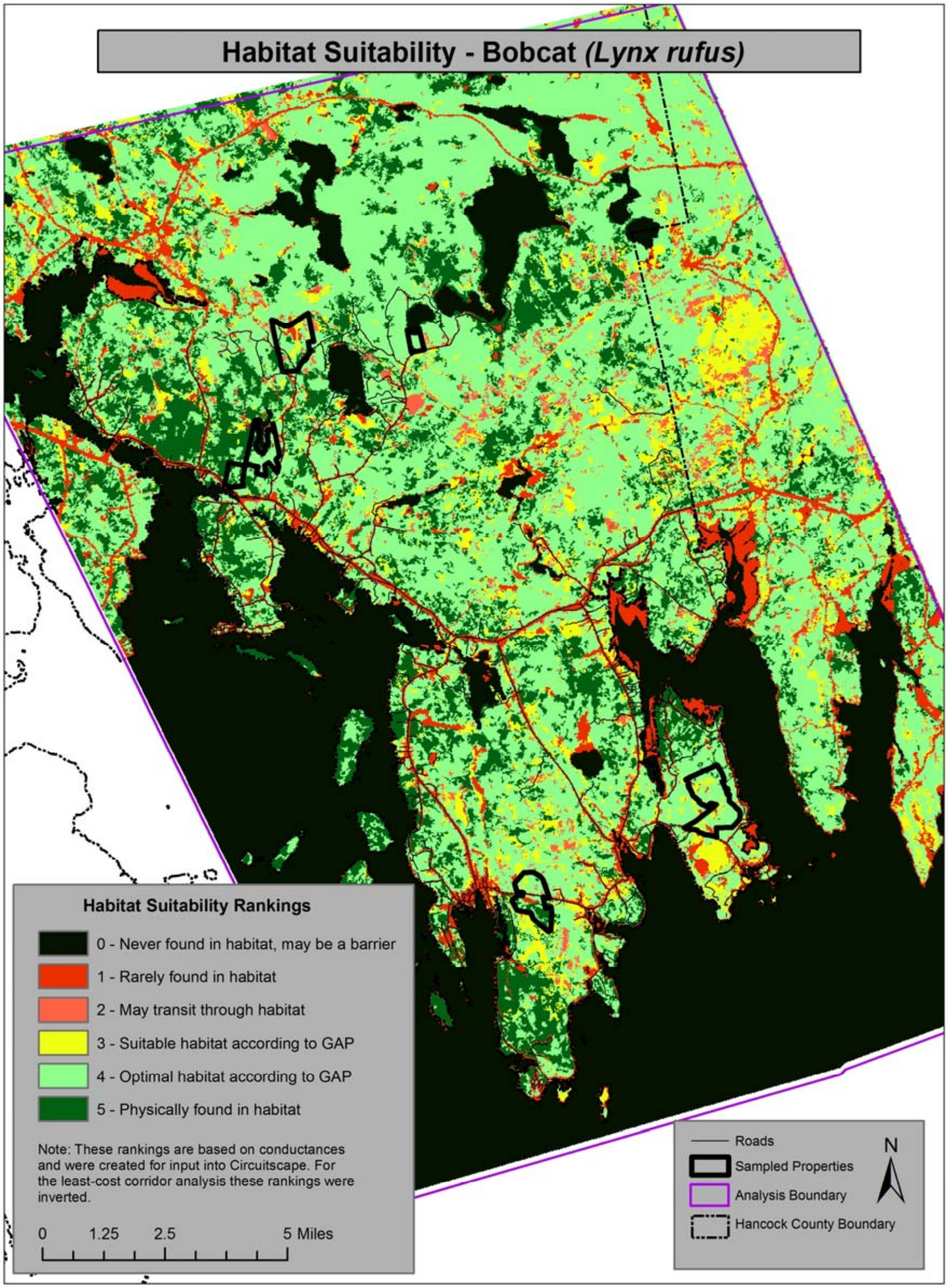
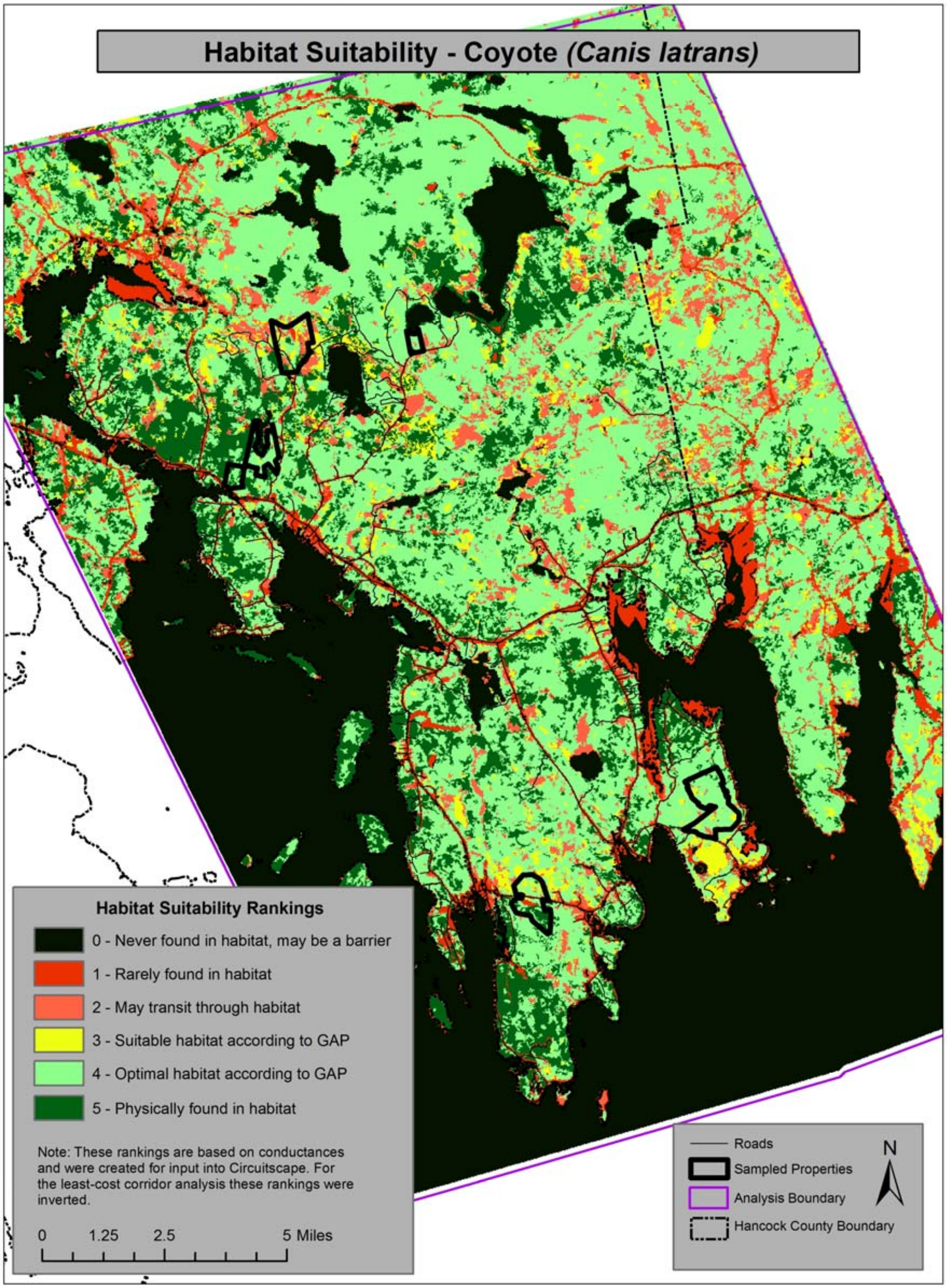
Appendix A

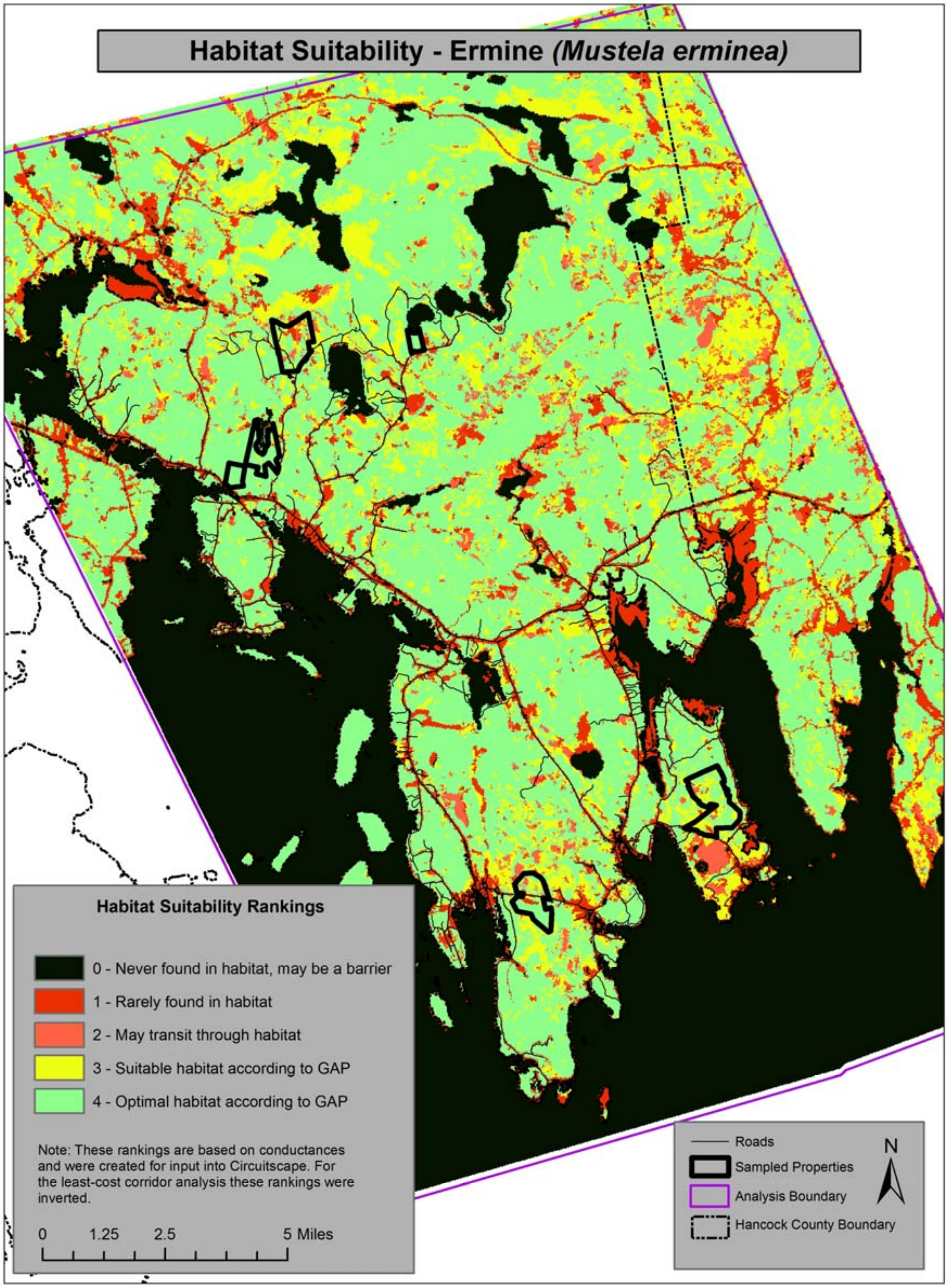
Habitat Suitability Grids for Focal Species



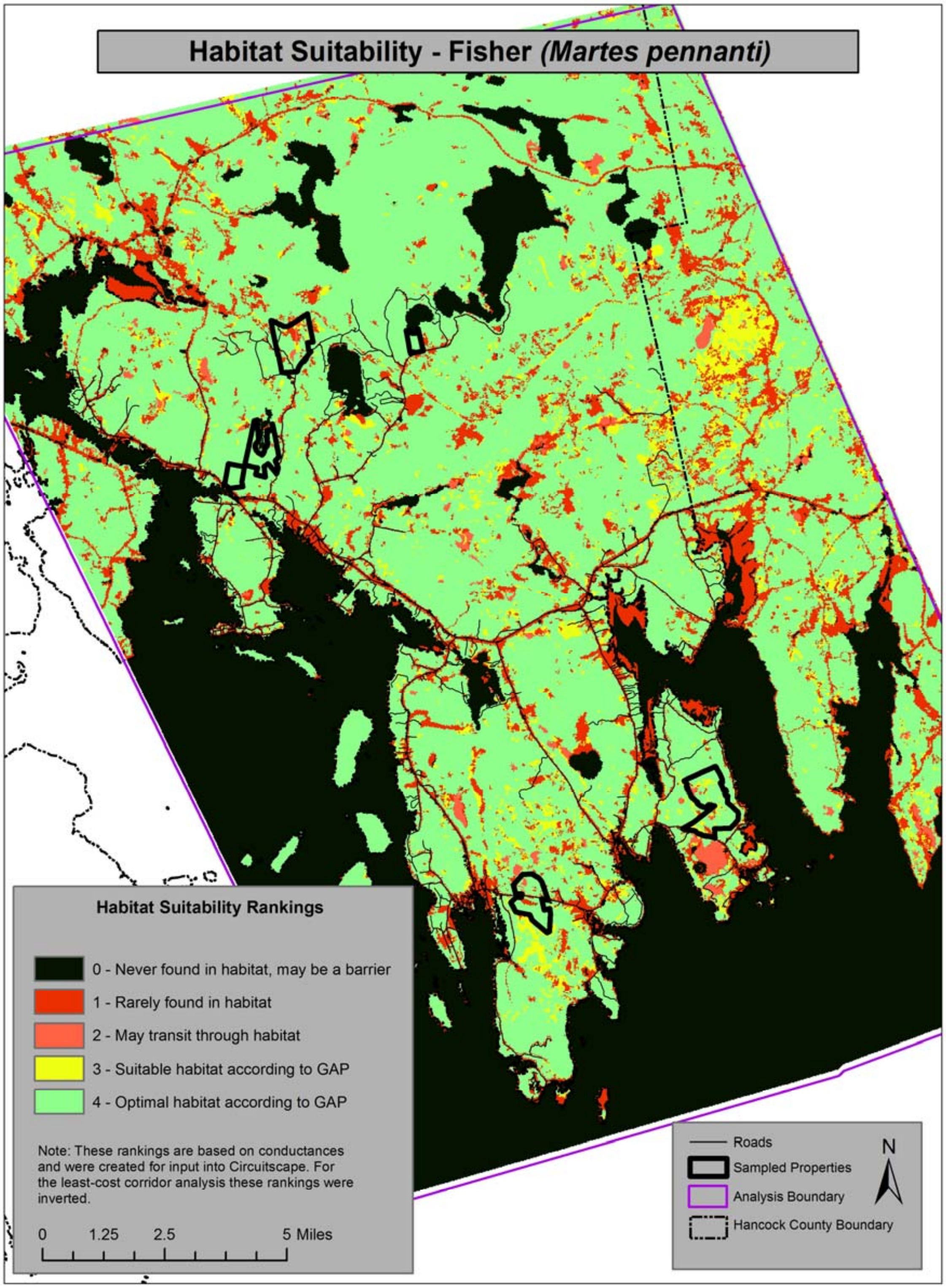


Note: These rankings are based on conductances and were created for input into Circuitscape. For the least-cost corridor analysis these rankings were inverted.

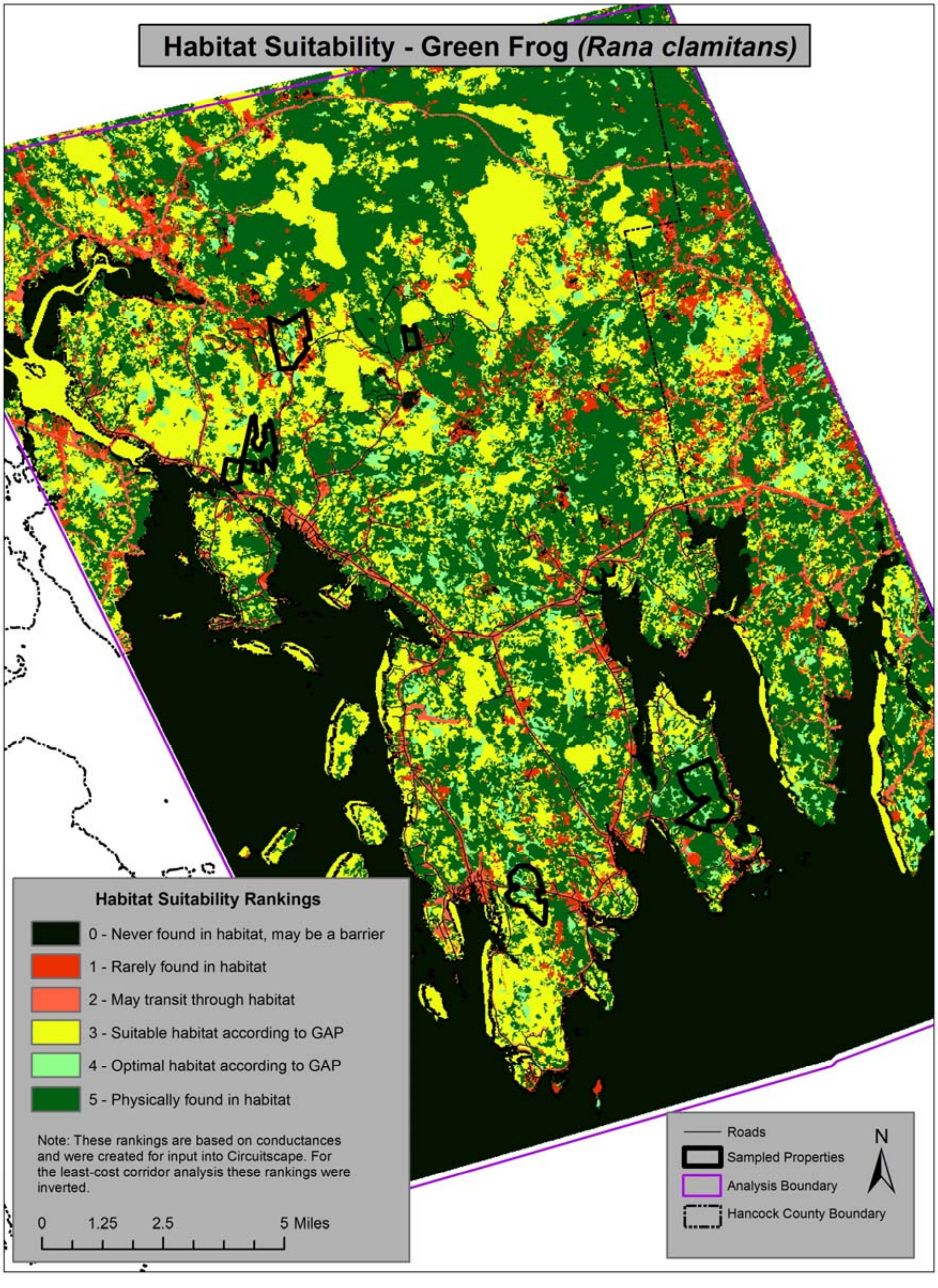

Habitat Suitability - Coyote *(Canis latrans)*
Habitat Suitability Rankings
0 - Never found in habitat, may be a barrier
1 - Rarely found in habitat
2 - May transit through habitat
3 - Suitable habitat according to GAP
4 - Optimal habitat according to GAP
5 - Physically found in habitat
Note: These rankings are based on conductances and were created for input into Circuitscape. For the least-cost corridor analysis these rankings were inverted.
0
1.25
2.5
5 Miles
Roads
Sampled Properties
Analysis Boundary
Hancock County Boundary
N

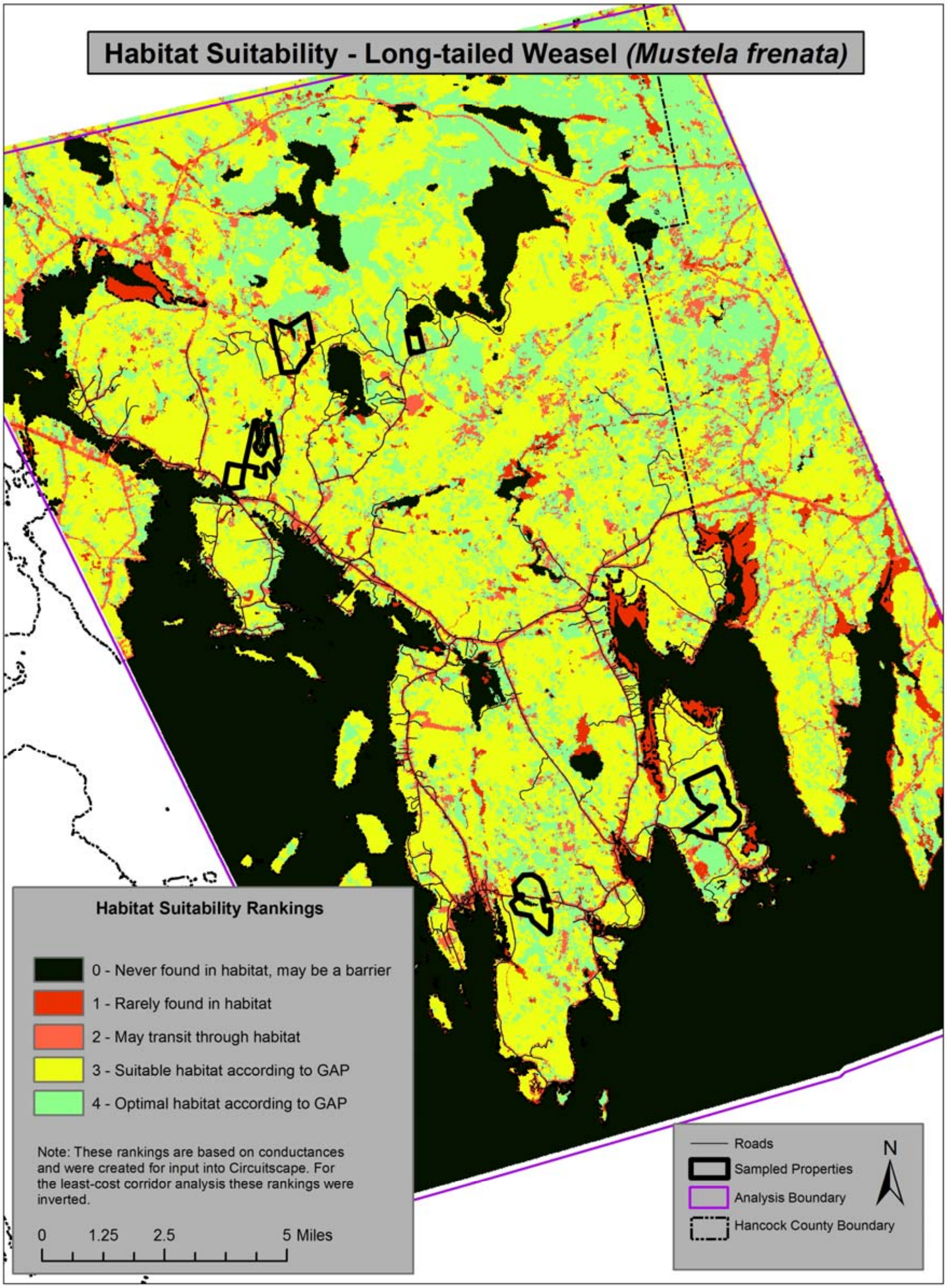


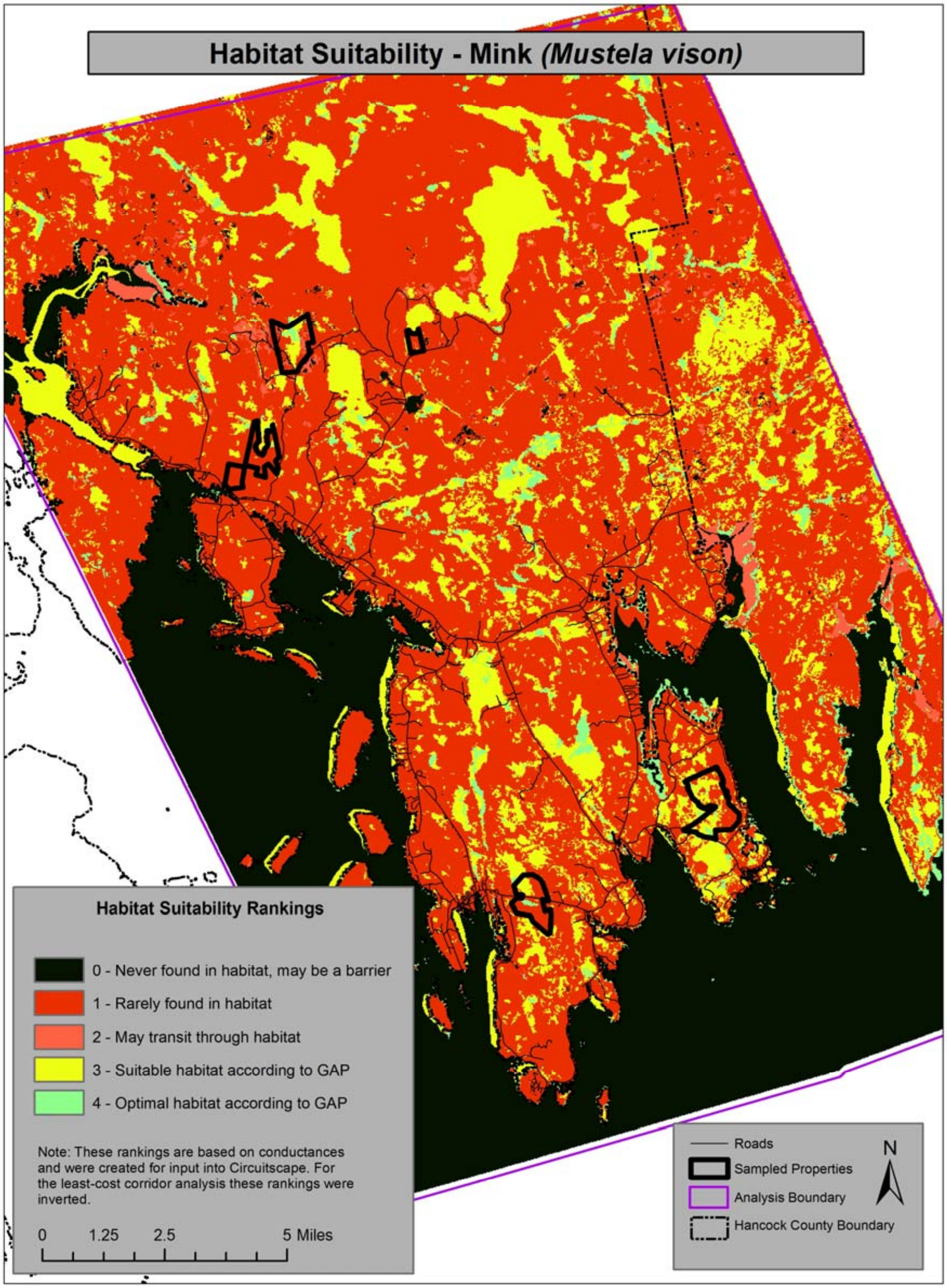
Note: These rankings are based on conductances and were created for input into Circuitscape. For the least-cost corridor analysis these rankings were inverted.



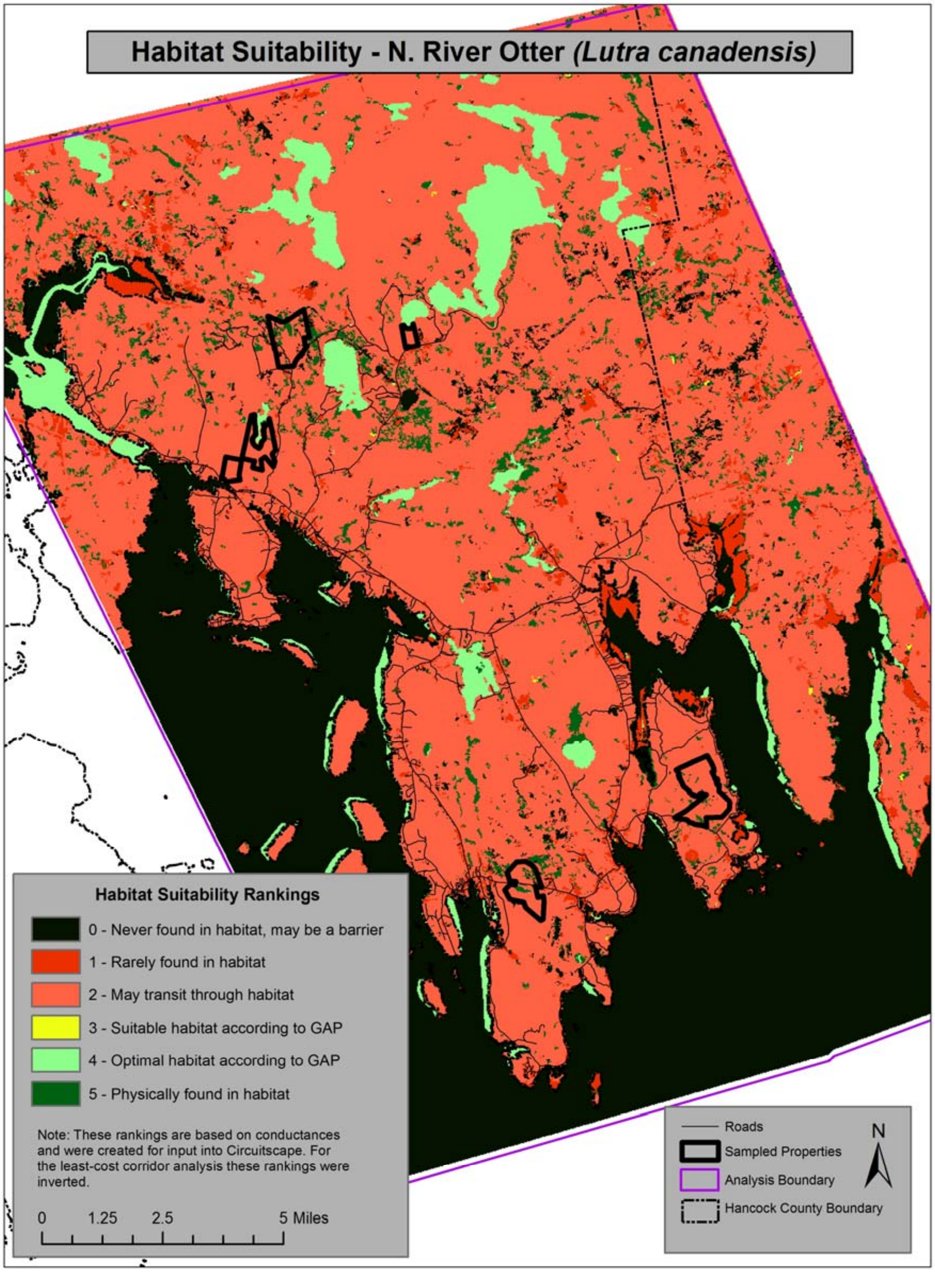
Note: These rankings are based on conductances and were created for input into Circuitscape. For the least-cost corridor analysis these rankings were inverted.

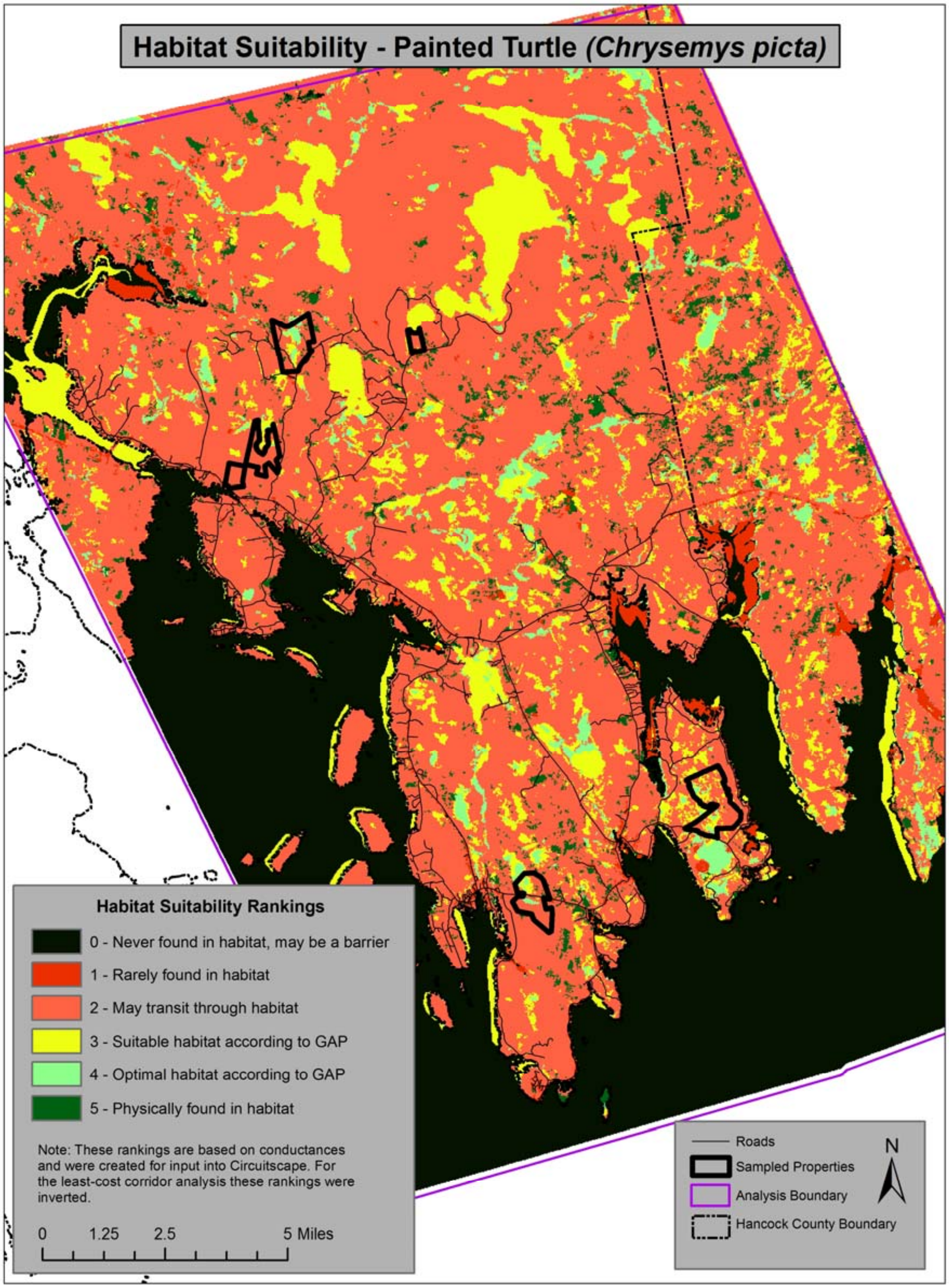

Habitat Suitability - Green Frog *(Rana clamitans)*
Habitat Suitability Rankings
0 - Never found in habitat, may be a barrier
1 - Rarely found in habitat
2 - May transit through habitat
3 - Suitable habitat according to GAP
4 - Optimal habitat according to GAP
5 - Physically found in habitat
Note: These rankings are based on conductances and were created for input into Circuitscape. For the least-cost corridor analysis these rankings were inverted.
0
1.25
2.5
5 Miles
Roads
Sampled Properties
Analysis Boundary
Hancock County Boundary
N

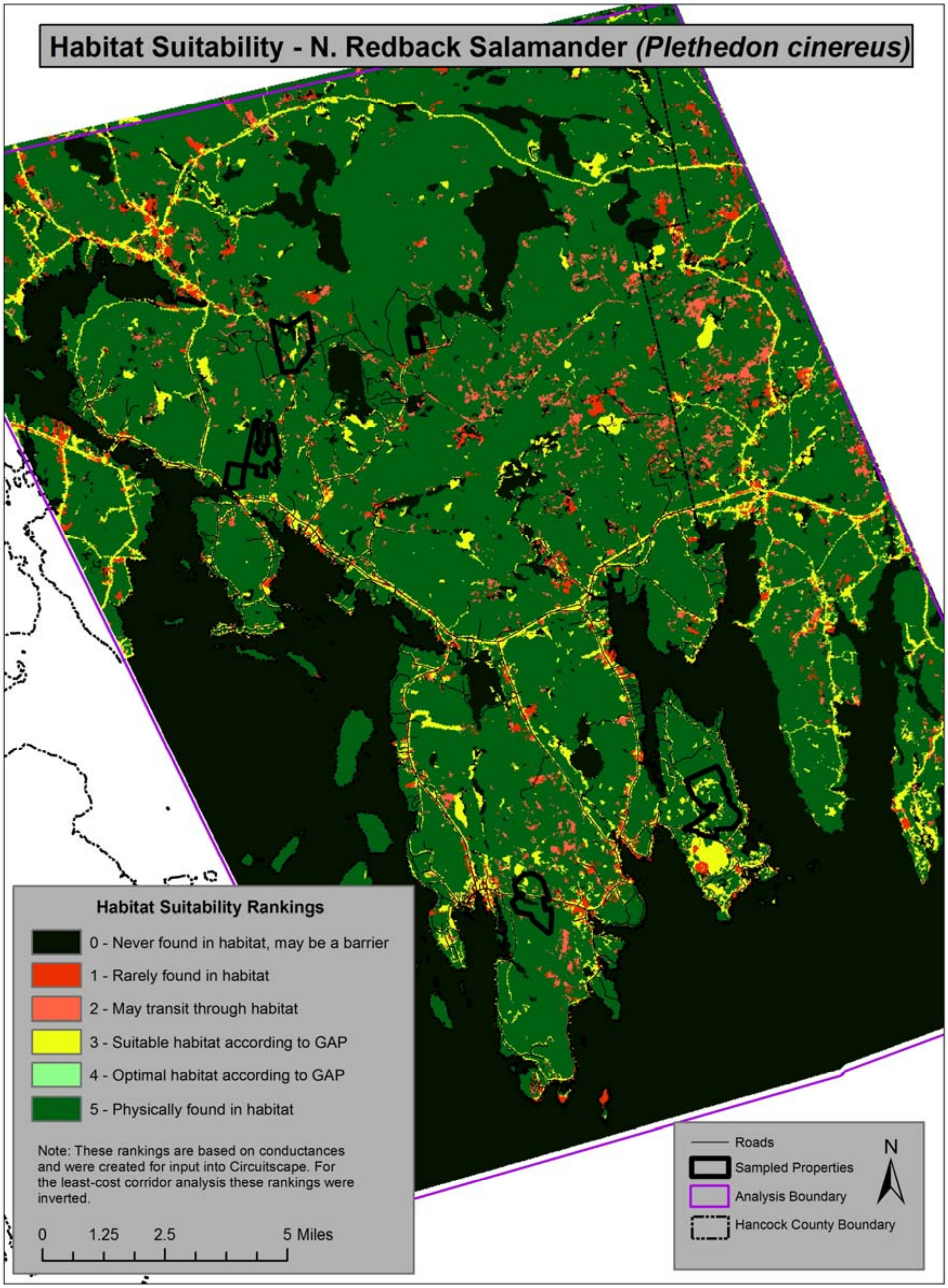

Habitat Suitability - Long-tailed Weasel *(Mustela frenata)*
Habitat Suitability Rankings
0 - Never found in habitat, may be a barrier
1 - Rarely found in habitat
2 - May transit through habitat
3 - Suitable habitat according to GAP
4 - Optimal habitat according to GAP
Note: These rankings are based on conductances and were created for input into Circuitscape. For the least-cost corridor analysis these rankings were inverted.
0
1.25
2.5
5 Miles
Roads
Sampled Properties
Analysis Boundary
Hancock County Boundary
N



Note: These rankings are based on conductances and were created for input into Circuitscape. For the least-cost corridor analysis these rankings were inverted.

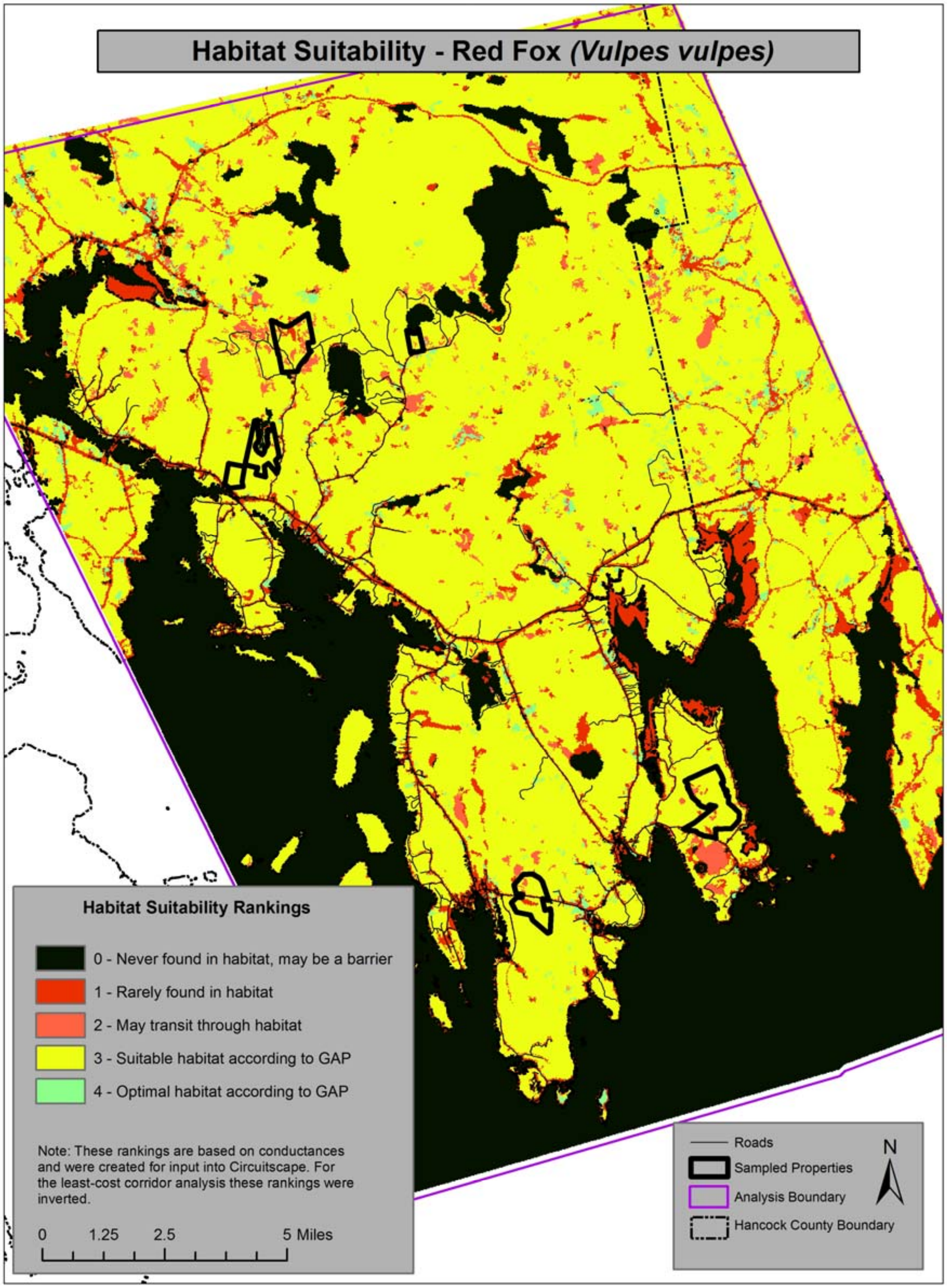

Habitat Suitability - N. River Otter *(Lutra canadensis)*
Habitat Suitability Rankings
0 - Never found in habitat, may be a barrier
1 - Rarely found in habitat
2 - May transit through habitat
3 - Suitable habitat according to GAP
4 - Optimal habitat according to GAP
5 - Physically found in habitat
Note: These rankings are based on conductances and were created for input into Circuitscape. For the least-cost corridor analysis these rankings were inverted.
0
1.25
2.5
5 Miles
Roads
Sampled Properties
Analysis Boundary
Hancock County Boundary
N


Habitat Suitability - Painted Turtle *(Chrysemys picta)*
Habitat Suitability Rankings
0 - Never found in habitat, may be a barrier
1 - Rarely found in habitat
2 - May transit through habitat
3 - Suitable habitat according to GAP
4 - Optimal habitat according to GAP
5 - Physically found in habitat
Note: These rankings are based on conductances and were created for input into Circuitscape. For the least-cost corridor analysis these rankings were inverted.
0
1.25
2.5
5 Miles
Roads
Sampled Properties
Analysis Boundary
Hancock County Boundary
N

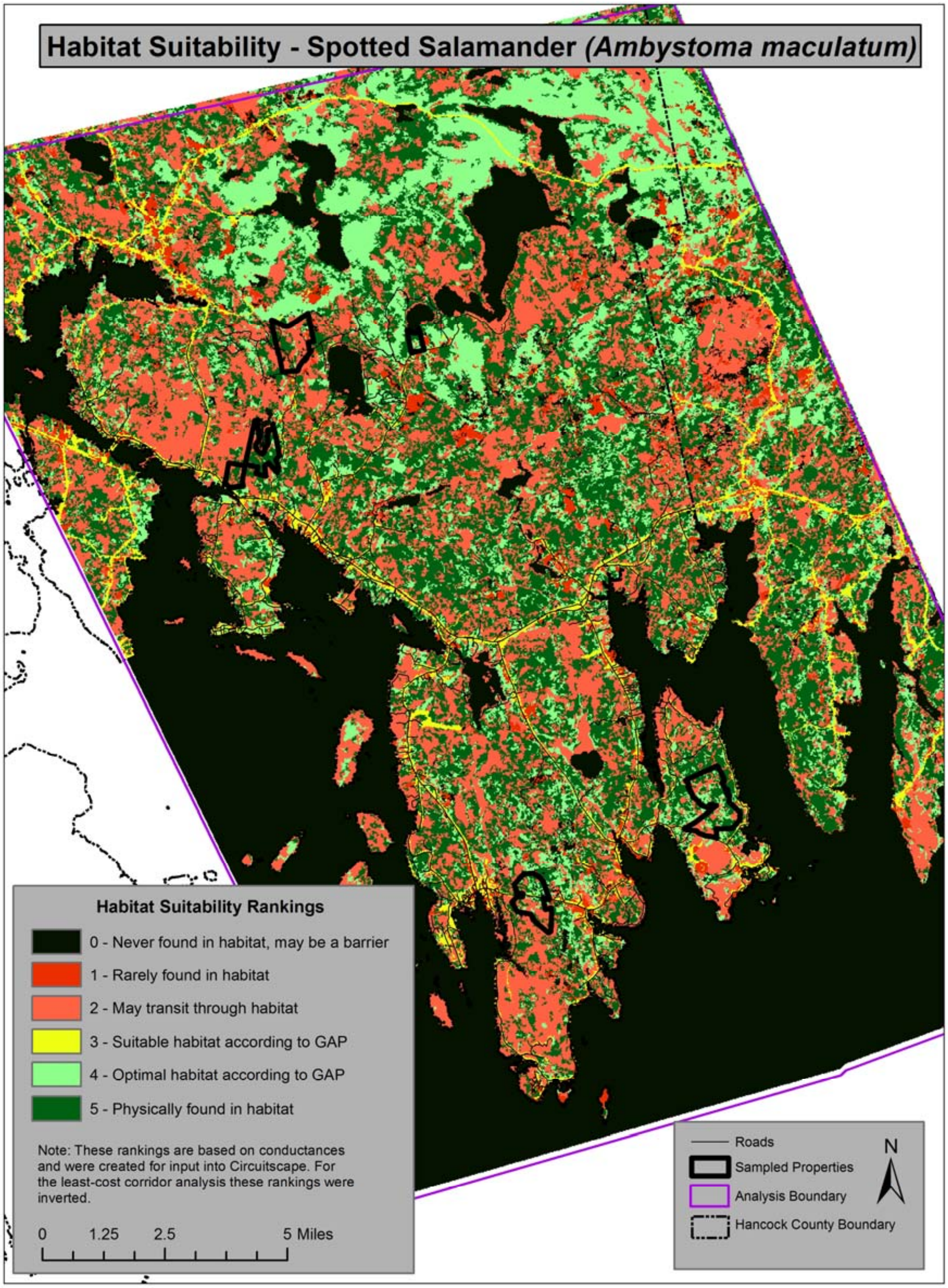


Habitat Suitability - N. Redback Salamander *(Plethedon cinereus)*

Note: These rankings are based on conductances and were created for input into Circuitscape. For the least-cost corridor analysis these rankings were inverted.



Note: These rankings are based on conductances and were created for input into Circuitscape. For the least-cost corridor analysis these rankings were inverted.



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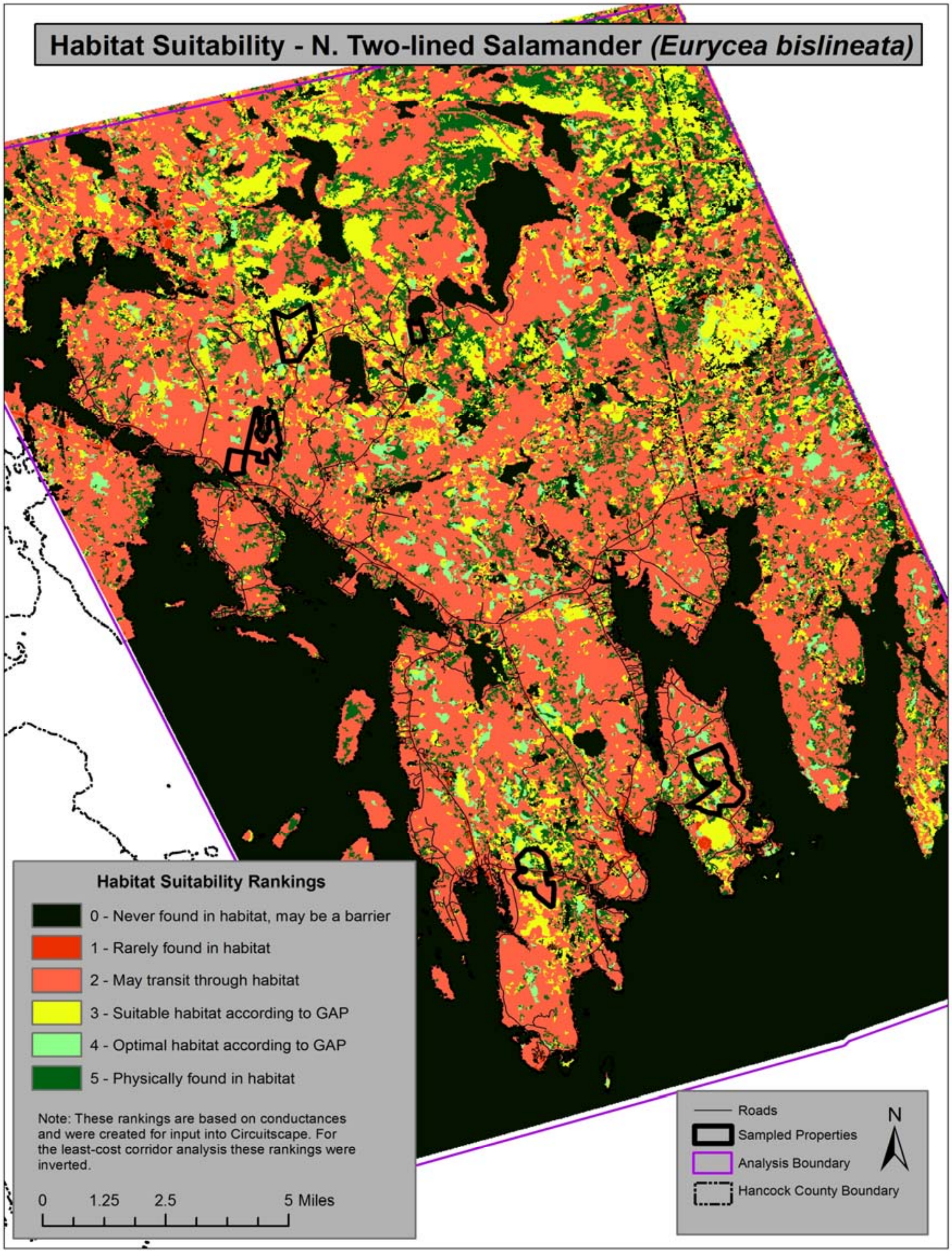
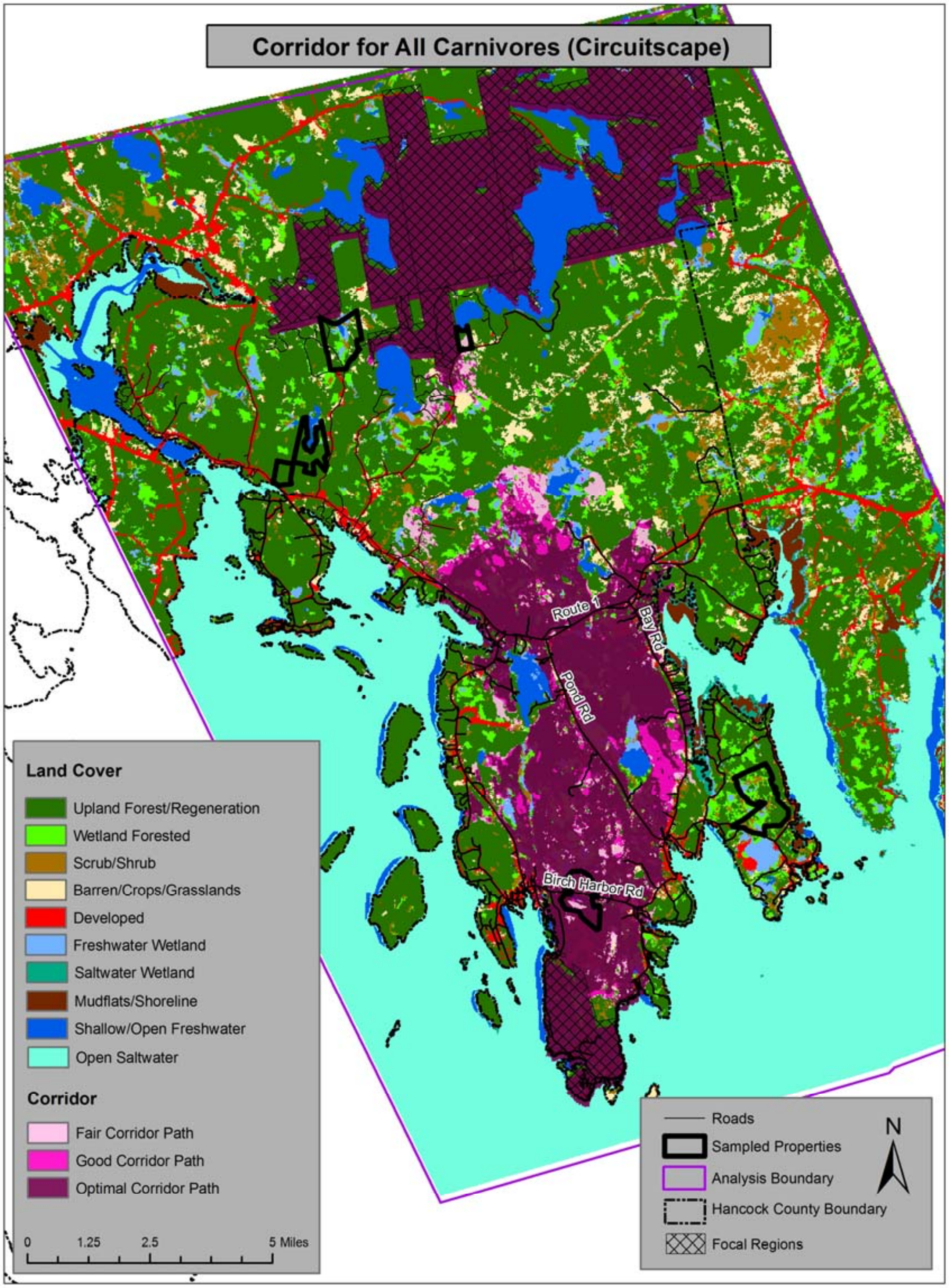
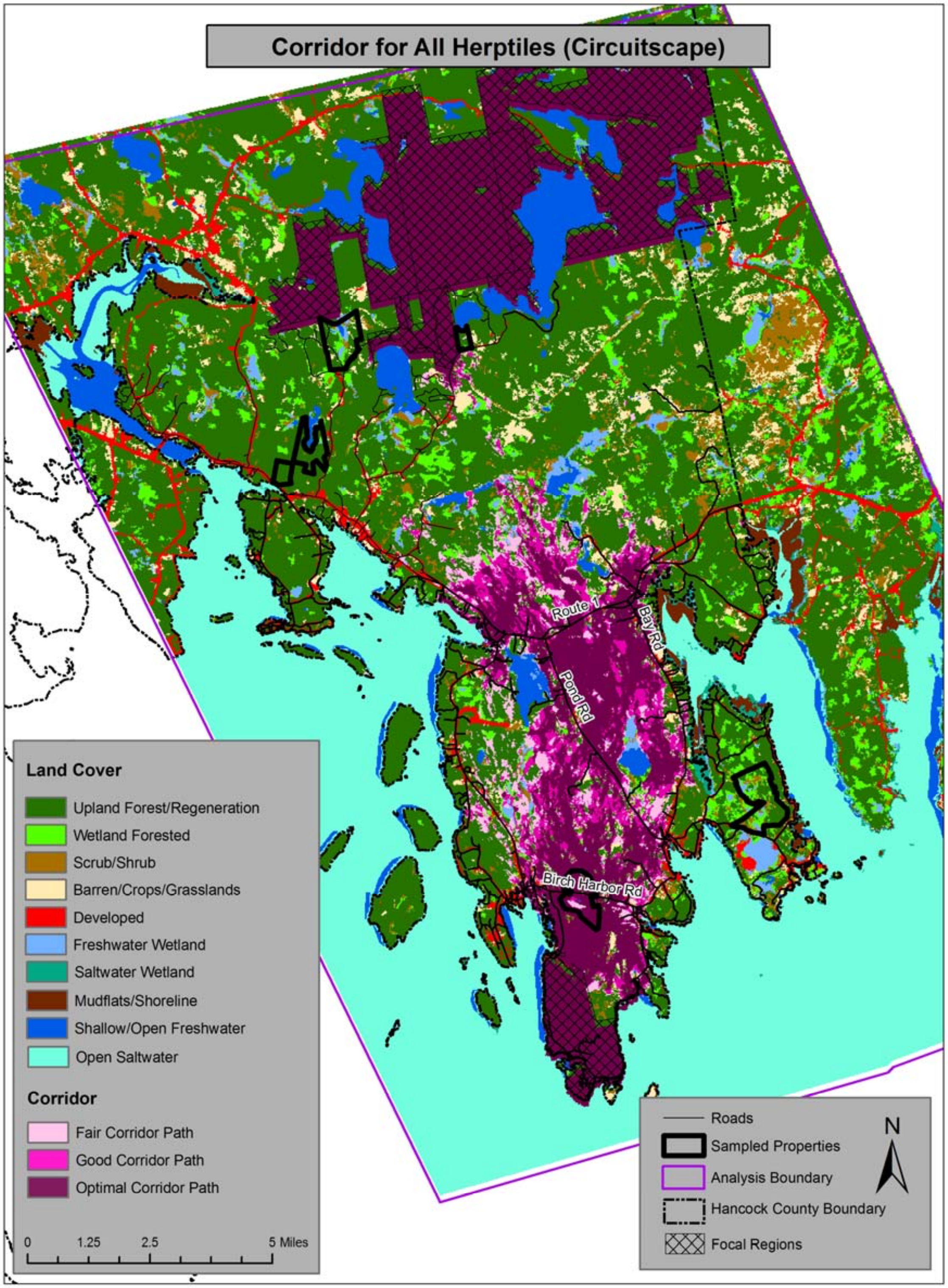
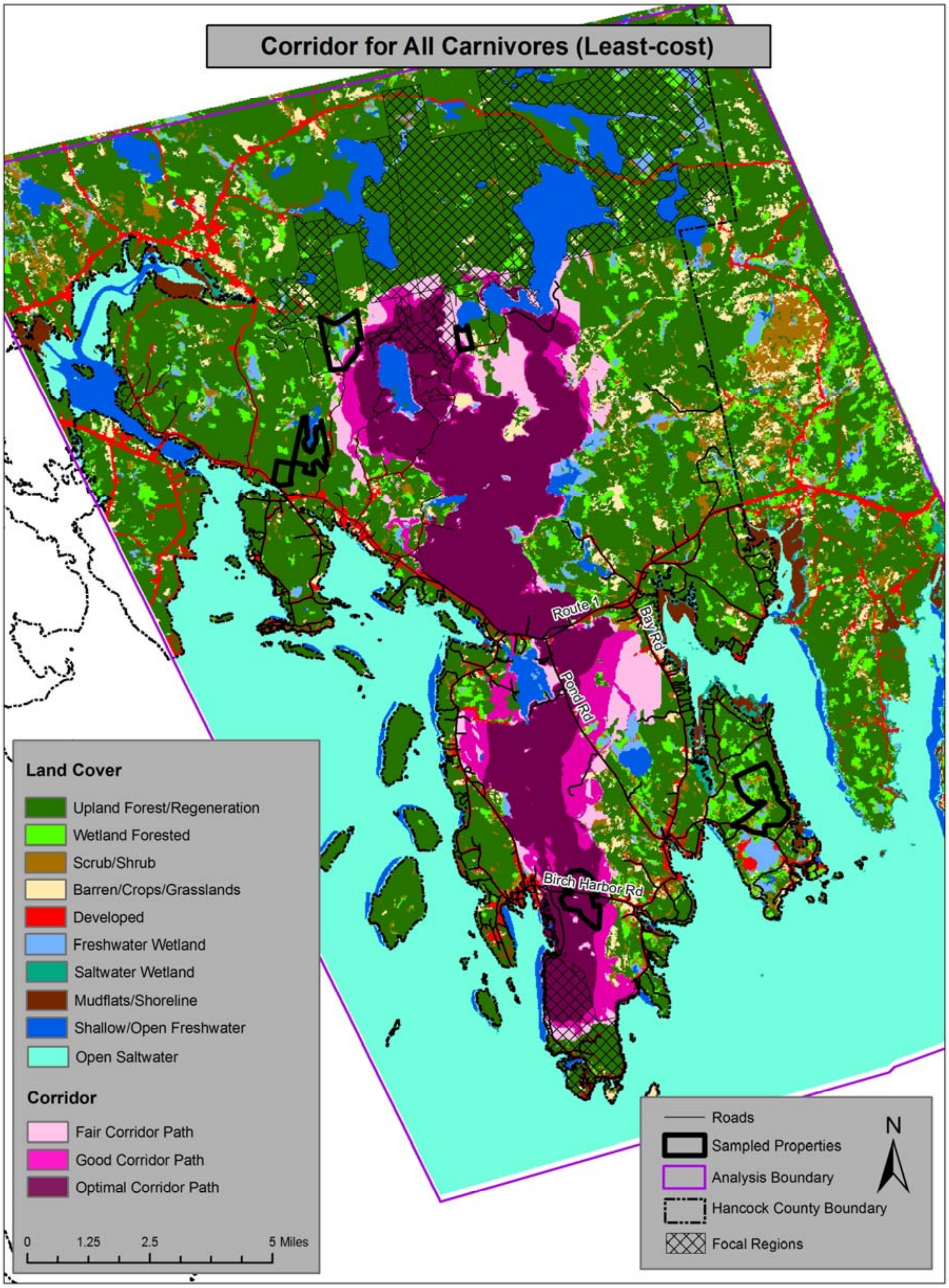

Habitat Suitability - N. Two-lined Salamander (Eurycea bislineata)
Habitat Suitability Rankings
0 - Never found in habitat, may be a barrier
1 - Rarely found in habitat
2 - May transit through habitat
3 - Suitable habitat according to GAP
4 - Optimal habitat according to GAP
5 - Physically found in habitat
Note: These rankings are based on conductances and were created for input into Circuitscape. For the least-cost corridor analysis these rankings were inverted.
0
1.25
2.5
5 Miles
Roads
Sampled Properties
Analysis Boundary
Hancock County Boundary
N

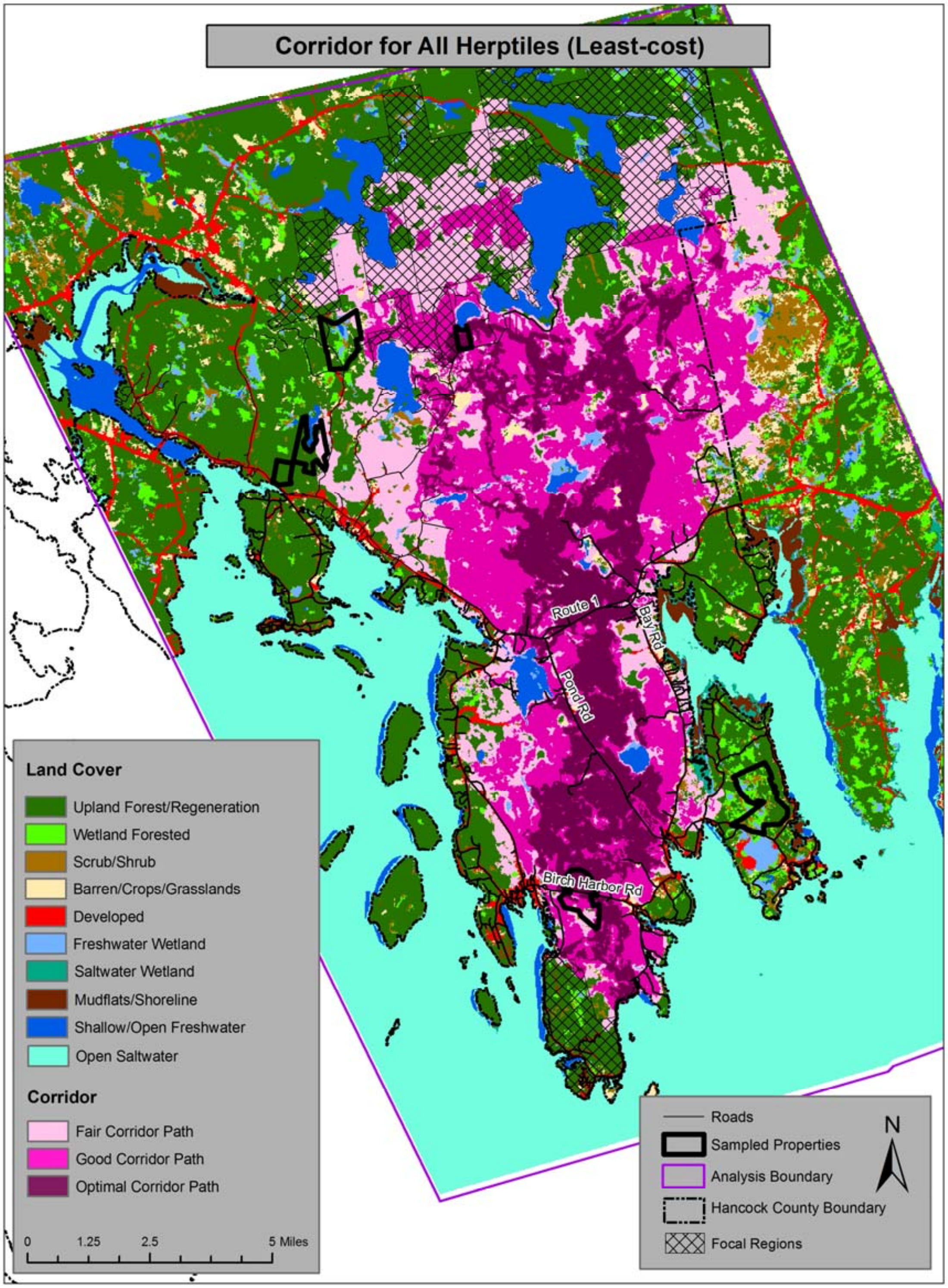
Appendix B

Circuitscape and Least-cost Corridor Maps for Herptiles and Carnivores




Corridor for All Herptiles (Circuitscape)
Route 1
Bay Rd
Pond Rd
Birch Harbor Rd
Land Cover
Upland Forest/Regeneration
Wetland Forested
Scrub/Shrub
Barren/Crops/Grasslands
Developed
Freshwater Wetland
Saltwater Wetland
Mudflats/Shoreline
Shallow/Open Freshwater
Open Saltwater
Corridor
Fair Corridor Path
Good Corridor Path
Optimal Corridor Path
0
1.25
2.5
5 Miles
Roads
Sampled Properties
Analysis Boundary
Hancock County Boundary
Focal Regions
N


Corridor for All Carnivores (Least-cost)
Route 1
Bay Rd
Pond Rd
Birch Harbor Rd
Land Cover
Upland Forest/Regeneration
Wetland Forested
Scrub/Shrub
Barren/Crops/Grasslands
Developed
Freshwater Wetland
Saltwater Wetland
Mudflats/Shoreline
Shallow/Open Freshwater
Open Saltwater
Corridor
Fair Corridor Path
Good Corridor Path
Optimal Corridor Path
0
1.25
2.5
5 Miles
Roads
Sampled Properties
Analysis Boundary
Hancock County Boundary
Focal Regions
N


Corridor for All Herptiles (Least-cost)
Route 1
Bay Rd
Pond Rd
Birch Harbor Rd
Land Cover
Upland Forest/Regeneration
Wetland Forested
Scrub/Shrub
Barren/Crops/Grasslands
Developed
Freshwater Wetland
Saltwater Wetland
Mudflats/Shoreline
Shallow/Open Freshwater
Open Saltwater
Corridor
Fair Corridor Path
Good Corridor Path
Optimal Corridor Path
0
1.25
2.5
5 Miles
Roads
Sampled Properties
Analysis Boundary
Hancock County Boundary
Focal Regions
N