Natural Ecosystem Connectivity across the Chignecto Isthmus - Opportunities and Challenges

May 2005 (with revisions June 2007)

By:

Alexander MacDonald
CPAWS Nova Scotia Chapter

Roberta Clowater
CPAWS New Brunswick Chapter

A Collaborative Project of CPAWS New Brunswick and CPAWS Nova Scotia

CPAWS
CANADIAN PARKS AND WILDERNESS SOCIETY

Background on the Canadian Parks and Wilderness Society

The Canadian Parks and Wilderness Society (CPAWS) is a national non-profit charitable organization. CPAWS is dedicated to safeguarding Canada's biodiversity through parks, protected areas and similar natural areas, coupled with the responsible management of the lands and waters that surround those protected spaces. We do this because our country's truly wild spaces should last forever….

CPAWS was founded in Calgary in 1963, when it was known as the National and Provincial Parks Association, and has since grown to include 13 chapters and approximately 15,000 members nation-wide. Our efforts to protect Canada's wilderness now extend from coast to coast to coast.

CPAWS Nova Scotia Chapter came into existence in 1994 with a mandate to pursue land-based and marine wilderness conservation work in Atlantic Canada. In 2003, CPAWS Newfoundland and Labrador Chapter was established. CPAWS Nova Scotia Chapter continued wilderness conservation work throughout the Maritime Provinces until fall 2004, when the CPAWS New Brunswick Chapter evolved from the long-standing New Brunswick Protected Natural Areas Coalition (NBPNAC). CPAWS Nova Scotia Chapter continues to focus on wilderness conservation on land and sea in Nova Scotia and Prince Edward Island.

The New Brunswick and Nova Scotia Chapters of CPAWS currently work together to address wilderness issues of a trans-boundary nature, such as the conservation of the endangered Acadian Forest ecosystem and the conservation of ecosystem connectivity within that Acadian Forest. The following report is the first published product of the important relationship between the New Brunswick and Nova Scotia Chapters, one that we intend to have relevance to wildlife managers, policy makers, planning specialists, residents and grassroots conservationists in both provinces.

Photo credit - Ian Smith, Cape Chignecto Provincial Park, NS.

Acknowledgements

The authors would like to acknowledge the generous support of The EJLB Foundation in making this project a reality.

Many thanks are extended to the numerous local residents, government representatives, conservationists, scientists and naturalists who provided advice essential to assessing conservation opportunities and challenges on the Chignecto isthmus. We appreciate the time these people took to share with us their firsthand knowledge of the area and allow us to see things from their perspective.

Additional thanks are offered to The Wildlands Project, the Wildlife Conservation Society Canada and the Nature Conservancy of Canada for laying the groundwork and providing a regional context in which to place this project.

Finally, we acknowledge the assistance of the New Brunswick Department of Natural Resources, the Nova Scotia Department of Natural Resources, the New Brunswick Eastern Habitat Joint Venture Partnership, the Nova Scotia Geomatics Centre, the Wildlife Conservation Society (WCS) Canada, the Municipality of the Town of Amherst, Heritage Gas and the Municipality of Cumberland County for providing digital data and maps relevant to our analysis of geographic information.

Many thanks are also extended to Kermit deGooyer for his services and patience in manipulating and processing our digital data, and to Graham MacDonald and Steve Reid for sourcing and preparing GIS data and maps whenever we were in a bind. Also, Cheyenne Lawrie is thanked for ideas and editorial flare she contributed to the recommendations regarding the proposed Missaguash/Amherst East Wildlife Management Area. Gillian Woolmer of WCS Canada went above and beyond the call of duty by extracting Chignecto-specific maps for us from a larger regional mapping profile of the Northern Appalachians. We also appreciate the contribution of the following reviewers, who took the time to provide comments and input on the first drafts of this report: Dr. Matt Betts, Dennis Brannen, Dr. Graham Forbes, Cheyenne Lawrie, Karen Potter, Dr. Justina Ray, and Steve Reid.

Cover satellite image of the Chignecto isthmus courtesy of NASA World Wind program (http://worldwind.arc.nasa.gov/).

For more information on this project, or any other CPAWS initiative in the Maritimes, please contact:

CPAWS-NS: 902-446-4155, coordinator@cpawsns.org or www.cpawsns.org on the web; and
CPAWS-NB: 506-452-9902, cpawsnb@nb.sympatico.ca or www.cpawsnb.org on the web.

Executive Summary

Between November 2004 and May 2005, the New Brunswick and Nova Scotia Chapters of the Canadian Parks and Wilderness Society assessed the opportunities and challenges involved in conserving 'ecosystem connectivity' on the Chignecto isthmus, a narrow land bridge between the two Maritime Provinces. Existing scientific, geographic and historical information was used to conduct a preliminary identification of challenges and opportunities in this area, coupled with the use of local knowledge to provide a relevant context for our efforts. The analysis was focused on the areas east of Shemogue and Sackville, New Brunswick, and west of the Shinimicas River and Nappan, Nova Scotia.

Ecosystem connectivity refers to a landscape-level approach to maintaining suitable habitats and functional movement corridors for flora and fauna. A group of focal species was used as a framework for assessing connectivity on the Chignecto isthmus, including moose, black bear, Canada lynx, American marten, northern flying squirrel, barred owl and interior forest bird species.

To understand the local challenges and opportunities related to habitat connectivity for these species, land-use and land cover information was compiled using GIS (geographic information system) analysis. The interpretation of this geographic information shows that habitat fragmentation by roads, forest harvesting, human development and small-scale agriculture may interrupt connectivity for a number of these species. The assessment was informed through conversations with more than forty-five local residents and stakeholders, who helped identify some of the challenges and opportunities discussed.

Identified challenges include:

- Community sprawl around the communities of Moncton and Shediac (NB) and Truro and Pictou (NS), has the potential, if it proceeds, to pinch off the entire isthmus from the anchor natural areas on either end of the land bridge;
- A number of highways and roads cross the breadth of the isthmus from north to south, creating potential barriers to wildlife movement, and fragmenting the landscape;
- The isthmus landscape is dominated by private land, which has lead to an uncoordinated approach to land use (forestry, agriculture, settlement) and a resultant ecosystem that is broken into fairly small patches of natural habitat;
- There is a dearth of ecological knowledge related to ecosystem connectivity issues, including a lack of knowledge about local species distribution and movement, and lack of coordination between NB and NS with respect to wildlife monitoring and management, outside of federally listed species at risk.

The Chignecto isthmus benefits from a myriad of conservation initiatives, predominantly around the internationally significant wetlands in the southern Bay of Fundy portion of the isthmus. This existing conservation work provides a number of interesting opportunities to extend stewardship to the forested portion on the northern side, including:

- A pioneering group of woodlot owners on the isthmus are being certified according to the standards of the Forest Stewardship Council, under the auspices of an FSC certified forest manager;
- Several land trusts and conservation organizations are active on the isthmus, and have developed productive working relationships with landowners and governments - these include Ducks Unlimited, the Nature Conservancy of Canada, the NB Community Land Trust, and the Chignecto Agro Club of the Soil and Crop Improvement Association;
- A collection of conserved lands have been designated to meet various objectives on the isthmus, including the Chignecto, Cape Jourimain and Tintamarre National Wildlife Areas, Amherst Shore Provincial Park, the Hackmatack and Round Lakes Game Sanctuary and the North Tyndal Protected Water Area. All of these areas could be cornerstones of an ecosystem connectivity network on the isthmus;
- Proposed conservation zones, such as the Missaguash/East Amherst Wildlife Management Area, and proposed conservation stewardship initiatives, such as the Fundy UNESCO Biosphere Reserve, could help increase on-the-ground conservation attention on the isthmus.

As a result of this exercise, the authors have identified areas of high conservation priority to potentially facilitate ecosystem connectivity across the isthmus, and best options for connectivity routes. These options are based on available data, maps produced for this project, and local knowledge. The options do not incorporate information on the quality or abundance of high quality habitat available on the isthmus, as this level of data was not available. Most notable among these high priority sites are lands located along the northern portion of Highway 16 in New Brunswick, which represent some of the largest patches of habitat in the border area, and are a critical part of the projected connectivity route.

CPAWS NS and CPAWS NB make several suggestions for next steps toward a new cooperative conservation venture - one that explores cross-border conservation and connectivity issues in more detail, and weaves together the conservation areas and initiatives that currently exist. As a first step, CPAWS NB and CPAWS NS intend to organize a steering committee to oversee such a cooperative project, and use the results of this phase of the project to spur collaborations and further research.

Table of Contents

1. Introduction

1.1 Project Objective

As part of our interest in broader biodiversity conservation in the Maritimes, CPAWS NS and CPAWS NB are concerned about the Chignecto isthmus - the narrow land bridge is all that connects Nova Scotia terrestrially with the rest of Canada. We have questioned whether *natural ecosystem connectivity* is at stake on the isthmus - natural ecosystem connectivity referring to the innate ability of wild plants and animals to migrate, disperse and exchange genetic material across a landscape composed of a variety of contiguous ecosystems and habitats.

Currently, several roads and highways cut across the width of the isthmus (see Figure 1). Through our discussions with people in the region, it appears that little if any research has been done to determine if these are acting as barriers to wildlife movement, or how regional ecosystem processes and connectivity may be impaired by development patterns on the isthmus.

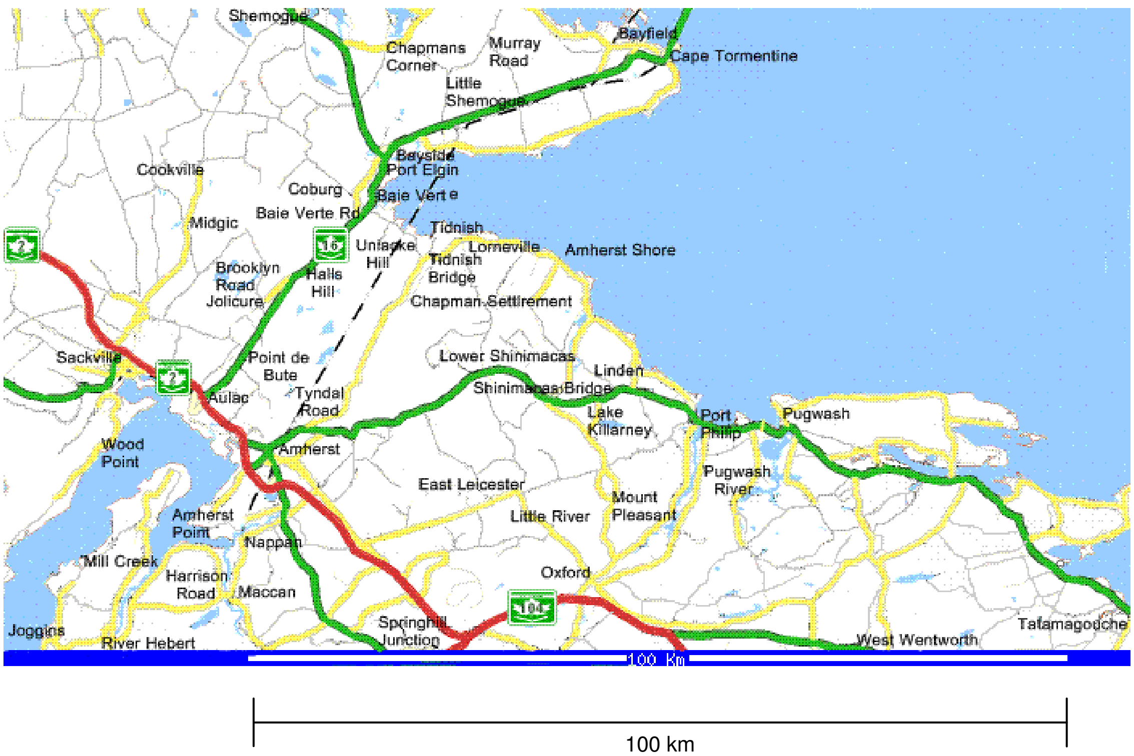


Figure 1. Map of major roads and communities on the Chignecto Isthmus (1:500,000)
*(Adapted from multi**map** online, 2005 AND Data Ireland, Ltd.)*

A myriad of current and historic factors appear to interrupt habitat connectivity across the isthmus, some of which are long-term and cannot practically be mitigated, for example, development of major inter-provincial highways. Likewise, the quality of forested habitats on the isthmus is variable based upon a wide range of uses of the forests over 400 years, during which time local abundance and diversity of wildlife have undoubtedly fluctuated. The over-riding challenge will be to find the best opportunities for connectivity based upon habitats currently present and those that may one day become suitable (for example, mid-successional mixed wood stands that have been harvested).

Based upon our knowledge of conservation issues in the Maritimes, we are concerned that if human expansion, habitat alteration and conversion and infrastructure development proceed without considering connectivity, natural ecosystem processes across the Chignecto isthmus could be severely weakened or even lost. Multi-stakeholder organizations such as the Two Countries, One Forest (2C1Forest) network have raised similar concerns, questioning the implications for biodiversity in the Northern Appalachians-Acadian region (i.e., northern New England and the Maritimes) if no action is taken to maintain and enhance connectivity across the isthmus. Finally, many biologists, conservationists and members of local Chignecto-region non-government organizations with whom we have discussed the foundations of this project have concurred with our objectives.

Our intent with this project is to evaluate existing information and assess the potential to conserve natural ecosystem connectivity across this narrow land bridge, with a special focus on maintaining and promoting wildlife movement between the provinces. Our assumption is that if a wide range of wildlife species are able to find habitat that allows them to move through or live on the isthmus, the likelihood increases that other ecosystem processes will also be conserved. This is the first phase of a project that will continue to develop and become more comprehensive over time.

Another objective is to engage wildlife managers, planners, academics, hunters and trappers and local residents in thinking about the isthmus as a continuous set of inter-connected ecosystems, existing across political boundaries and jurisdictions. Our overarching goal is to safeguard regional biodiversity by maintaining crucial links with neighbouring regions.

1.2 Methodology

The project ran from November 2004 to June 2005. Our approach in this initial phase of the project included reviews of existing biological, historical and geographical information relating to wildlife populations, land-use patterns, unique habitats and species, existing conservation areas and initiatives and priority areas for conservation on the Chignecto isthmus. An analysis of the quality of habitats or the abundance of various types of habitats on the isthmus was beyond the scope of this project. The following steps were taken:

- We conducted interviews and meetings with over 45 local residents and contacts to learn about local wildlife populations:
    - We collected information on the following themes: wildlife known to be present on the isthmus; known examples of wildlife movement between the provinces; known areas that are most important to wildlife movement across the isthmus; potential obstacles to wildlife movement across the isthmus; unique habitats that

should be conserved; current or past conservation efforts in this area; the relevance of this project to local communities; ecosystem processes that may be being interrupted on the isthmus; and, advice on the boundaries most suitable as our project area.

  - Interviewees included regional university faculty, representatives of local municipalities and planning commissions, provincial wildlife, habitat and Crown lands management programs, the Canadian Wildlife Service Habitat Program, Environment Canada's Eco-Gifts program, Bird Studies Canada, the Nappan Project, the Cumberland County River Enhancement Association, the Atlantic Canada Conservation Data Centre, volunteers with the Nature Conservancy of Canada - Atlantic, the NB Community Land Trust, as well as local conservationists, landowners, hunters, trappers and independent biologists.

- We reviewed project reports, scientific papers, case studies, examples of similar projects, locally-based theses from NS and NB pertaining to connectivity, habitat fragmentation, habitat requirements for "focal species," wildlife presence/movement and gene-flow, wildlife corridors and focal species-based landscape conservation.
- We reviewed and compiled information on existing conservation/protected areas and initiatives within the project area.
- Based upon our reviews of information, interviews and meetings, we assembled a group of "focal species" of particular concern on the isthmus: moose, marten, northern flying squirrel, Barred Owl, river otter, black bear and lynx. We used this group of species, each with specific dispersal or habitat requirements, as our basis for identifying the types of habitats needed to maintain connectivity on the isthmus.
- We performed three field visits to the project area to follow-up on suggestions of priority areas for conservation. The field visits included a tour of a working woodlot on the northern portion of the isthmus, in addition to drives along the two major, perpendicular roadways along the isthmus: Trans-Canada Highway 16 (NB) and the Tyndal Road to Tidnish Bridge (NS). More extensive field work was not a part of this scoping phase of the project.
- We compiled maps and information layers for analysis using GIS (geographic information systems) software, MapInfo™ and ERDAS Map Viewer™. Maps and information layers included:
  - 1999 and 2000 LANDSAT projections of project area. The 2000 projection, while available, was not used because of problems with cloud cover masking part of the image.
  - Land cover, hydrography and roads for project area in NS and NB; Canada Land Inventory land-use suitability layers for ungulate habitat, wetlands, agriculture and forestry, spanning the project area; Crown lands and protected areas in NS and NB; Eastern Habitat Joint Venture conservation areas in NS and NB; and, the NS significant old growth and unique forests layer.
- We conducted a GIS analysis using the roads layers for NS and NB. Buffers of 200 and 600m were placed around all roads to identify patches with relatively low human influence. The resulting patches were then projected onto existing information layers to determine the amount of overlap and to identify priority areas (based on land-use suitability and land cover) for conservation for chosen focal species.

1.3 The Setting

The Chignecto isthmus is a narrow, 21km stretch of land that joins the province of Nova Scotia to the province of New Brunswick and the North American continent. The isthmus affords Nova Scotia recognition as a peninsula, as it effectively separates the warm waters of the Northumberland Strait (via Baie Verte), to the north, from the cold, powerfully tidal waters of Chignecto Bay (via the Cumberland Basin), to the south. Between 120,000 and 70,000 years ago the isthmus was part of the ocean floor, until a global cooling trend brought on the Wisconsonian glaciation[1], locking the landmass beneath a solid ice mass until about 14,000 years ago[2]. The isthmus began to resemble its current form at that time, as the depressed landmass rebounded with the weight of the glacier removed, and eventually came to sit at a high elevation.

Between 10,000 and 4,000 years ago, the isthmus became thickly forested, first with boreal species and then pines, hemlocks and hardwoods, until gradually rising sea levels depressed the landmass again, and flooded much of the forest under the sea, eventually forming the extensive salt marshes currently present[3]. The geology underlying all of this activity comprises carboniferous sediments of Pennsylvanian origin, with bedrock in the Pictou Group (conglomerate, sandstone, shale and some limestone) found on the Nova Scotian side of the isthmus[4], complemented by the grey sandstone, conglomerate, shale and red sandstone of the Petitcodiac Group in New Brunswick[5].

Today, the entire area is below 90m in elevation and is characterized by influences of both continental and maritime climates: cold winters with frequent precipitation; warm summers with high humidity; and spring and fall seasons with ample rainfall and moderate to low temperatures[6]. The southern portion of the isthmus lies within the 'Fundy fog belt' and the open landscape is prone to high winds blowing in off the Cumberland Basin and Bay of Fundy. The north-westerly winds blowing off the Northumberland Strait on the northern portion of the isthmus also tend to be intense during the winter, but fog is minimal[7] and annual precipitation is lower than elsewhere in the region due to the sheltering effect of land formations to the south[8]. Average climate data between 1971-2000 for Sackville, New Brunswick, include a yearly average temperature of 5.5°C, a daily average temperature of 17.5°C in July (-5.5°C in January) and 1163.9mm annual precipitation[9].

The isthmus is dominated by low-lying saltmarshes, wetlands and spruce-bog habitats on the southern Chignecto Bay (Bay of Fundy) side, while relatively better-drained mixed forest habitats dominate the northern, Northumberland Strait portion of the narrow landmass[10]. According to Nova Scotia's Ecological Land Classification[11], the eastern flank of the isthmus comprises two different landscape ecosystems[12]: the Tantramar Marshes and the Northumberland Lowlands. On the western flank of the isthmus, the latter landscape ecosystem is termed the Northumberland Coastal ecodistrict in New Brunswick[13], and falls into the Eastern Lowlands ecoregion of that province.

The Tantramar marshes are low-lying grasslands that used to be extensive salt marshes before being dyked by Acadian settlers to reclaim land for agriculture[14]. More than half of the 185 km^2 area is peat land and bog habitat. The Northumberland Lowland is forested and comprises some undulating relief (lower than 50m in elevation), with little freshwater present in lakes and rivers (approximately 4500ha) and frequent forest fires given the annual precipitation deficit along the Northumberland Strait[15] . Based upon the forest regions of the Maritimes[16], the northern part of the isthmus falls into the Maritimes Lowlands Ecoregion (Red Spruce-Hemlock-Pine zone)[17].

Notwithstanding the many broad themes to define patterns and features in this landscape, local researchers have opted for their own systems of landscape classification. Given the impracticality of combining existing provincial landscape classification schemes, Erskine and McManus, Jr. (2005) subdivided the isthmus into six local physiographic regions[18]:

a) Shores and coastal waters of the Northumberland Strait
b) Northumberland plain (<50m above sea level [asl]) – comprising the landscape along southern shore of Northumberland Strait;
c) Higher ridges and uplands (up to 175m asl) – leading into the Cobequid foothills in Nova Scotia and spanning east in New Brunswick to the uplands defining Memramcook Valley;
d) Fundy lowlands (<30m asl) – includes dyked and functional salt marshes and wetland habitats on the southern portion of the isthmus;
e) Fundy 'fog belt' uplands (30-60m asl) – includes capes extending into bays on the southern portion;
f) Shores and coastal waters of upper Bay of Fundy

For the purposes of this report, regions b, c and d are most relevant to our discussion of habitat connectivity across the isthmus.

Seven major river watersheds drain our study area on the isthmus to the north and south sides: the Nappan, Laplanche, Missaguash, Aulac and Tantramar Rivers to the south, and the Shinimicas, Gaspereau and Tidnish Rivers to the north (as shown in Figure 2). These rivers and the freshwater wetlands that lie along their paths play a crucial role in transporting organic matter and nutrients from inland to the salt and brackish marshes and estuaries that line the shores of the isthmus. Where the outflows of these rivers meet the tides, sediments in the seawater are deposited to replenish those lost seasonally to coastal erosion, as well as gradually rising sea levels, and provide a nutrient-rich environment for invertebrates, birds, fish and mammals. Much of the coastally deposited sediment is classed as silt or silty clay loam[19]. In recent times, however, coastal erosion on the Northumberland Strait seems to be occurring at a much faster rate than sediment accretion, leading to coarser substrates along a gradually reproaching coastline[20].

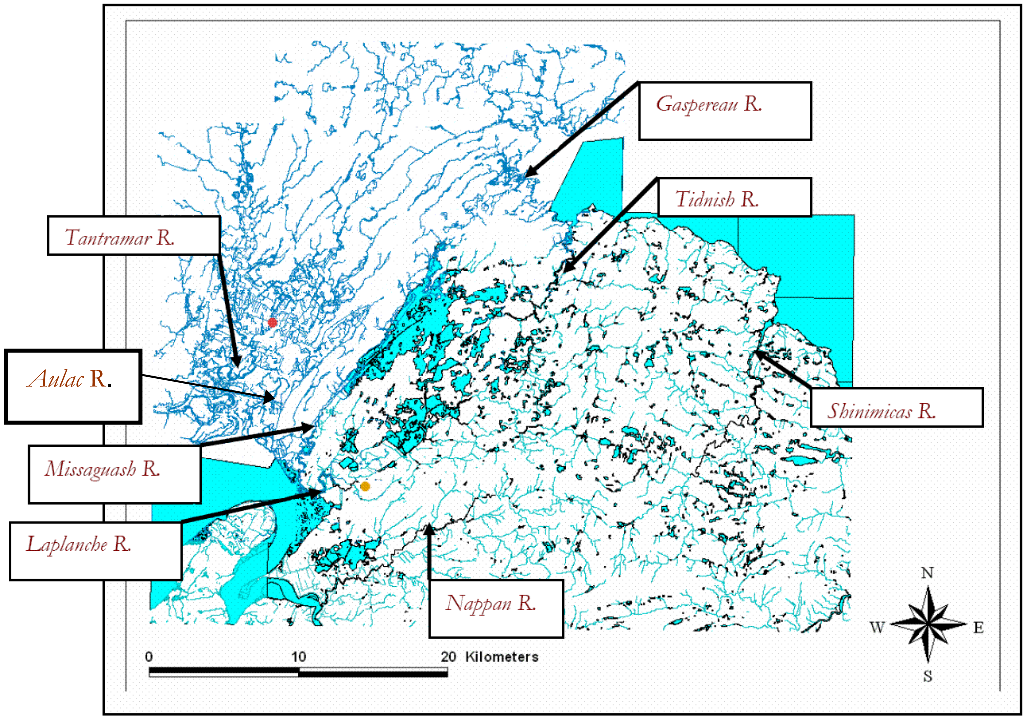


Figure 2. Major Rivers on the Chignecto Isthmus. Data from each province are provided at different level of detail. New Brunswick river systems are in dark blue, Nova Scotia river systems in blue-green. *Data courtesy of Service New Brunswick and Service Nova Scotia and Municipal Relations.*

2. History of the Isthmus

2.1 Historical Context for Natural Ecosystem Connectivity

Since the end of the last glaciation, it would seem that the isthmus has provided a biogeographical bridge between Nova Scotia and the rest of the continent; however, that was not always the case. During and after the Wisconsonian glaciation, a land bridge existed between present-day Nova Scotia and Massachusetts along what are now the submerged Georges and Browns Banks in the Gulf of Maine[21]. As recent as about 20,000 years ago, just as the glaciers began to retreat, southern species from the present-day United States started to migrate north to Nova Scotia along this 'coastal plain' land bridge[22]. Species thought to have made that journey include the southern flying squirrel (*Glaucomys volans*), the Eastern ribbonsnake (*Thamnophis sauritus*), the Blanding's turtle (*Emydoidea blandingi*), and species of coastal plains flora, including blue-eyed grass (*Sisyrinchium atlanticum*) and Plymouth gentian (*Sabatia kennedyana*). These species may have colonized a large portion of the Nova Scotian peninsula at that time.

After the glaciers melted and both water- and land-levels rose and fell over time, respectively, the coastal plain land bridge became submerged, isolating the flora and fauna that were once connected to other populations of their own kind. Later periods of significant cooling limited most of these species to the milder southwest part of the province[23], where many are currently at the northernmost extent of their range in south-western Nova Scotia.

Nova Scotia and New Brunswick are in the unique position on the continent of being the home to southern species at the northern extent of their range, as well as northern species at the southern extent of their range. While the coastal plain land bridge provided a route for many species to colonize the province from the south, the native fauna of Nova Scotia at that time typically comprised northern species, such as wolf (*Canis lupus*), lynx (*Lynx canadensis*), moose (*Alces alces*), wolverine (*Gulo gulo*) and woodland caribou (*Rangifer tarandus caribou*)[24]. Between approximately 10,000 and 7,000 years ago, these species were able to colonize Nova Scotia from the continent by moving across the (then larger) isthmus[25], where boreal forest vegetation, including birch-spruce-fir had begun to dominate[26]. Since the end of the post-glacial warming period, the Chignecto isthmus has been the only land route for many species to colonize Nova Scotia, and to facilitate movement that would help maintain viable populations.

Additional groups of species used the Chignecto isthmus to colonize Nova Scotia in the post-glacial period[27]. Salt-tolerant freshwater fish were able to 'leap-frog' from river to river along the coast of the isthmus to eventually colonize rivers in the northern part of the province; freshwater molluscs moved eastward across watersheds in Nova Scotia, and rare species are still found in isthmian lakes[28]; more than 50% of Nova Scotia's snails and slugs colonized the province across the isthmus during warm periods in the post-glacial; southern mammal species such as white-tailed deer (*Odocoileus virginianus*), coyote (*Canis latrans*), porcupine (*Erethizon dorsatum*), raccoon (*Procyon lotor*), striped-skunk (*Mephitis mephitis*) and woodchuck (*Marmota monax*) all colonized Nova Scotia across the isthmus. Moreover, Nova Scotia hosts no endemic invertebrates (though subspecies do occur), indicating that these species mainly had to arrive from adjacent areas in New Brunswick. Tree species from southeast New Brunswick, such as black ash and eastern white cedar, are also found locally on the Nova Scotia side of the isthmus, suggesting some migration from New Brunswick over time[29].

The open salt marsh and wetland ecosystems on the southern portion of the isthmus are regionally unique given their size[30]. Acadian words such as "Tintamarre," relating to the sound made by the wings of thousands of birds flying over the marsh[31], reflect such understanding.

It is important to highlight that prior to human settlement of Nova Scotia and the New World, it is quite likely that persistence of wildlife populations in the peninsular province did not necessitate connectivity with continental North America. Flora and fauna on the roughly 5,600,000 ha landmass may have been subject to adequate levels of gene flow, migration and dispersal according to ecological constraints, habitat disruption and availability.

2.2 Human-induced Changes in the Landscape - 1600s to Present

a) Settlement

Prior to European contact in the late 1600's, Mi'kmaq inhabitants used the isthmian wetlands to harvest locally plentiful waterfowl and fish, and possibly other species, such as moose, bear and porcupine. The name "Chignecto" refers to the "great marsh district" in the local Mi'kmaq dialect[32]. A 3,500 year old site in the Tantramar marshes yielded walrus bones and stone "plummets", which may have been used to hunt small game or as a fishing tool[33]. It is apparent that the waterways and wetlands linking the Missaguash marsh and the Portage Lakes (on the centre of the isthmus) were important travel corridors for early Mi'kmaq inhabitants[34].

With the arrival of agrarian French (later "Acadian") settlers, the borderlands underwent a significant alteration. The Acadian settlers saw the potential to drain and dyke the extensive salt marshes to reclaim fertile sedimentary soils below the tides for agriculture, i.e., hay cultivation, specifically valuable marsh hay (*Spartina* spp), and livestock grazing, with other crop cultivation took place primarily on cleared 'upland' areas around the marshes[35]. More than 70 per cent of the area originally covered by salt marshes was converted in this manner[36]. Adjacent forests were cleared for agriculture, to create defendable space and for building materials and firewood. Settlements surrounding the area were extensive, comprising several villages across the isthmus that were home to approximately 4000 Acadians by the 1750s; the English arrived shortly after and established Fort Lawrence and captured the French Fort Beauséjour as their own[37].

After the Acadian deportation in 1755, regional land-use again changed significantly, with the arrival of New Englanders and the high demand for timber for the booming shipbuilding industry. Forest clearing was not extensive on the isthmus, given the low supply, but home- and ship-building materials and firewood were still sought locally. Farming continued on the dykelands, with marsh barns being prevalent features on the landscape, though some areas were allowed to revert to salt marsh. A peak in the demand for pulpwood around 1900 led to clear-cutting practices in the region, though forest clearing was still not extensive on the isthmus[38].

By the post-war period, with increasing rural to urban migration in society, many small, marginal farms were abandoned and allowed to revert to woodland and in some cases salt marsh. In great contrast to this trend, the federal Maritimes Marshland Rehabilitation Act (MMRA 1948) was put in place to improve drainage and eliminate tidal influence on dykelands, as a means of supporting the regional agricultural industry[39]. Only coastal salt marshes seem to have been spared from this, with dams and sluice gates being installed in estuaries of the Tantramar and Missaguash Rivers. However, the influence of the MMRA was counteracted after the 1960s, when Ducks Unlimited Canada and the Canadian Wildlife Service began serious efforts to restore and create suitable habitats for waterfowl and wetland species on the isthmus.

The towns of Sackville, NB, and Amherst, NS, are currently the main urban centres within the project area, though much of the human settlement on the isthmus is of a rural residential nature, with some small-scale agriculture; rural areas fall into the Westmorland and Sackville Parishes, New Brunswick, and Cumberland County, Nova Scotia. The population within the study area was, as of the 2001 census, approximately 22,319, with approximately 10,433 private dwellings[40]. The Municipality of the Town of Amherst, with 9470 residents in 2001, is the smaller centre, covering only 12.02 km^2; the population density is thus very high, at 787.9 people/km^2. The Town of Sackville, with 5,361 residents in 2001, covers 74.32 km^2 and has a population density of 72.1 people/km^2. These densities compare to the provincial averages of 10.2 people/km^2 in New Brunswick and 17.2 people/km^2 in Nova Scotia. Regardless of area, Amherst is proportionally the largest local settlement, with extensive commercial development sprawling into the outskirts of the town.

Given that the project area spans the provincial border and most of the development outside of Sackville and Amherst is rural residential, it is pragmatic to combine the geopolitical statistics[41] for Westmorland and Sackville Parishes, which encompass the communities of Midgic and Baie Verte, New Brunswick, with those for Cumberland County (census district C), which corresponds to the areas immediately north and east of Amherst, including the community of Tidnish Bridge, Nova Scotia[42]: the approximate population of this 1648.2 km^2 area is 7,488 residents, yielding an overall population density of 4.5 people/km^2.

b) Transportation Routes

In 1888, New Brunswick engineer Henry Ketchum set out to construct the Chignecto Marine Transport Railway across the isthmus from Tidnish Dock (Northumberland Strait) to Fort Lawrence (Bay of Fundy). Its intent was to serve trade ships travelling between Annapolis Royal and Quebec City, which could be loaded on a train and sent across the isthmus in short time[43]. The project was never completed, but the rail bed still transects the isthmus, serving as a corridor for wildlife movement in the winter months[44]. The partly overgrown rail-bed now sits as high as 2m above the wetlands it crosses, and during its construction required a change in the course of the Tidnish River[45].

In the post-war era of the 1950s, rural to urban migration became a major socio-economic trend in North American society. Such trends led to increases in the development or improvement of highways and primary and secondary roads, something evident on the Chignecto isthmus, particularly spurred by population growth with the increasing importance of both Amherst and Sackville to the local economy[46]. Currently, seven two-lane roads transect the isthmus on both sides of the border. The most significant of these is the Trans-Canada Highway 16, with a wide shoulder and speed limits of up to 90km/hr, providing a route from Aulac, New Brunswick, to the fixed link bridge to Prince Edward Island at Cape Tormentine. For the most part, residential development along the roadways (outside the towns) is low density and many old farms are reverting to woodland. Highway 16 is classified as a restricted access highway by the NB Department of Transportation, meaning that future development and access directly off the highway is not permitted across most of the northern portion of the borderlands.

c) Land Use

Small-scale livestock production and blueberry production (particularly on the Nova Scotia side) are present, though not extending far from the main roads. Some areas of forest or field on the northern portion of the Nova Scotia side are being cleared for potato production, specifically the fertile uplands between the Tidnish and Shinimicas Rivers[47].

Two natural gas pipelines are present on the isthmus: the Maritimes & Northeast Pipeline, travelling east to west across the northern portion and the watersheds of the Tidnish, Tintamarre and Gaspereau Rivers; and, the Heritage Gas high-pressure alignment travelling southeast from the latter into the Town of Amherst. The pipelines are below ground and are marked with cleared 25m right-of-way corridors on the surface. Some minor alteration of riparian habitats resulted from the installation of pipeline sections below streambeds. Although environmental impact assessments did not find unnecessary risks to wildlife related to the rights-of-way, it should be noted that assessments of impacts to habitat connectivity and landscape-level wildlife movements were not addressed.

Industrial forestry activity is prevalent in three areas on the isthmus: first, in the area due north of the Tintamarre National Wildlife Area in New Brunswick; second, on the boundary of the Missaguash marsh and the Tidnish River watershed in Nova Scotia; and third, on the upland north of the Missaguash marsh on the Nova Scotia-New Brunswick border. Extensive logging road networks are associated with each area, and in many cases, commercial plantations are replanted on cut-over sites. Given the mixed forest composition, clear-cutting seems to be the predominant harvest method. Smaller-scale forestry harvesting also occurs on private lands throughout the study area, but large-scale landscape alteration and infrastructure development is not as likely to be associated with such activity.

In the 1970s and 1980s, the isthmian forests were affected by an outbreak of spruce budworm that significantly affected softwood forests in New Brunswick and Nova Scotia. After the outbreak, defoliated trees were removed from drier, upland areas and marsh margins by salvage cutting, leaving little mature coniferous forest cover in the area[48]. This, coupled with regular cutting for firewood, left the forests of the isthmus quite denuded, until the mid 1980s when forest regeneration began to restore cover[49]. In any case, there is little mature forest present in the area and forest cover is younger than in previous decades. In contrast to long-standing practices of harvesting one's own firewood, recent alternative fuels have allowed some forest cover to regenerate[50].

3. The Current State of the Chignecto Isthmus

3.1 Land Cover Patterns on the Isthmus

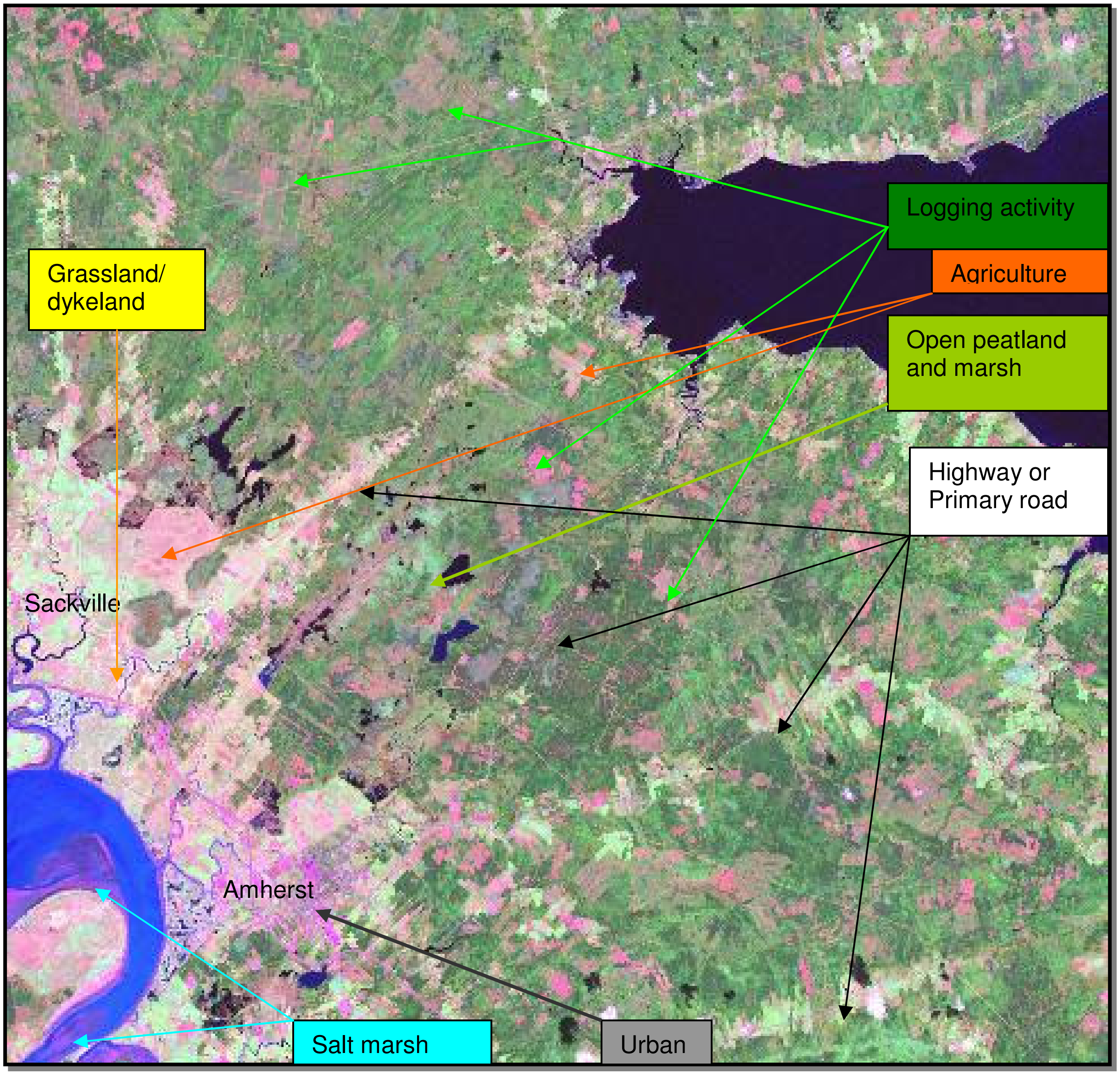


Figure 3 - 1999 LANDSAT image (bands 6, 4, 2) depicting land-use patterns within the study area. *Image courtesy of NASA.* **Areas of brightest pink can be correlated to very recently cut areas and/or bare soil or rock (as shown by the salt marsh habitats). Light and dark green correspond to closed forest canopy in this image, with light green likely depicting hardwood canopy and darker green signifying softwood stands. 'Mint green' areas correspond to grassland or cleared space associated with residential areas, agricultural development or abandoned farmland. Explanations of the colours shown are provided in the text boxes overlain on the image.**

Figure 3 is a false colour composite satellite image that can be interpreted to show general land-use patterns on the isthmus. The inlaid text boxes point to examples of land-uses such as agriculture, grassland, urban, open bog and logging activity. It appears that logging activity and associated regrowth is present on the 'interior' area of the woodlands on the isthmus, and is generally far from urban development and between the roadways transecting the isthmus. It should be noted that it is difficult to distinguish open bog from recent cutover areas using this solely visual method, though landscape patterns are intuitive, and bogs are generally closer to rivers and lakes than cutover areas.

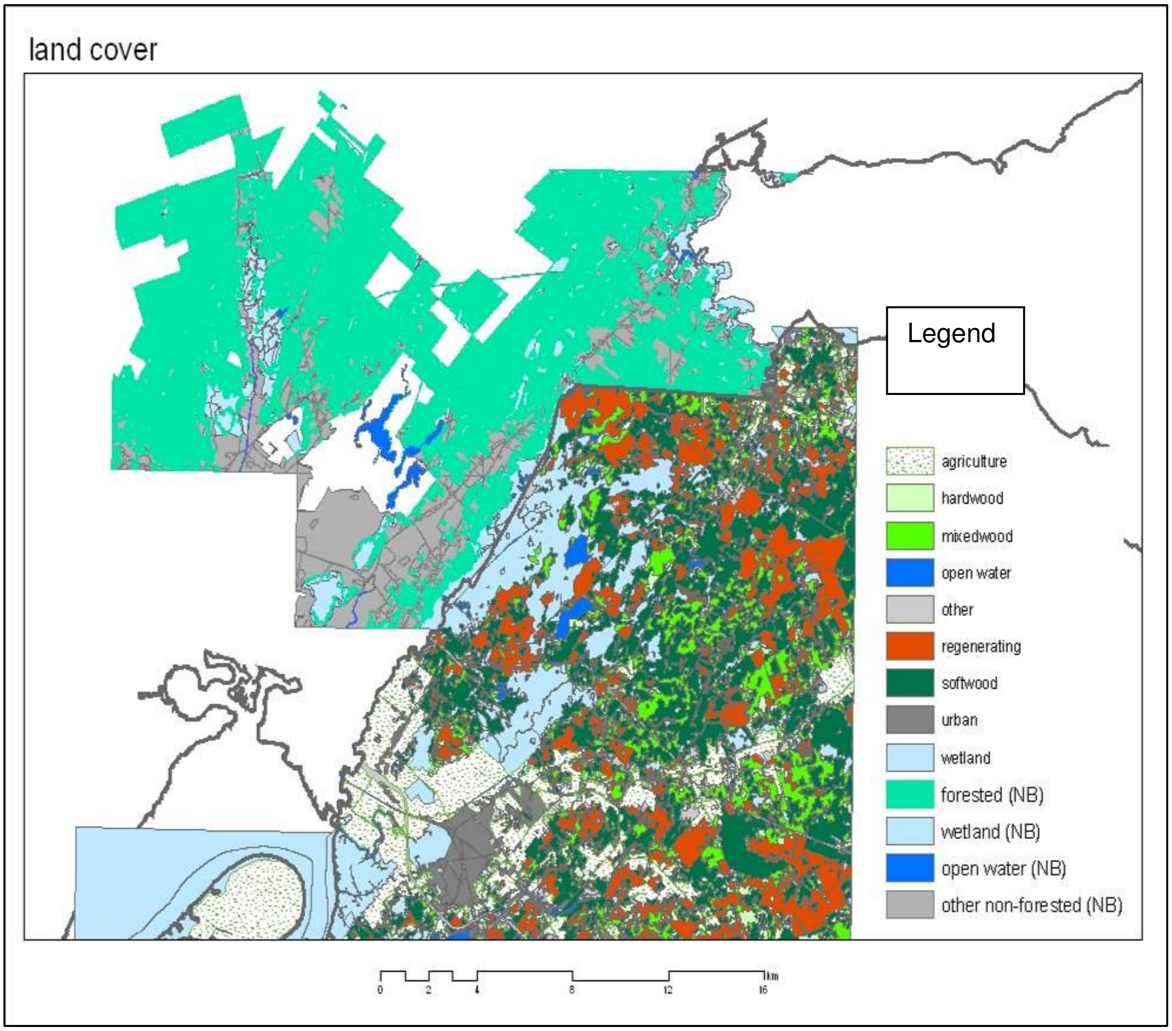


Figure 4 - Land cover classification of the Chignecto Isthmus. Note that the level of detail surrounding actual land use differs greatly between Nova Scotia and New Brunswick, based upon differences in data collection. Also, land cover data for sections of the project area in New Brunswick have been excluded based upon proprietary rights. To the north, these missing sections are found on lands used for forestry, and to the south the missing block represents the Tintamarre National Widlife Area, which is mostly wetland. Likewise, land cover data for Nova Scotia fall short of the project area boundary to the east. ***Data courtesy of Nova Scotia Department of Natural Resources, New Brunswick Department of Natural Resources and Service New Brunswick.***

Figure 4 shows general details relating to present-day land cover on the isthmus. Because the level of detail surrounding specific land cover in New Brunswick is much lower than that for Nova Scotia, it is difficult to make comparisons. As explained above, much of the land cover on the southern portion of the isthmus is wetland, urban and agricultural land, with the latter two shown as "other non-forested" in New Brunswick. Along the northern portion, land cover is almost entirely forest, regenerating or existing, with only minimal urban development around roads and the seacoast in that area.

3.2 Forest Cover

Softwood stands are most common on the isthmus, with some mixed wood and little to no pure hardwood stands present. The same trends can be interpreted for New Brunswick, based upon the fact that the local forest zones are the same as those for Nova Scotia.

Field visits to forests on the northern part of the isthmus indicate that there is a diverse mix of tree species found in stands in that area. Such diversity, when natural, can indicate a high level of ecological integrity.

3.3 Agricultural Lands

Given the history of this landscape, agricultural activity has been focused on the production of hay and some crops, with livestock production occurring, as well. Soils on the isthmus have varying suitability for agriculture, given significant differences in drainage and nutrient availability between areas, i.e., low-lying dyked salt marshes or upland forests. Blueberry production occurs on the isthmus, with large areas cleared for low-bush blueberry fields on Uniacke Hill in New Brunswick.

3.4 Wildlife

a) Local Wildlife Knowledge on the Chignecto Isthmus

Throughout this initial phase of the project, CPAWS staff corresponded with over forty local residents to obtain a firsthand perspective on the area and its wildlife. Some of these contacts were private woodlot owners who have lived and managed woodlots and farms on the isthmus for decades. Others were biologists, naturalists or trappers who spend a considerable amount of their time noticing wildlife and patterns in nature. Such ecological knowledge is valuable in conservation planning, as it provides a perspective on local interactions with the land and a more intimate sense of its valuable qualities.

From our discussions with local residents, we learned a good deal about furbearers and large mammals typically observed on the isthmus, with some accounting of the bird life, amphibians and reptiles observed there. A summary of wildlife knowledge reported by local residents is found in Table 1. This table is not an exhaustive list of wildlife in the area. The types of questions asked during local meetings, which focused on the forested habitats of the isthmus, led to a list that is predominantly based on upland wildlife. While upland species dominated these discussions, it is recognized that wetland and coastal wildlife are an important part of the isthmus ecosystems.

Moose cow and calves. *Photo courtesy of Graham Forbes.*

Table 1 - Summary of Reported Local Knowledge Regarding Wildlife on the Chignecto Isthmus

Species	***Remarks***
Common species	
Black bear (*Ursus americanus*)	Present in abundance along the northern portion of the isthmus. Sightings are becoming more regular over time, possibly in relation to habitat loss.
American moose (*Alces alces*)	Regular sightings of this species appear to be more frequent on the western, New Brunswick portion of the isthmus. Isolated sightings of moose south of Amherst and on the Missaguash marsh were also reported. Poaching was suggested to be a problem in Nova Scotia. Individuals are present and moving from inland towards the Baie Verte seashore on northern portion of the isthmus. Unfortunately, a lot of the best habitat for this species has been lost to timber extraction.
Bobcat (*Lynx rufus*)	Reported to be plentiful throughout the coniferous stands surrounding the wetlands where prey species are plentiful.
Red fox (*Vulpes vulpes*)	Present throughout.
Raccoon (*Procyon lotor*)	Present throughout.
Beaver (*Castor canadensis*)	Many residents reported apparent varying abundance for this species, as lodges were removed periodically to maintain the flow of the waterways and access to hunting camps. There is evidence to indicate that hardwood browse species are becoming scarcer over time.

***Snowshoe hare* (Lepus americanus)**	Appear to currently be at a peak population.
***American mink* (Mustela vison)**	Plentiful in the marsh, though current numbers of preferred prey, the muskrat, uncertain.
***Fisher* (Martes pennanti)**	Present on NB and NS sides of the isthmus in what appear to be two disjunct populations gradually moving towards one another. Most reports referred to the northern portion of the isthmus, along the Tidnish and Gaspereau Rivers.
***River otter* (Lontra canadensis)**	Becoming scarcer over time, possibly in relation to the declines in fish prey along local rivers where water quality has significantly decreased due to siltation. Wetland habitats and riparian zones are available.
***Muskrat* (Ondatra zibethicus)**	Current number of muskrat dens in local wetlands not certain, though this species seems to be ubiquitous.
***Short-tailed Weasel* (Mustela erminea)**	Present throughout and occasionally seen.
***Red squirrel* (Tamiasciuris hudsonicus)**	Plentiful in forested areas across the isthmus.
***Eastern chipmunk* (Tamias striatus)**	Present in forested areas.
Bald eagle	Present.
Osprey	Present.
***Porcupine* (Erethizon dorsatum)**	Present as road kill along all local roads.
***White-tailed deer* (Odocoileus virginianus)**	Known to move freely across the open areas on the southern portion, and use the margins of dykeland and wetland areas for grazing. Also present along the northern portion, especially moving from inland towards the Baie Verte seashore. Like moose, optimal deer habitat may have been lost due to timber extraction. Also, browse species such as red-osier dogwood and amelanchier are becoming scarce. Deer numbers are getting better on the NB side.
***Coyote* (Canis latrans)**	Known to move freely across both the northern and southern portions of the isthmus.
Species that have always been rare on the isthmus, or were extirpated	
***American Marten* (Martes Americana)**	One anecdotal report of a possible marten sighting on the northern portion in Nova Scotia, though not substantiated.
***Woodland caribou* (Rangifer tarandus caribou)**	Not present, though the last individual in the area was reported to be shot on the Cookville Bog in 1917.
***Eastern cougar* (Felis concolor cougar)**	Some sightings reported around Tidnish Bridge, particularly of a black panther. A cougar was confirmed to be present at Fundy National Park, based upon scat and hair analysis, in fall 2004. Supposed sightings of this species are filed regularly with Dept. of Natural Resources offices throughout the region[51].

b) Species-at Risk, Rare or Unique Species

A brief list of extirpated fauna in the Maritimes, including species at risk of extirpation, that currently live or travel through the Chignecto isthmus, or lived in the region[52]

Great Auk – Extirpated in Nova Scotia and New Brunswick, and globally extinct
Labrador Duck – Extirpated in Nova Scotia and New Brunswick, and globally extinct
Passenger Pigeon – Extirpated in Nova Scotia and New Brunswick, and globally extinct
Laughing Gull – Extirpated in Nova Scotia, though occasionally sighted on Bay of Fundy
Sea Mink – Extirpated in Nova Scotia and New Brunswick
Walrus – Extirpated in Nova Scotia and New Brunswick
Wolf – Extirpated in Nova Scotia and New Brunswick
Woodland Caribou – Extirpated in Nova Scotia and New Brunswick
Wolverine – Extirpated in New Brunswick
Eastern cougar – "Endangered" in Nova Scotia and New Brunswick and officially considered to be extirpated or of undetermined status, though sightings are still recorded.
Canada lynx – Provincially "Endangered" in Nova Scotia (2002) and New Brunswick
Moose (mainland population) - Listed as provincially "Endangered" in Nova Scotia in 2003.
American marten – Provincially "Endangered" in Nova Scotia in 2003.

The isthmus provides habitat for a number of unique or rare natural elements that have become established in this complex landscape over time. Some local people contacted as part of this study shared with us examples of disjunct populations of eastern white cedar and black ash on the Nova Scotia side of the border, small clusters of rare skunk cabbage growing along lakeshores within the Missaguash marsh[53] and occurrences of a plant called "ground nut" or Indian potato, a tuber cultivated by pre-contact Mi'kmaq peoples[54] in the Port Elgin area. Summary information obtained from the Atlantic Canada Conservation Data Centre in 2005 shows that the isthmus is home to a number of rare or uncommon species, most notably 56 species of birds, and 101 species of plants.

c) Consumptive Use of Wildlife Resources

Hunting, fishing and trapping occur on both sides of the isthmus, though actual numbers of licence holders were not assessed for this report. Trapping activity for rabbit, muskrat, mink, beaver, fisher (historically), otter, bobcat and coyote is evident on the isthmus based upon our conversations with local residents.

d) Inland Fisheries

Fishing seems to occur mostly on a recreational level within the study area. The rivers draining into the Northumberland Strait currently sustain recovering populations of Atlantic salmon and resident populations of brook trout, though the same cannot be said about rivers draining into Cumberland Basin. The Laplanche River was reported to support a good run of brook trout, though fishing for this species is said to be poor along the Missaguash River due to siltation of the streambed and fluctuations in water levels. MacLellans Brook also supports brook trout[55]. The Tidnish River supports a number of species, including Atlantic salmon, brook stickleback (a provincially rare minnow), gaspereau and brown trout, as well as sucker and eel[56].

3.5 Aquatic Ecosystems

Local residents talk about reductions in the quality of inland waters over time and subsequent impacts on salt marsh ecosystems. Widespread forestry activity across the narrow isthmian landscape has led to increased deposition of silt into the tributaries of streams and rivers in the area. Locals also report that spring flooding and stream bank erosion are more frequent than in previous memory, due, in their view, to clearcutting practices on the upland ridges surrounding the low-lying isthmus. On the Nova Scotia side of the border, siltation and subsequent "choking" of aquatic substrates could have an impact on recovering Atlantic salmon stocks, which are present on the Tidnish and Shinimicas Rivers, as well as River Philip outside the study area. At the coast, silt-laden outflows from rivers deposit fine sediments over the sandy mud substrates[57] where the preferred invertebrate prey of foraging shorebirds is found. Further affecting the situation, increasing coastal erosion along the Northumberland Strait is leading to the deposition of larger-grained particles further altering the foreshore habitat for shorebirds.

3.6 Present Conservation Measures on the Isthmus

a) Conserved Public Lands

Approximately 70% of the study area portion of the isthmus is privately owned land (i.e., a combination of industry freehold and private woodlots/properties), which means that there is only a small proportion of land available for government conservation designations. A total of 4,182.6 hectares is protected by governments: 3,695 hectares by the federal government in three National Wildlife Areas and a National Historic Site, and 487.6 hectares by the Province of Nova Scotia in a provincial park and a game sanctuary. These conservation areas (all except the Nova Scotia Game Sanctuary and Cape Jourimain NWA) are shown in Figure 5:

1. The Chignecto National Wildlife Area (1,020 ha) in Nova Scotia, containing both the Amherst Point Migratory Bird Sanctuary and the John Lusby Salt Marsh, was designated as a "Wetland of International Importance" under the RAMSAR Convention in 1985[58]. Reasons for the designation include the importance of the John Lusby salt marsh to large flocks of Canada Geese, Green-winged Teal, Northern Pintail and Black Duck, among others, as well as the status of this site as the largest continuous salt marsh on the Bay of Fundy. The diverse freshwater wetlands of the Amherst Point Sanctuary are cited as the most productive in Nova Scotia and are home to the largest recorded nesting density of Pied-bill Grebes, as well as many locally rare waterfowl species[59].
2. In New Brunswick, the Tintamarre National Wildlife Area (2000 ha) boasts one of the largest concentrations of nesting Northern Harriers in North America[60], with 35 breeding pairs recorded within a 300 ha patch on the Tantramar marsh in 1980[61].
3. The Cape Jourimain National Wildlife Area in New Brunswick is a 675 ha site located on the shore of the Northumberland Strait at the extreme east end of the Cape Tormentine peninsula. Over 170 bird species use the site at various times during the year, taking advantage of eleven different habitats ranging from sand dunes, to freshwater marsh, to cedar swamp, to coastal hardwood[62]. In fact, the coastal hardwoods on the site, e.g., red oak, are locally very unique and possibly represent

local forests long ago dominated by hardwood species found in rich soils. The hardwood patches are isolated on small islands[63].

4. Fort Beauséjour National Historic Site (182 ha) on the Fort Lawrence ridge at Aulac, New Brunswick, is mainly an historic site and fort, but also contains a small stand of coniferous forest bordering on dykeland that offers good habitat for raptors. This is one of the largest patches of forest on the far southern portion of the isthmus.
5. Amherst Shore Provincial Park (328 ha) is located near the mouth of the Shinimicas River on the shore of the Northumberland Strait. The park comprises coniferous, mixed and upland forest, abandoned farmland, estuary, salt marsh, bog and sand beach habitats. Forest vegetation in the park is diverse, with Black Spruce, Balsam Fir, Tamarack, Jack Pine, White Spruce, Red Maple, Hemlock, White Pine, Beech, White Birch and Sugar Maple present[64]. Given its size and composition, this could be an important natural "refuge" area on the isthmus for terrestrial mammals and birds. Coastal erosion is problematic and surrounding cottage development threatens to isolate the park from adjacent habitats[65].
6. The Hackmatack and Round Lakes Game Sanctuary (159.6 ha) on the Missaguash Marsh in Nova Scotia was designated before restoration of waterfowl habitat was underway on the isthmus[66]. The goal of the area was originally to provide natural habitat for waterfowl. Land uses are not restricted in the sanctuary, although as Crown land, the area will not be built upon. Consumptive wildlife activities are controlled.

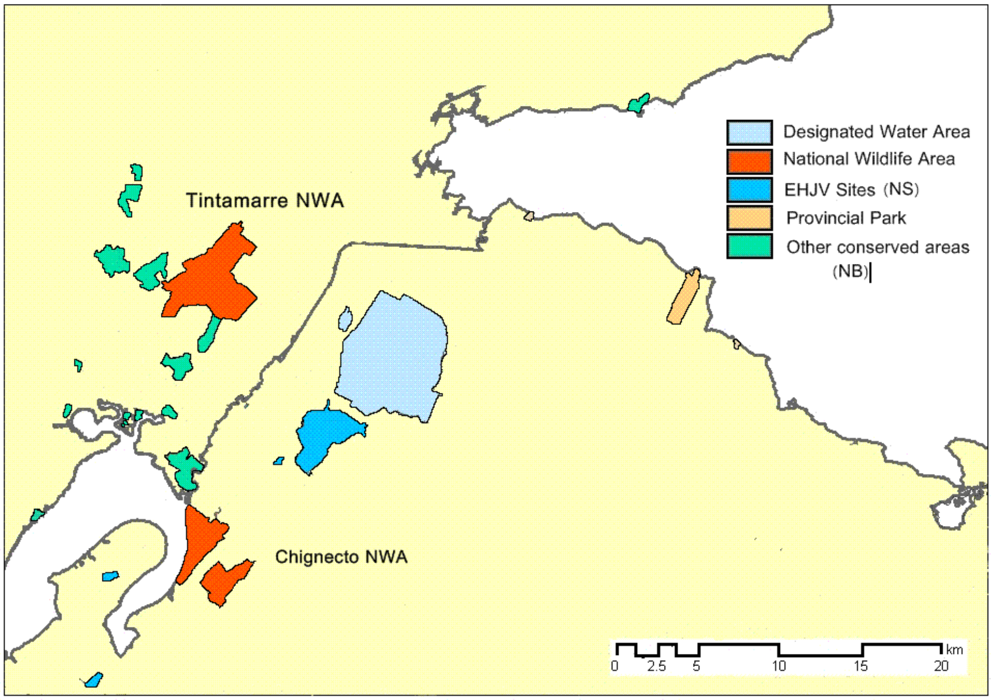


Figure 5. Selected conserved areas on the Chignecto Isthmus. Neither lands owned by Ducks Unlimited in Nova Scotia nor Nova Scotia Wildlife Management Areas are shown on this map. Areas labelled 'Other conserved areas' in NB are mainly EHJV sites. *Data courtesy of NS Department of Natural Resources and the NB Eastern Habitat Joint Venture Partnership.*

b) Protected Watershed Area

The North Tyndal Protected Water Area is a 4,050ha section of land situated almost on the Nova Scotia-New Brunswick border at approximately 15km north and east of the Town of Amherst, lying on the centre of the isthmus. It comprises the watersheds of four tributaries of the Tidnish River. The area was designated in 1992 to protect underlying groundwater resources in the North Tyndal Well field, which supplies drinking water for about 10,000 residents of the Town of Amherst and part of rural Cumberland County[67]. Land-use is strictly controlled according to regulations under the Nova Scotia Environment Act (R.S.N.S. 1994/95), and a multi-stakeholder well field advisory committee oversees land-use decisions[68]. Forestry activity above a certain limit is subject to the committee's approval of a professionally generated forest management plan.

The well field area is divided into 3 zones of varying levels of land-use restriction. No mining is permitted in the well field (Figure 6). Zone 1 has the strictest land-use controls, with only some minimal forestry permitted to protect from fires (no chemical spraying permitted) and no agriculture; Zones 2 permits controlled agriculture, forestry, residential development (large lots) and recreation; Zone 3 is managed for current and future land-uses to reduce potential for contamination of groundwater[69].

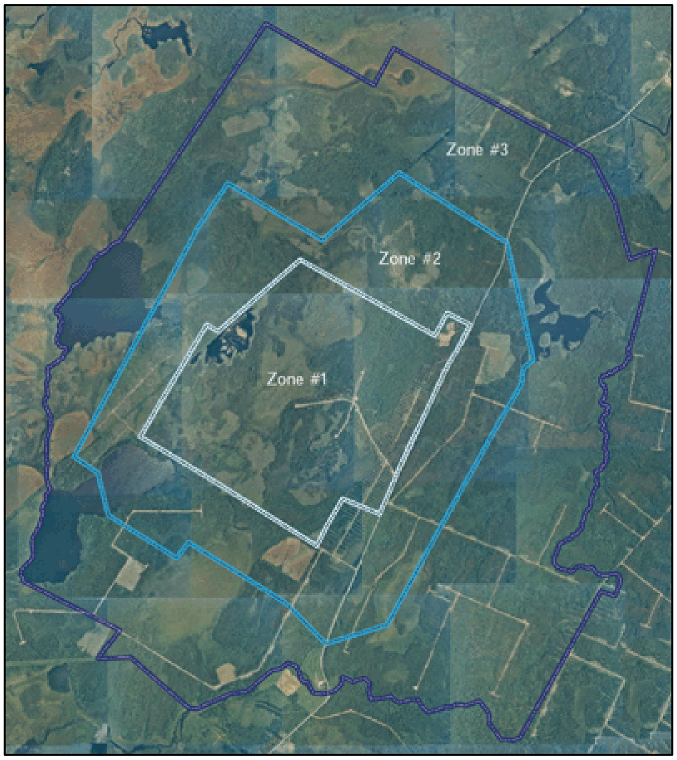


Figure 6 - Aerial photograph (1:40,000) of the North Tyndal Wellfield (Protected WaterArea), demarcating management zones 1, 2 and 3. *Image courtesy of Town of Amherst.*

c) Wetland Conservation Designations

There are several very significant wetland designations within the study area, which seek to conserve habitat for the 1,000,000 migratory shorebirds and thousands of waterfowl that move through the internationally significant wetlands in the area each year. These designations include:

< An Important Bird Area (IBA) exists within the Upper Cumberland Basin (approximately 3000 km^2), encompassing the Minudie Marsh and the Chignecto NWA, primarily to highlight the importance of this globally significant area for migratory Canada Geese and Semipalmated Sandpipers[70]. Both the IBA and the Chignecto NWA comprise muddy, silty substrates inhabited by *Corophium volutator*, an excellent source of food for foraging shorebirds. The sites are also recognized as a Hemispheric Shorebird Reserve through the Western Hemisphere Shorebird Reserve Network. While the IBA designation does not provide legal protection, it does help focus research and conservation attention on the area.

< Numerous wetland creation and conservation initiatives of the Eastern Habitat Joint Venture also exist on the borderlands, including areas conserved by EHJV partners the Province of New Brunswick (145 hectares - White Birch wetland), the Province of Nova Scotia, and Ducks Unlimited (230 ha owned on NB side, manage more than 2500 ha).

From 1996 to 1999, the NB Department of Natural Resources led a project to develop a cooperative wildlife strategy for the Tantramar Dykelands in New Brunswick. The Tantramar Dykeland Wildlife Habitat Project brought together various government and non government organizations to identify the key wildlife habitat values in the dykelands, and outlined various ways that agencies and organizations could build on existing stewardship programs or conservation designations[71]. This initiative has sparked considerable cooperative work among landowners and agencies to conserve wetlands habitat values on private lands in the NB portion of the isthmus.

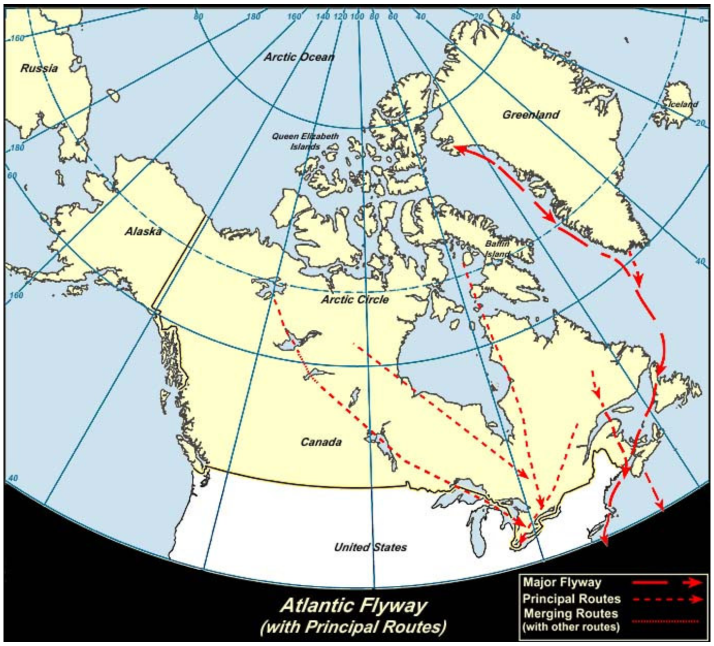


Figure 7 - The Atlantic Flyway, illustrating the position of the Chignecto Isthmus beneath a major route
Obtained from www.birdnature.com

Exemplified by the concentration of waterfowl and shorebird concentration measures, the isthmus sits at a very important juncture along the northern portion of the Atlantic Flyway (see Figure 7) used by migratory birds to travel to and from wintering grounds to the south. Hundreds of species use the flyway, including the Peregrine Falcon[72], listed as nationally endangered by COSEWIC (Committee on the Status of Endangered Wildlife in Canada). The ecology of the local salt marshes is critical in attracting so many migratory birds, and is directly connected to land-use practices within the watersheds inland from the coast.

3.7 Gaps in Conservation Areas – Forest Ecosystems

A great deal of conservation and research attention has been focused on the wetlands and salt marshes of the borderlands by federal and provincial governments and non-profit organizations. However, little coordinated attention has been given to the forest ecosystems on the isthmus. The forested lands to the north of these ecosystems represent potentially important habitat for species reliant upon forest landscapes for breeding, cover or feeding. For example, moose winter concentration areas are known to exist in the forests of the northern isthmus and on the Cape Tormentine peninsula[73]. Also, black bear are known to be plentiful on the northern portion of the isthmus. Both of these species have large home ranges and are sensitive to human influence to some extent, tending to avoid habitats near roads or trails[74]. The forests are also home to a wide variety of songbirds, as well as owls and small- and medium-sized mammals.

The key value of the forested habitats is that unlike the extensive wetlands to the south, the forested habitats are more representative of the contiguous natural ecosystems found on either side of the isthmus, and as such, could be considered as inherently connective ecosystems in this landscape. Though the forests have historically been greatly altered by logging, insect epidemics and fire, the local mix of tree species compares to that of southern New Brunswick and mainland Nova Scotia, and are the only option for local wildlife that require forest cover.

4. The Need for Connectivity across the Chignecto Isthmus - Identifying Challenges

4.1 Why is Natural Ecosystem Connectivity Important on the Isthmus?

The isthmus is a small biogeographical land bridge, or a landmass important for the migration of entire communities into new regions over time[75]. The Chignecto isthmus has facilitated the passage of a wide variety of organisms, including humans, into Nova Scotia since the last glacial period, exemplifying its role in connecting natural ecosystems between the provinces. More specifically, this isthmus is a natural corridor that currently represents the only opportunity to connect habitats for terrestrial species between Nova Scotia and New Brunswick. The most appropriate corridor description for the Chignecto Isthmus may be as a "landscape mosaic" corridor, capturing habitat for edge-preferring and interior forest species[76].

The IUCN Forest Conservation Program publication *Linkages in the Landscape*[77] relates corridors to connectivity under the following scenarios:

- Large-scale modification of the landscape covers a significant area;
- Target species are habitat specialists or require intact, unfragmented habitats;
- An undisturbed matrix is required to maintain ecological processes;
- Suitable habitat patches are separated by distances beyond the target species' ordinary range of movement across the landscape; and,
- Where mixing of individuals between adjacent populations or sub-populations is necessary.

Given human impact on the local environment during the last 400 years, each of these scenarios applies to the Chignecto isthmus in some way. The isthmus' ability to continue to indefinitely facilitate connectivity for certain species between the provinces has been significantly compromised. The gradual loss of original forest cover has undoubtedly affected the overall quality and structure of forest habitats on the isthmus. Mature, multi-structured forests are crucial habitat for some species, such as Pileated Woodpecker and northern flying squirrel, fisher and marten. The loss of this type of forest cover may have greatly reduced the ability of the isthmus to function as a suitable habitat, or movement corridor between suitable habitats, for such species.

It should be noted that the wetland and salt marsh ecosystems on the southern portion of the isthmus may actually serve as barriers to the movement of some species[78], and those landscapes are thus not a focal point in our discussion of natural ecosystem connectivity. It has been shown, however, that some water-obligate birds, i.e., Common Eider, do move between the wetlands during their migration over the isthmus[79]. Alternatively, Scoter species completely avoid flying over the narrow isthmus on their southward migration and instead fly completely around Nova Scotia[80].

a) Preventing Nova Scotia from Becoming an Ecological Island

Without protecting ecological integrity and natural processes such as gene flow, migration and dispersal across the Chignecto isthmus, the province of Nova Scotia will effectively become isolated from New Brunswick and mainland North America. In the case of Nova Scotia, increasing ecological isolation on the isthmus will reduce the opportunity for migration and dispersal of terrestrial wildlife between the provinces. Likewise, habitat destruction, degradation and fragmentation, in addition to increased competition, impacts from natural disturbances, inbreeding depression and increased demographic pressures, are important factors that could affect species' ability to survive in isolated 'island' landscapes in Nova Scotia.

b) Connecting Habitats for Species Sensitive to Fragmentation

At varying scales, wildlife need connected habitats to survive and thrive. Some wildlife species are generalists - they thrive in a wide variety of habitats, and are likely to be common even in areas where people live - crows, raccoons and red foxes are some examples. Generalist wildlife species are an important part of our natural heritage, but are not as likely to be of conservation concern, because of their ability to live in a variety of ecosystems.

American marten
Photo courtesy of Nova Scotia Department of Natural Resources, Wildlife Division.

Other wildlife species are of conservation concern because they need certain habitats that are becoming rarer across our landscape, or are sensitive to human disturbance. Some wildlife need wide areas over which to range for food, mates and shelter, seasonally or from year to year, for example, moose, bear or lynx.

Some wildlife need specific kinds of habitats for their populations to thrive, and will do better under conditions where they can easily move to find those specific habitat characteristics - interior forest songbirds, barred owls or American marten are species that fit this category. All of these wildlife species are sensitive to habitat fragmentation at the scale covered by the Chignecto isthmus.

The isthmus is a largely fragmented landscape. Many studies suggest that fragmentation is a principal cause of extinction and a leading threat to biodiversity and forest species[81]. The term "fragmentation" applies to the overall result of habitat loss due to trails, roads and highways, railroad lines, agricultural lands, urban and residential developments, power-line corridors, surface mines and removal of forest cover. It affects the *original* continuity and structure of a given landscape. The extent to which any of these serve as barriers to movement is generally species-specific.

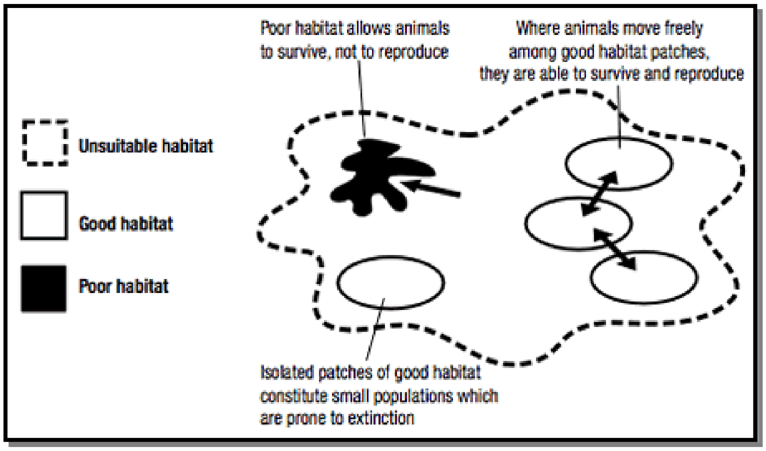


Figure 8 - A depiction of the effects of fragmentation on a landscape (Taken from Parks Canada, "Habitat Loss and Fragmentation" Special Places: Eco-lessons from the National Parks in Atlantic Canada. 2004. © Parks Canada)

Habitat loss leading to fragmentation can affect landscape connectivity in two ways: it can decrease the total area of the original land cover and it can interrupt the structure and arrangement of the original landscape[82]. These effects, in turn, can influence the ability of wildlife to access necessary resources and move among remaining patches of the original landscape.

The habitat loss associated with fragmentation also introduces new features into a landscape, such as transition zones on the edges of the original land cover, narrow corridors for movement between patches of the original landscape, an "archipelago of stepping stones" or even complete barriers to movement across the landscape[33]. Figure 8 depicts some of the root problems with "patch isolation" associated with fragmentation. When land-use patterns or changes in the original landscape become obstacles to movement of individuals, the viability of populations can be threatened.

Isolated patches may not be large enough in area to match a species' entire home range, thus even where patches of suitable habitat exist on an altered landscape, connectivity is essential to permit individuals to move between and through them. To conserve a viable population of a species over time, recruitment (new individuals being born or new individuals moving into a territory) has to exceed mortality and habitat has to be present. The presence of connectivity can indirectly affect recruitment success for some species, though it is not an exclusive factor[83].

Fragmentation effects resulting from habitat loss due to roads and development create isolated patches of forest habitat, of various sizes, across the isthmus. These patches may not provide suitable movement corridors or stepping-stones for the focal species identified for this report.

For a more detailed discussion of habitat and connectivity needs for certain wildlife species, as they relate to the Chignecto region, please see "Appendix 1 – Habitat and Connectivity Needs for Select Species" on page 61.

c) Roads and Fragmentation

The negative influences of roads on wildlife in adjacent habitats have been shown to extend as far as one kilometre from the road[84]. Negative impacts associated with roads, all of which can further exacerbate problems related to fragmentation, include: disruptions in regular patterns of wildlife movement and dispersal; habitat avoidance; introduction of exotics; increased mortality through vehicle collisions, predation and competition; disruptions of social interactions between members of the same species; increased access of humans to interior forests (i.e., logging roads); increased poaching pressure (in the case of endangered moose (mainland population) in Nova Scotia); and impacts on aquatic ecosystems[85].

Notwithstanding their negative effects, roads can also be beneficial to the movement of some species[86], and some birds. For example, Mourning Doves and American Goldfinches readily use the edge habitats created by road-building.

Moose - Endangered in Nova Scotia, Not in New Brunswick - Why Worry?

Moose are present in relatively healthy populations on the New Brunswick side of the isthmus, though appear to be much less regularly seen on the Nova Scotia side of the border.

The Nova Scotia mainland population of moose are listed as endangered by the province of NS (moose on Cape Breton are not included in this designation), while in NB there is not much concern about the provincial populations. However, local residents in south-eastern NB have expressed concern that moose populations are getting smaller, with fewer areas of winter concentrations.

Research on moose in mainland NS is leading to concerns about the ability of this species to maintain the viability of their populations over the long term. Making sure that moose in NS can interbreed with moose in south-eastern NB may be critical to the conservation of the species in NS.

More coordinated research needs to be done by both provinces on the habitat and recovery needs of moose in Nova Scotia and the Chignecto isthmus. Populations of moose that currently winter on the Tormentine Peninsula headland (NB) and south of Uniacke Hill (NS) may play a vital role in the continued existence of the moose on Nova Scotia's mainland.

The presence of several primary roads and two perpendicular sections of the Trans-Canada Highway illustrate the degree of fragmentation of the original isthmian landscape. Also, logging roads penetrate a great deal of the local wooded landscape, creating additional patches within the already isolated tracts of forest. The lands abutting the major roadways comprise a mix of residential and agricultural development and abandoned farmlands, all of which represent a small transitional space between the forest and the roadway. These effects serve to increase the distance between patches and reduce connectivity in a piecemeal fashion.

Various studies suggest that a threshold road density of 0.6km/km^2 is the point above which populations of large mammals can be negatively affected by road fragmentation[87]. Based upon work by Beazley et al (2004)[74], the density of all roads, trails and tracks on the northern and southern portions of the isthmus in Nova Scotia was calculated to be greater than 0.6km/km^2.

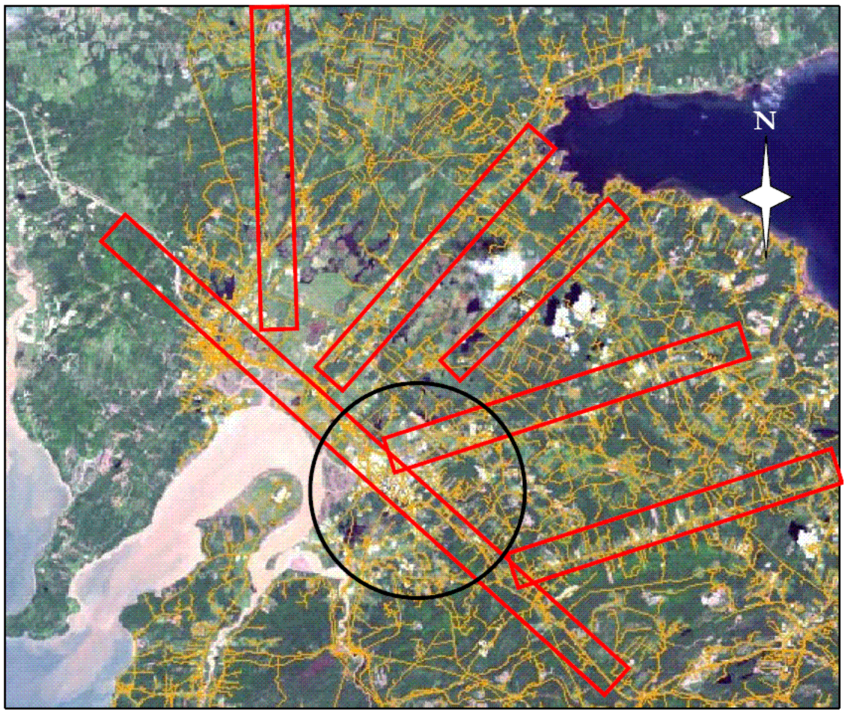


Figure 9 - 2000 LANDSAT Image of the project area showing highways, major roads and logging roads in orange. Note the extensive network that covers the isthmus. The black circle roughly captures an area shown to have a road density higher than 3km/km^2 by Beazley et al, 2004. Based upon the same source, the outlying areas on the Nova Scotia side of the isthmus were calculated to have a road density between 0.6km/km^2 and 1km/km^2. Road density statistics for New Brunswick were not available, though it is apparent that the same north-south increasing pattern exists. Red rectangles outline major roads transecting the isthmus. *Base image courtesy of NASA.*

A small area of lower density exists in the North Tyndal Protected Water Area and the Missaguash marsh. When only taking into account highways, primary and secondary roads, however, only the area around the Town of Amherst and corridors along each roadway show a density greater than the threshold level. This means that large portions of the isthmus may still be functionally connected enough to allow general wildlife movement. However, the degree to which the highways and primary roads are a barrier to movement of certain species across the isthmus, such as moose, lynx, or bears, has not yet been studied. Statistics show that nineteen moose of both sexes and various ages were lost in vehicle collisions in Cumberland County, Nova Scotia, between 1992 and 2004[88].

Figure 9 shows the roads in the project area. It is apparent that much of the isthmus landscape is easily accessible by road. This leaves few areas free from potential human contact and the activities associated with humans, such as outdoor recreation, hunting (legal and illegal) and use of off-road vehicles. One can see how accessible the landscape is based upon the number of small 'dead end' roads that spring from the main roadways and trail into green or open spaces on the image. Some of the roads readily jump out as potential obstacles to wildlife movement across the isthmus based upon their location and orientation (highlighted with red rectangles), and it is for this reason that local, landscape and regional level connectivity is important to address at this time. However, not all species will in fact see the roads as direct obstacles to movement, as moose, bear and deer are known to cross roads in this area[89].

It should be noted that each type of road has a different impact on wildlife based upon factors such as size and proximity to foraging, denning or protective habitat. This different 'weighting' is described in more detail later in the report (i.e., section 4.3(a): Human Influence - Roads).

d) Forestry, Agriculture and Fragmentation

The degree of forestry activity, and resulting habitat loss, on the isthmus is a significant concern with regards to fragmentation. Fragmentation in forested ecosystems has been shown to negatively affect a variety of species, including birds, small mammals and insects[90]. Fragmentation of forested landscapes can increase competition, parasitism and pressure of predatory species such as blue jays, crows and raccoons on interior-forest birds[91] in the remaining patches. For some woodland birds, such as Veery, confirmed to breed on the Nova Scotia side of the isthmus[92], probability of breeding may be near zero in isolated forest patches[93]. Studies of small mammals have shown abundance to be lower in fragmented forest patches created by logging, and have even suggested a "fence effect" that inhibits some small mammals from crossing open spaces to leave isolated patches[94].

Forestry and agriculture, both livestock and crop-based, appear to dominate the northern portion of the isthmus that is the current focus for natural ecosystem connectivity. Habitat loss resulting from timber extraction has fragmented the largest areas of available forested habitat, except the lower Missaguash marsh. Agricultural land use lines (or formerly lined) the major roadways and covers some fertile upland areas, e.g., the top of Uniacke Hill, New Brunswick, fragmenting a formerly forested landscape.

In the North Tyndal Protected Water Area, some of the regulations may help reduce fragmentation of the forested and forested-wetland habitats. Land-use is only strictly limited in zone 1 of the protected well field, while some selective forestry is permitted there. In zones 2 and 3, forestry operations are supervised and must be compliant with provincial wildlife habitat and watercourse regulations[95], with removal of 40% of forest on any landholding permitted over 5 years and whole-tree harvesting prohibited[96]. Strip cutting (20m spacing) is generally undertaken in zones 2 and 3[97], which may create barriers for some species, i.e., fisher or marten, if spacing distances are increased over time. The existing road infrastructure for forestry may contribute to fragmentation of this forested area, making it less effective as a movement corridor for some species that tend to avoid roads and trails, or those sensitive to the negative effects associated with roads.

e) Remaining Patches of Contiguous Habitat

The Nova Scotia Department of Environment and Labour uses road buffering (600m) analysis as part of their process to identify suitable protected areas in that province[98]. We chose to reflect this methodology and, given the high road density relative to the total size of the project area, adapt it to also show a 200m buffer distance around all roads (Figure 10).

A buffer with a 200 m width was calculated around all existing highways, roads and logging trails to generate patches representing roadless or relatively undisturbed habitats and parts of the landscape. The concept for this analysis was derived from recent work on road density and habitat use by large mammals in Nova Scotia[99]. As the figure shows, there are many small patches of landscape that are roadless and less directly impacted by roads at this scale. The patches can be interpreted as one pattern of habitat alteration and disturbance on the landscape, and offer some insights into the degree of fragmentation on the isthmus.

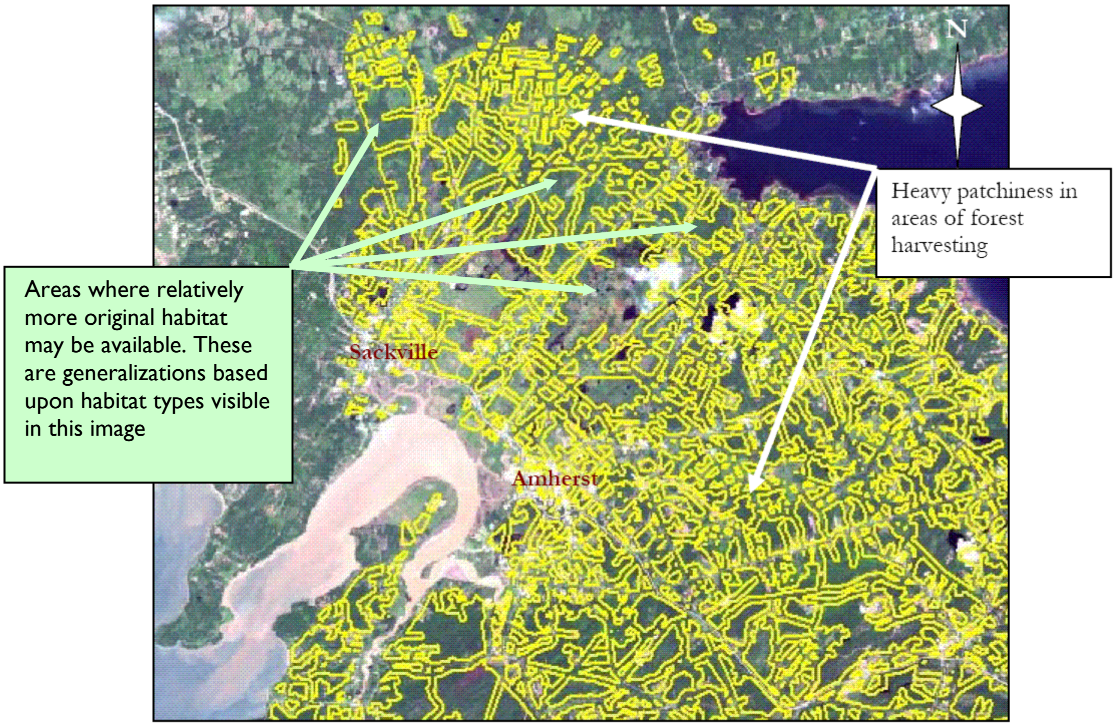


Figure 10 - 2000 LANDSAT satellite image of the isthmus showing the patches (transparent, but outlined in yellow) remaining around roads shown in Figure 9 after a 200m buffer was applied. Note the high number of small patches created, showing one aspect of landscape fragmentation in relation to habitat disturbance due to roads. Highways, roads and trails were removed from this image, though the areas they occupied can be seen as 'corridors' running between patches. *LANDSAT courtesy of NASA.*

It should be noted, however, that this analysis does not take into account land cover, habitat type or habitat quality. **It merely shows areas of any type of land cover that are 200m from roads of all types.**

Roads located where forest harvesting was taking place when this satellite image was captured appear to impact the landscape pattern in a way that may promote fragmentation (see text box and arrows in white). Given the number of logging trails associated with harvest areas, many small patches have been created. Not all patches arising within harvest areas contain trees, and some patches may actually be unforested. Relatively large patches are also found along the edges of the project area - light green colour on the figure. At a regional level, the location of these large patches serves to illustrate the 'bottleneck effect' on the isthmus with respect to the limited area in which human development and suitable habitat and movement corridors for wildlife compete for space, at least for species requiring large, relatively undisturbed and intact patches. Perhaps the most useful indication of figure 10 is to show areas where there is ***relatively more original habitat available***[100], such as some of the largest patches and those associated with the Tintamarre National Wildlife Area, the North Tyndal well field and the East Amherst marsh, which appear again in Figure 11.

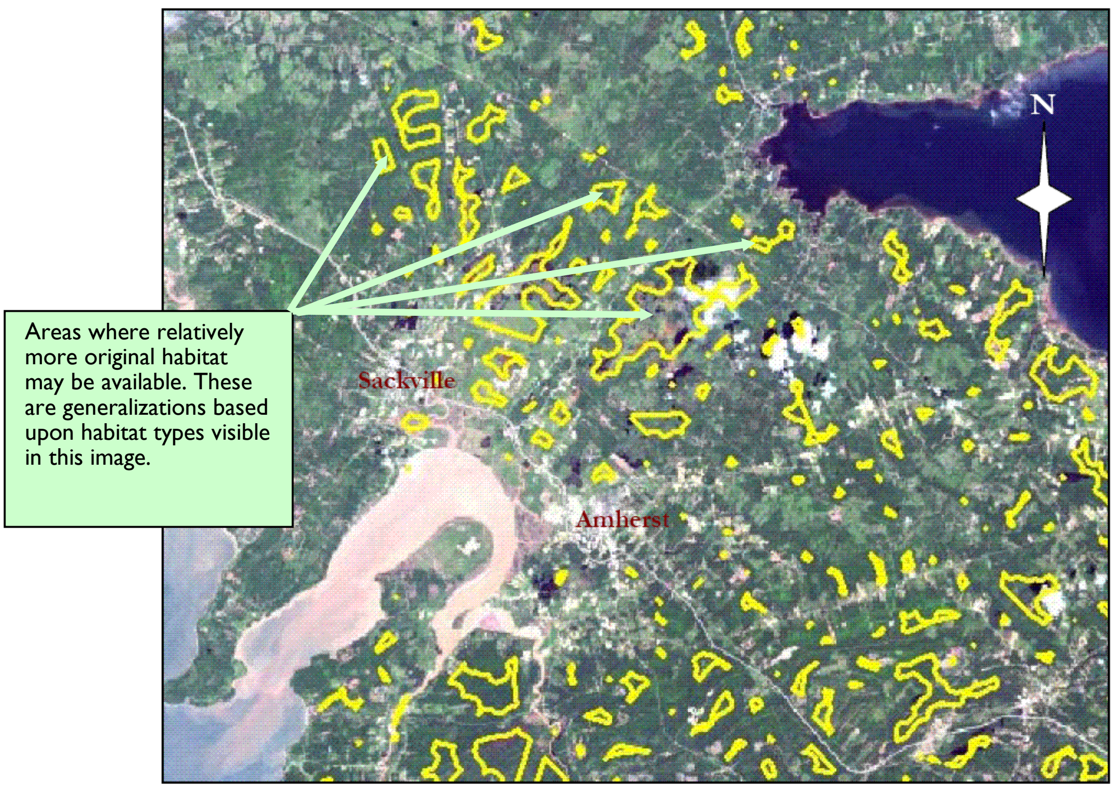


Figure 11 - 2000 LANDSAT image of the isthmus showing the patches (transparent, but outlined in yellow) remaining around all existing highways, roads and logging trails after a a 600m buffer was applied. Note the few patches that remain in comparison to Figure 10, and again many are small in size. Highways, roads and trails were again removed from the map, though the areas they occupied can be seen as corridors running between patches. *LANDSAT courtesy of NASA.*

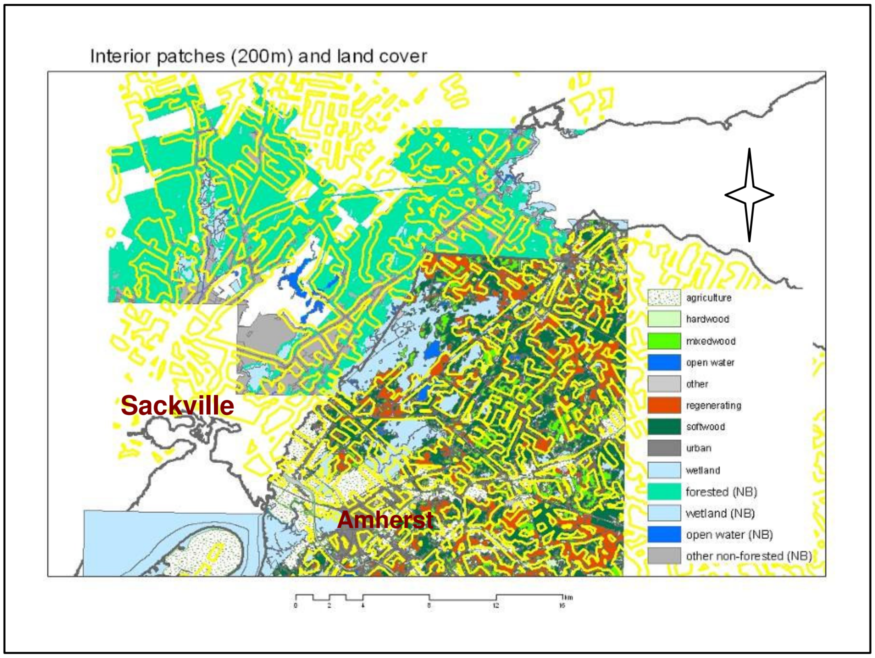


Figure 12 - Land cover details from Figure 4 superimposed on 200m buffer patches from Figure 10 (outlined in yellow). Note that the land cover information falls short of the eastern boundary of the project area. *Data are courtesy of the NB and NS Departments of Natural Resources.*

Figure 11 shows the results of our 'buffer analysis', using a 600m buffer around all existing roads shown in Figure 9. This analysis generates patches representing roadless or relatively natural habitats on the landscape. The 600m buffer may reveal habitats more important for area-sensitive species. As expected, there is much less landscape on the isthmus that is more than 600m from existing roads. This again indicates the high density of roadways in this small area. The overall landscape pattern made up by these patches shown in figure 11, which we interpret as one indicator of the degree of fragmentation, may not be as important as the actual size of the individual patches, which would more directly limit their use by certain species[101].

Figure 12 shows general types of land cover on the isthmus, superimposed on the patches shown in Figure 10. Of interest here is that most regenerating forests on the Nova Scotia side of the isthmus are located outside the patches in Figure 10 (a similar level of detailed data was not available for New Brunswick). This indicates that forest harvest and/or forest clearing occurs predominantly within 200m of roads and logging roads, illustrating that forested landscapes in the area are fragmented, lost or converted to other habitats by harvesting activities.

Similarly, roads are a cause of fragmentation and loss of original forested landscapes. Of course, it is not known how old any of these regenerating forest stands are, or how they were harvested. This level of data was not available for the purposes of our report. If the species mix and age class of regenerating stands were appropriate, such areas could provide foraging opportunities for moose and deer, as well as fruit-eating (i.e., raspberries and blackberries) mammals and birds. However, many species may avoid such areas depending on road traffic[102]. The fact that regenerating forests are closely associated with roads supports our notion that roads are a principal source of fragmentation and habitat conversion of the original forested landscapes on the isthmus.

4.2 - Riparian Corridors and Connectivity

It is believed that riparian areas and the transitional vegetation and habitats associated with such spaces (for example, aquatic/streamside/wetland/upland[103]), act as natural sinks and corridors for some wildlife. Typically less than 1% of a landscape is categorized as riparian area, though wildlife has been found to be disproportionately concentrated in these quintessentially diverse and complex areas[104] in comparison to upland habitats.

The true function of riparian corridors in promoting wildlife movement and mitigating the effects of fragmentation is not clear. However, these landscape features have been documented, in some cases, to promote wildlife movement, enhance gene flow, and provide habitats for animals either permanently or during disturbance in adjacent habitats[105]. Surrounding land-use and management will influence how riparian areas function as corridors.

At the landscape-level on the isthmus, healthy riparian areas linked to unaltered upland habitats are crucial for wildlife such as amphibians and reptiles that rely on seasonal movement between each habitat for reproduction, as well as small and large mammals, such as otters, mink, and muskrat.[106]. In Nova Scotia, Wildlife Habitat and Watercourse Protection Regulations[107] , and New Brunswick's Watercourse and Wetland Alteration Regulation - *Clean Water Act*[108], provide some protection from large-scale fragmentation of riparian zones, though measures should be taken to maintain continuous forest cover between inland/upland area and riparian zones.

4.3 Regional Ecosystem and Habitat Analyses - Lessons for Chignecto

There have been two recent studies done at a larger regional level, which shed significant light on the need for further conservation in the Chignecto Isthmus. By looking at these and similar studies, a clearer picture begins to develop of the urgency for action.

a) Human Footprint for the Northern Appalachians

Wildlife Conservation Society (WCS) Canada has undertaken research to determine the extent of human influence (human footprint) on ecosystems in the Northern Appalachian region, which includes the Maritime Provinces. This exercise uses methodology developed for a global analysis[109], using regionally specific data with a higher spatial and informational resolution than the global data sets utilized by the original analysis. It tailors "human influence" (HI) scores to the specific conditions and threats that characterize the ecoregion, and adopts a finer analytical scale than was used in the global analysis.

The Human Influence index was determined based on a combination of scoring for four categories of human impact - population density, dwelling density, land cover and roads, each made up of several data layers. The following four maps show the details of draft human footprint research results (as of April, 2005) for the Chignecto Isthmus.[110]

Human Influence - Dwelling Density
The areas of lowest dwelling density are located on the New Brunswick side of the isthmus, in the Halls Hill area, south and west of Baie Verte. These areas include a large parcel of J.D. Irving Ltd.'s private forest land holdings, and the Tintamarre National Wildlife Area, both of which do not have dwellings.

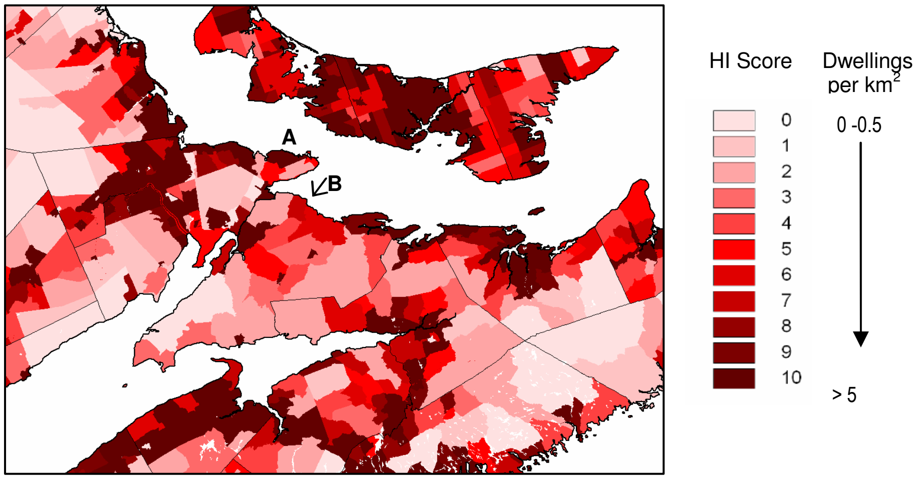
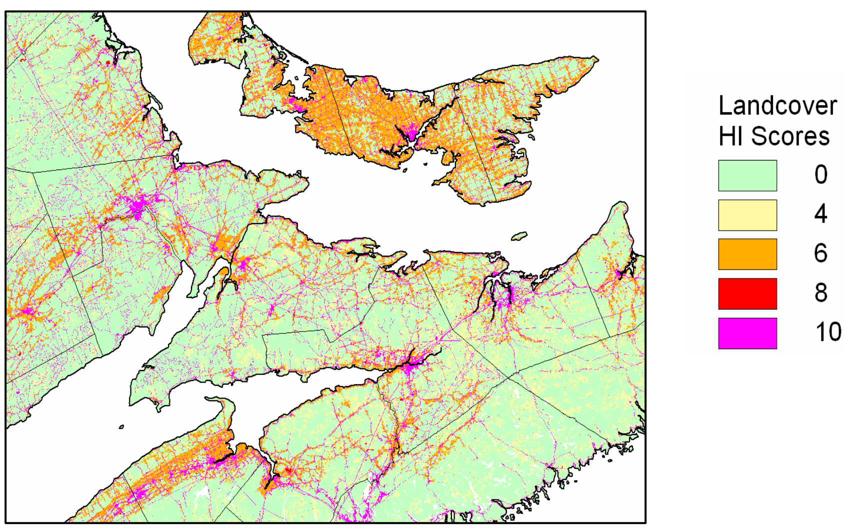


Figure 13: Dwelling Density Draft map. *Courtesy of WCS Canada, April, 2005 version.*

The *Population Density* map (not included here) shows fairly similar results, with a lower population influence on the northern Tormentine Peninsula ("A" on above map) and the northern Cumberland County shore ("B", on above map), compared to actual dwelling density in those areas. The slight difference is likely caused by seasonal dwellings (cottages, camps) that are located in these areas.

Human Influence - Land Cover
The land cover HI map (Figure 14) shows that much of the land in and around the Chignecto isthmus can still be considered natural habitat. However, as discussed previously, extensive road networks connecting villages and urban centres fragment the habitats into fairly small blocks, compared to areas NW of Moncton, or areas SE of Truro and New Glasgow.



Land Cover HI Scores:
0 = open water; bare rock; sand/clay; deciduous/conifer/mixed forest; shrubland; forested or shrub wetland
4 = regenerating forest (forestry)
6 = agriculture/plantations/cultivated
8 = quarries, strip mines, gravel pits, peat bogs
10 = urban; commercial/industrial/transportation

Figure 14. HI Land Cover. *Draft map courtesy of WCS Canada, April, 2005 version*

Human Influence - Roads

Figure 15 shows the degree of impact roads may be having on ecosystems (areas that are least influenced by roads are shown in the deep green colour). Scores from 0 (least influence caused by roads) to 10 (highest influence caused by roads) were assigned to all areas, based on the types of roads they are near, and the distance from those roads (Table 2).

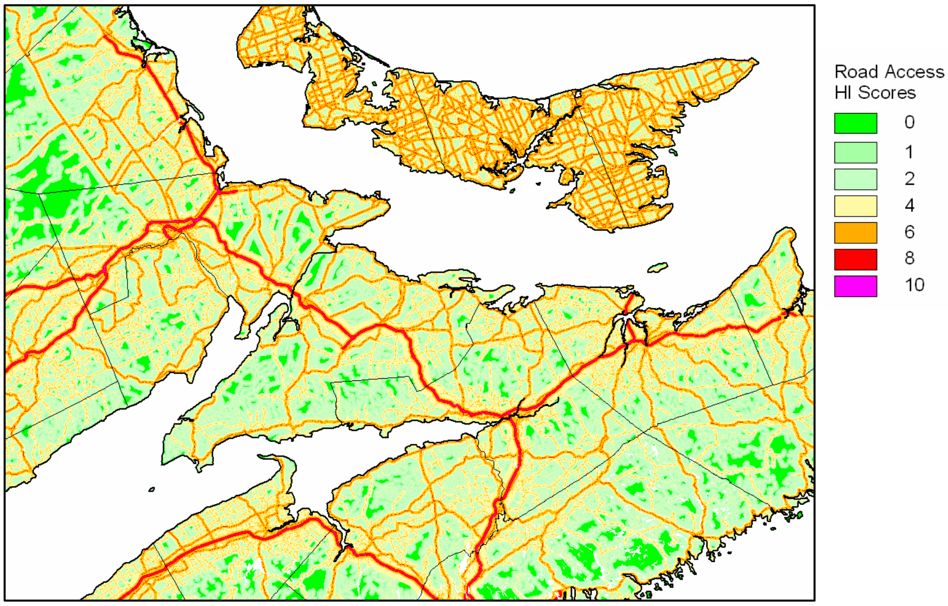


Figure 15: Influence of Roads. *Draft map courtesy of WCS Canada, April, 2005 version.*

Table 2. Northern Appalachians Human Footprint Study - Roads: HI Distances & Scores[110]

Road Class	**Feature Description**	**0m**	**90-500m**	**500-1000m****	**1000-3000m***
Class 1: Expressways	Complete habitat conversion. Significant barrier to movement. Road kill	10	8	6	4
Class 2: Primary and Secondary Highways	Complete habitat conversion. Considerable barrier to movement. Road kill	8	6	4	2
Class 3: Primary and secondary local roads and ice roads	Complete habitat conversion. Moderate barrier to movement. Road kill	6	4	2	0
Class 4: Tracks and trails (4WD or by Foot)	Moderate to minor habitat conversion. Minor to no barrier to movement. Minor to no road kill.	4	2	1**	0

*The GLOBIO (*Global Methodology for Mapping Human Impacts on the Biosphere*) study considers areas >3km from road in deciduous and boreal forest ecoregions to be roadless.
** Boer (1990) 90% of moose kills in New Brunswick occur within 1km of a road or trail.

Human Footprint Map Draft Version 0.1

The Human Footprint of the region was calculated by summing the HI scores for each input layer to give the Human Influence Index (HII), which was then normalized by ecoregion to give the Human Footprint. From this, the "Last of the Wild" – the largest and wildest areas receiving an HI score of 10 or less – have been identified for the region (Fig. 16)

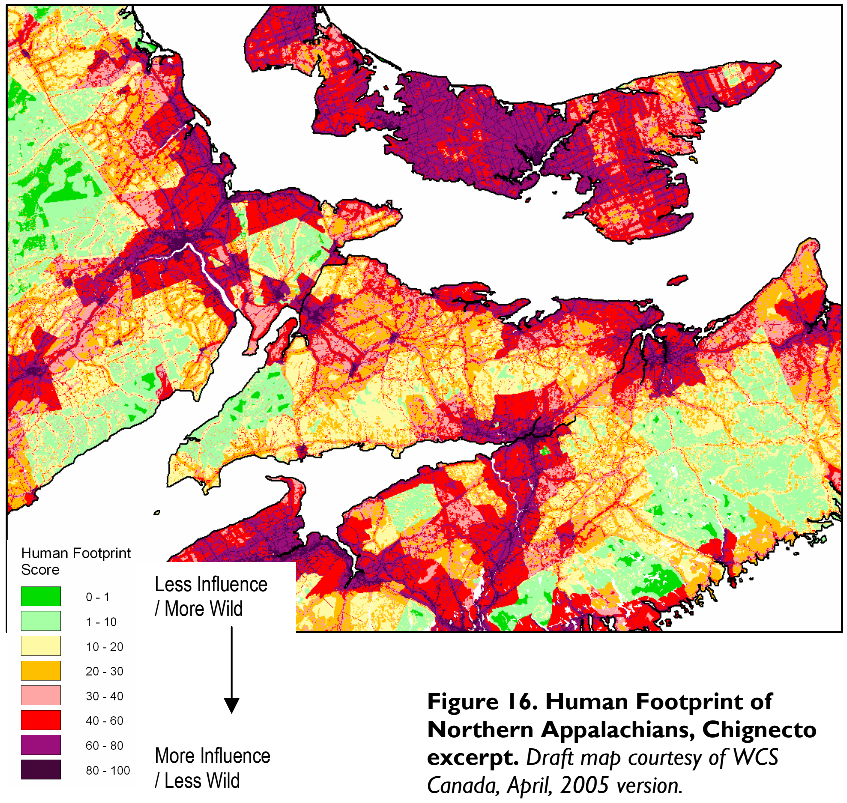
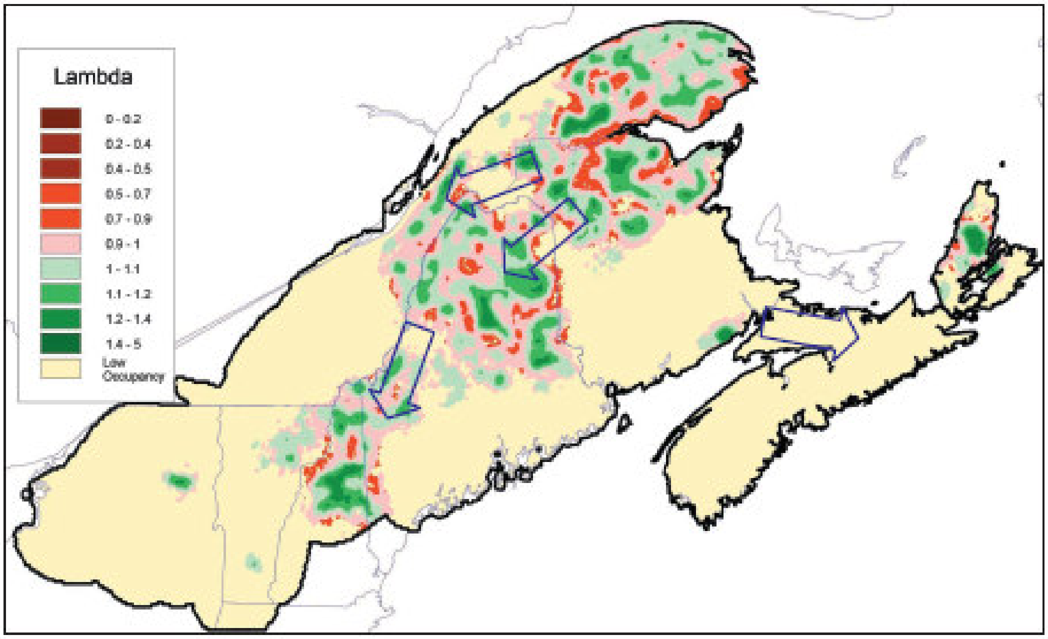


Figure 16. Human Footprint of Northern Appalachians, Chignecto excerpt. *Draft map courtesy of WCS Canada, April, 2005 version.*

b) The Wildlands Project: Carnivore Restoration in the Northeastern U.S. and Southeastern Canada

The Wildlands Project is a U.S.-based conservation organization that is developing conservation plans for wide-ranging wildlife species in the Northern Appalachians region. They are developing wildlands network designs for various parts of North America, including one in the Northern Appalachians (New England and the Maritimes), making recommendations for connections among natural habitats that will allow wildlife to have the room they need to find food and shelter, and mates for breeding.

One research study done for The Wildlands Project focuses on identifying areas of suitable habitat that will allow lynx and marten to be conserved in the Northern Appalachians. The research found that while the Chignecto isthmus does not necessarily contain much high quality habitat that is suitable to support populations of lynx or marten, the isthmus may support occasional dispersing (i.e. travelling) individuals of those species. As long as there is enough linked habitat to allow for potential lynx or marten movement between Nova Scotia and New Brunswick, the isthmus provides a critical ecological function over the long term - important to conserving the genetic viability of the isolated lynx and marten populations on Cape Breton Island.[111]



Potential linkages predicted by the PATCH model to be critical for persistence of the marten metapopulation in the northeastern U.S. and maritime Canada under an increased timber harvest scenario (Table 4), as well as a potential linkage to Cape Breton Island population. The legend shows population growth rate (Lambda) values predicted by PATCH model simulations.

Figure 17: Marten linkages map. *Courtesy of Dr. Carlos Carroll and The Wildlands Project* [111]

c) Regional Connectivity Challenges

According to the preliminary results of the Northern Appalachians Human Footprint Study, the Chignecto isthmus region may be losing some of its ability to provide solid ecological connections between Nova Scotia and New Brunswick. The natural areas located on the NB/NS border on Figure 16 appear to be being cut off from other areas with a similar natural character in south eastern New Brunswick (NW of Moncton and around Fundy National Park) and east-central Nova Scotia (south of New Glasgow and Stellarton). This points to a need to monitor and manage community sprawl and road networks in the parts of NB and NS leading up to the border (as far back as Moncton and the Truro/New Glasgow areas), to ensure conservation of broader wildlife dispersal routes and ecosystem connections.

The provinces of New Brunswick and Nova Scotia do not have regulatory frameworks in place to manage land use or transportation corridors in a coordinated way. Monitoring of community sprawl around the communities mentioned above is limited.

4.4 Land Ownership Pattern Challenges

The fact that so much of the land is privately owned will be a prime consideration in any conservation strategies to explore or facilitate ecosystem connectivity on the isthmus.

Figure 18 shows the Crown, or public, lands on both the New Brunswick and Nova Scotia portions of the isthmus. Landscape patches located 200m from roadways (i.e., Figure 10) are also shown. There are some medium-sized provincial Crown lands in Nova Scotia near the border, though there are very few provincial Crown lands in this part of south-eastern New Brunswick, and none of any notable size. The federal government holds most of the land comprising local national wildlife areas, with the Nature Conservancy of Canada owning the northern portion of the John Lusby section of the Chignecto NWA. Land ownership on the isthmus is predominantly local, with up to 70 different titles held on the Nova Scotia portion of the border[112].

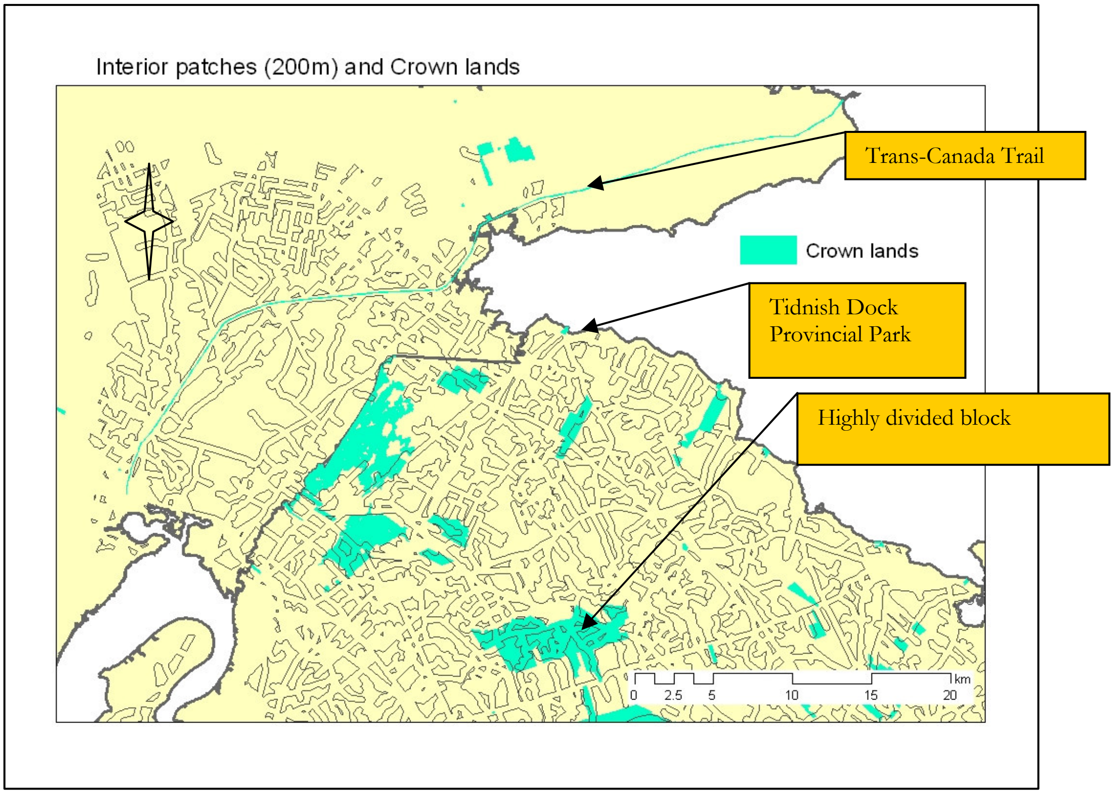


Figure 18 - Map showing local provincial Crown land holdings in Nova Scotia and New Brunswick. Unfragmented patches from Figure 10 are outlined in gray for comparison to location of Crown land blocks. This map extends well beyond the project area to the east. ***Data courtesy of NBDNR Public Services and NSDNR Land Services Branch, Surveys Division.***

Most of the Crown lands in the Chignecto area of Nova Scotia comprise existing or proposed conservation and protected areas. Much of the remaining Crown land on the isthmus appears to be broken up by roads, and some blocks are transected by multiple roads (as shown by the "Highly divided block" box on the map). Based upon interpretation of land cover in Figures 3 and 4, forest harvesting has occurred on these lands, leading to logging roads being put in place, which can contribute to fragmentation at the landscape-level. A local section of Trans-Canada Trail makes up a narrow section of Crown land in New Brunswick.

The creation of a new wildlife management area on Crown lands immediately on the Nova Scotia side of the border represents a good opportunity for long-term conservation measures on public land. Most of the Crown lands in this part of Nova Scotia, except for the provincial parks and small Crown holdings, are classified as "C2" through Nova Scotia's "Integrated Resource Management" strategy[113]. This generally indicates that there are conflicts surrounding the use of the lands for resource extraction, outdoor recreation or conservation[114].

4.5 Concerns with Connectivity?

In our conversations with local residents, planners and wildlife managers, the idea of promoting connectivity across the isthmus was well received. However, some contacts suggested that we should also consider negative impacts that could be associated with increased connectivity across the Chignecto isthmus.

The most obvious concern associated with enhanced or increased wildlife movement in a landscape fragmented by roads is, of course, wildlife mortality caused by vehicle collisions. This can have significant impacts on local wildlife populations, i.e., up to 50% mortality for large carnivores on major highways[115], not to mention social impacts for humans. Such impacts have been mitigated by constructing wildlife underpasses in areas such as Banff National Park in Alberta[116]. Given the paucity of data surrounding movement of terrestrial wildlife across the isthmus or near each provincial border, it is difficult to assume the impacts of vehicle mortality.

Transmission of wildlife diseases, particularly into the province of Nova Scotia from other areas, is a minor concern. By 1999, raccoon rabies had spread from its 1977 epicentre in Virginia, USA, to Prescott, Ontario and the Maine-New Brunswick border[117]. Increased dispersal of vector species from New Brunswick into Nova Scotia could be a concern over time. However, conserving effective corridors for wildlife movement between the provinces will engage wildlife managers in more active monitoring of wildlife populations, and hence increase opportunities to develop pre-emptive strategies to combat wildlife disease transmission. The potential for disease transmission should not preclude efforts to conserve connectivity across the isthmus. It should be noted that species commonly seen as vectors for wildlife diseases may often be generalists[118].

Like disease transmission, movement of invasive species is also of concern, though it is difficult to argue that a functional connecting corridor across the isthmus would in any way accelerate the transmission of invasives, given that many of the most biologically and economically harmful invasive species are already present in Nova Scotia and New Brunswick, such as purple loosestrife (*Lythrum salicaria*) and gypsy moth (*Lymantria dispar*), and vectors for invasive species transmission are often associated with human activity. Though there is a negligible risk for invasive species introduction across natural ecosystems on the Chignecto isthmus, the retention of intact habitats with communities of native wildlife will promote the ecological integrity of this landscape, effectively providing natural protection against invasive species establishment.

4.6 Knowledge-base Challenges

There are a number of challenges relating to the lack of ecological knowledge relating to connectivity issues on the isthmus. These include:

- Knowledge of local species distributions, e.g., moose, differs between the provinces, making it difficult to assess the connectivity situation across the isthmus. Anecdotal information provides only a snapshot of certain areas and habitats that are used by different species, making it an uncertain basis for arguments about habitat connectivity;
- Empirical data on wildlife populations are province-specific and are usually organized according to county (NS) or management zone (NB) and cannot be applied to the isthmus. Also, it seems that wildlife managers from each province do not work together on large mammal management and conservation, except on working groups for regional species-at-risk;
- Research on the amount of quality habitat for a range of terrestrial species on the isthmus is lacking, and amount of habitat may be as important to ecosystem function and species composition as the pattern of habitats on the landscape;
- Up-to-date LANDSAT images of land cover are not readily available, so it is difficult to determine current quality and extent of habitat for species present;
- There is relatively little knowledge of where (terrestrial) special elements occur on the isthmus, outside of protected salt marsh and wetland habitats, and the locations of special elements in Nova Scotia are not available at a small enough scale to eventually identify high priority public and private lands for conservation;
- Connectivity between existing conservation/protected areas is not obvious, mainly because the focus of conservation areas has not necessarily been terrestrial fauna.

5. Opportunities for Conserving or Restoring Connectivity across the Chignecto Isthmus

5.1 Regional Connectivity Opportunities

a) Municipal and Regional Planning

There are several regional planning frameworks that could help ensure that habitat connectivity in the Chignecto isthmus region is maintained. In New Brunswick, the Tantramar District Planning Commission develops rural and municipal plans and manages development for the communities on the isthmus (including the communities of Sackville, Aulac, Baie Verte and Port Elgin). In addition, the Beaubassin District Planning Commission and the Greater Moncton District Planning Commission provide similar community planning services to the areas leading up to the isthmus, where community sprawl has the potential to restrict or prevent wildlife movement to and from the isthmus. Preliminary discussions are being held within the NB Department of Environment and Local Government to improve the regulatory framework for planning. This would encourage district planning commissions to coordinate their plans across district boundaries, with the possibility of setting regional planning goals.

In Nova Scotia, the NS Municipal Services Division of Service NS and Municipal Relations oversees municipal planning activities in the province. The division has also undertaken a project entitled "Urban Development in Rural Areas", a study of sprawl issues and hotspots in the province. This research could be expanded to examine sprawl trends and issues as they relate to natural areas connectivity across the isthmus. Municipalities, such as the Town of Amherst, have the jurisdiction to develop Municipal Planning Strategies and accompanying land use by-laws. Zoning by-laws and planning policies could be coordinated with neighbouring jurisdictions, including the Municipality of the County of Cumberland, which includes the unincorporated areas on the Nova Scotia side of the isthmus. In fact, much of the undeveloped northern part of the isthmus in Nova Scotia is zoned "general," though it may be pragmatic to reassess this categorization in light of opportunities for connectivity.

b) Forest Certification

Three private woodlot owners in the New Brunswick part of the Chignecto region have obtained Forest Stewardship Council (FSC) certification for sustainable management of their woodlots, approximately 1,500 hectares in total. As the woodlot owners are working with a FSC certified forest resource manager (Nagaya Forest Restoration Ltd.) who works throughout the Maritimes, there is potential for these woodlots to be managed with regional habitat connectivity in mind.

c) Stewardship Programs

Because of its regional and international significance for migratory birds, there have been extensive programs developed to work with private landowners to conserve habitat for waterfowl and other wetland species. Much of this work has focused on wetlands, such as that of the NB and NS Eastern Habitat Joint Venture programs. There is an opportunity to encourage increased private land stewardship among those who own land in the forested part of the northern isthmus. Other organizations that are able to work with private landowners to encourage voluntary habitat stewardship include:

- the New Brunswick Community Land Trust, which works with landowners who want to include conservation in working woodlots and farms;
- the Pollett River Watershed project of the Greater Fundy Ecosystem Research Group, undertaking transboundary conservation and stewardship planning work on private woodlots in south-eastern New Brunswick[119];
- the Nature Trust of New Brunswick and Nova Scotia Nature Trust, which work with private landowners in each province to conserve special natural areas;
- the Nature Conservancy of Canada- Atlantic Regional Office, which works to conserve special natural areas in Atlantic Canada;
- Ducks Unlimited, which has offices in New Brunswick and Nova Scotia, and has been active on the Chignecto isthmus is helping acquire wetlands for conservation, and supporting programs that work with farmers to reduce their farming impacts on wetlands;
- The Soil and Crop Association in New Brunswick has a Chignecto Agro Conservation Club, which develops farm plans and stewardship agreements with farmers that outline actions they will take to conserve habitats on and around their farms.

5.2 Building on Existing Conservation Zones

The conservation zones that exist on the Chignecto isthmus are important, especially considering the fact that the region is dominated by privately owned land. Efforts to conserve the internationally significant wetlands on the isthmus have created a lasting spirit of partnership and cooperation among landowners, municipalities, federal and provincial government agencies, land trusts and non-government organizations. This cooperative spirit can now become the basis for a new conservation venture - one that explores cross-border conservation and connectivity issues, and weaves together the conservation areas that currently exist.

Figure 19 shows a map of conservation and protected areas (a GIS layer), placed on the 200m roadless patches map from Figure 10 to assess whether these spaces would coincide with what we have termed “relatively undisturbed” areas. Very few existing conservation and protected areas, the Tintamarre National Wildlife Area (see box), the Chignecto NWA (John Lusby section) and the proposed Missaguash/Amherst East Wildlife Management Area (location outlined by blue circle; see Figure 20), are located in relatively large patches when a 200m buffer is placed around existing roadways.

With reference to connectivity, it is interesting to note the number of smaller patches of roadless area surrounding these spaces, as well as some of the larger patches present. This again speaks to the amount of habitat loss – and in many cases, fragmentation of the original landscape – caused by roads on the isthmus. In contrast, the other conservation and protected areas are made up of a number of different roadless patches, probably in relation to access or public roads on or near the sites. The North Tyndal Protected Water Area is the most obvious example, given that the Tyndal Road and several access/logging roads cross the area.

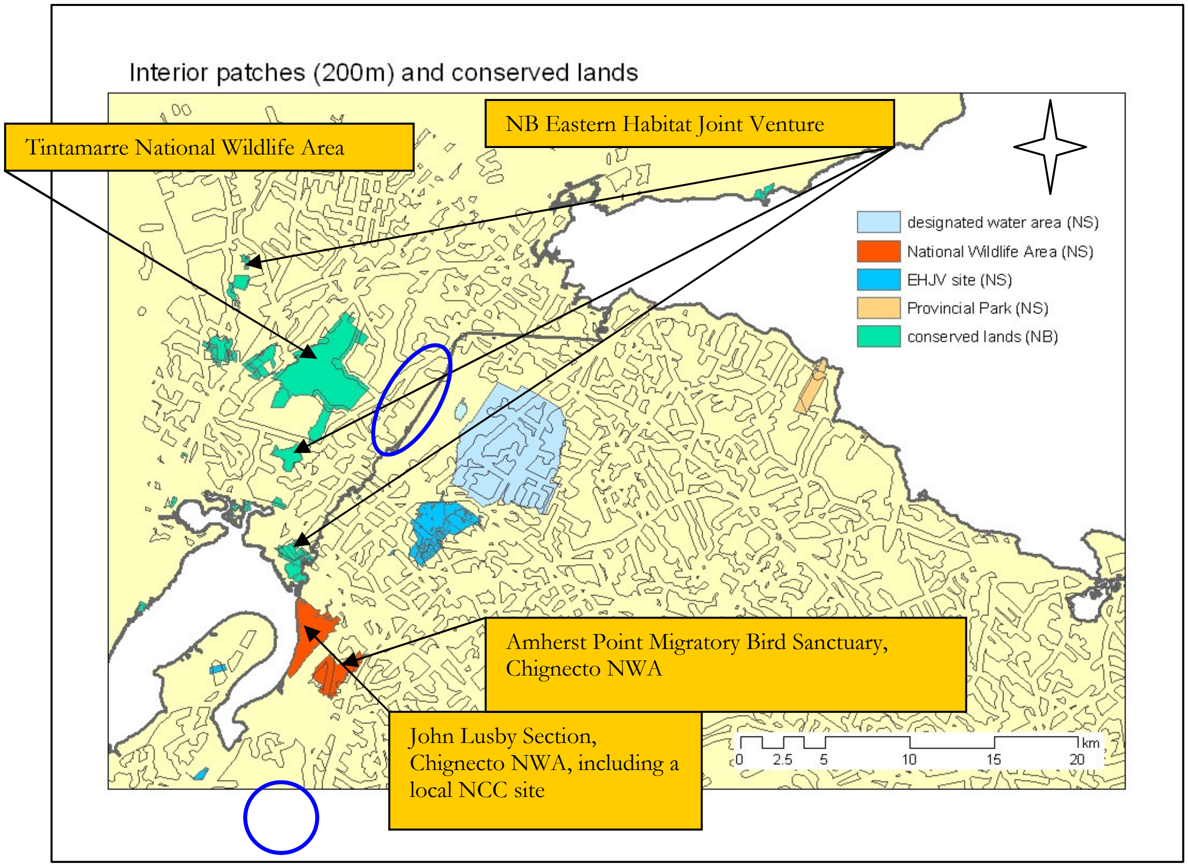
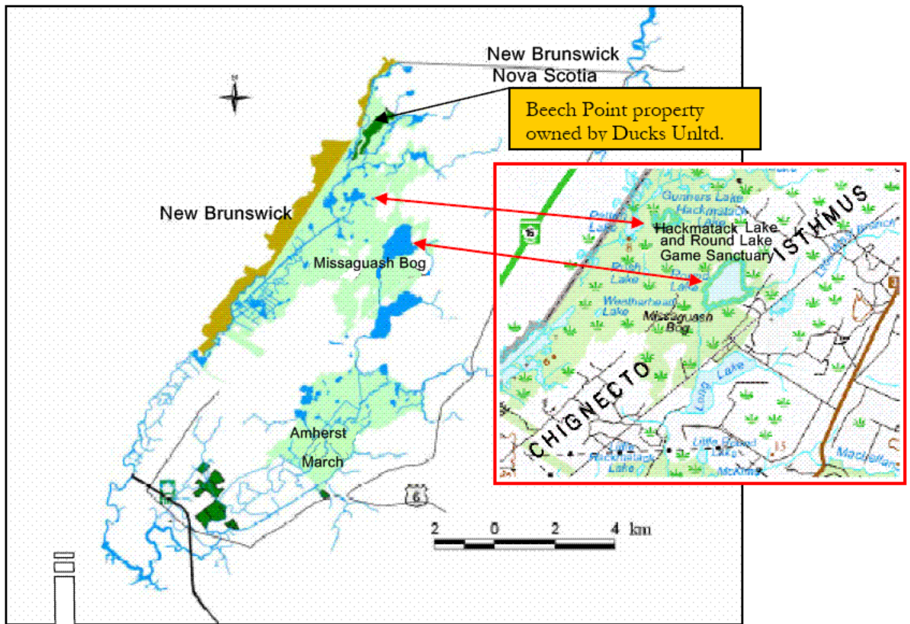


Figure 19 - Map of conserved and protected areas on the Chignecto Isthmus and surrounding areas, overlain on 200m roadless patches from Figure 10 (outlined in grey). Note that Eastern Habitat Joint Venture (EHJV) conservation areas and the Tintamarre NWA are shown as the same colour. Small aqua green blocks in New Brunswick represent EHJV sites, while the Tintamarre NWA comprises the large block identified in the by an arrow. EHJV sites are present on the borders of the NWA. In Nova Scotia, the Chignecto NWA is shown in orange, while the Amherst Shore Provincial Park is shown in peach. The North Tyndal Protected Water Area is shown in sky blue (designated water area), with NS EHJV sites presented in darker blue. Blue circles highlight the general location of Maccan River and Missaguash/East Amherst WMAs, shown in detail in Figure 20. ***Data are courtesy of NB and NS EHJVs of NB and NSDNR, respectively, as well as Service New Brunswick and Service Nova Scotia and Municipal Relations.***

The Tintamarre National Wildlife Area and the proposed Missaguash/Amherst East Wildlife Management Area (and part of the North Tyndal Protected Water Area) are also the largest roadless patches across the isthmus with a 600m buffer placed around roadways, as seen in Figure 11. However, there are no large stepping-stone patches present to connect these spaces to other large roadless patches on the isthmus at this scale.

It is obvious from Figure 19 that habitat conservation and protection activities have been focused on the wetlands and salt marshes of the southern portion of the isthmus. Only the North Tyndal Protected Water Area and Amherst Shore Provincial Park seem to capture upland habitats on the northern portion of the isthmus that could be important to landscape- and regional-level connectivity for forest-dependant wildlife.



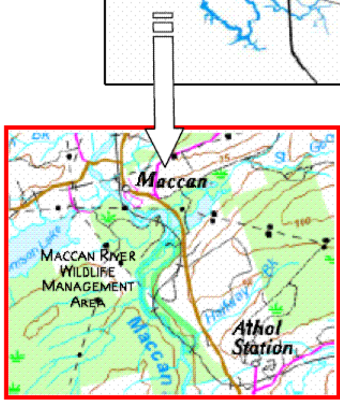


Figure 20: (Top) Location of the proposed Missaguash/East Amherst Wildlife Management Area, comprising all coloured areas on the map, including a small section of land across the Nova Scotia-New Brunswick border. This area coincides with the area highlighted by the large blue circle in Figure 13. Ducks Unlimited lands area shown in dark green. (Right) This map shows the area of the existing Hackmatack and Round Lakes Game Sanctuary (which will become part of the Missaguash/East Amherst WMA), highlighted with a bold blue-green line. Red arrows show how the two areas relate between the maps. (Bottom left) This map shows the existing Maccan River Wildlife Management Area, which is several kilometres south and west of Amherst, NS. The dashed arrow indicates that the distance between the maps is not relative, ass shown by the position of the small blue circle in Figure 19. The Maccan WMA is outside the project area discussed in this report. *All maps courtesy of NSDNR, 2005, taken from online PDF documents prepared for a review of existing and new Wildlife Management Areas.*

Figure 20 shows detailed views of additional conservation areas in Nova Scotia. The Missaguash/East Amherst Wildlife Management Area encompasses some upland forested habitats to the north, especially around the Beech Point area shown on the map, which could be important to landscape- and regional-level connectivity for wildlife. The area is located in a large roadless and relatively natural patch when a 200m buffer is placed around roadways, as shown in Figure 18. The land cover types inside the patch are still relatively intact. This area is also an important riparian/wetland space that could be suitable for a number of species, including mink, muskrat and otter[120], as year-round habitat. It may also be important to other species as a watering or seasonal-use area, as in the case of moose[121]. As shown in Figure 11, this area is among very few roadless and relatively natural patches on the isthmus when 600m buffers are placed around roadways.

The Proposed Fundy UNESCO Biosphere Reserve may also play a part in encouraging stewardship and conservation efforts on the isthmus, as its proposed boundaries include the southern portion of the isthmus, and the watersheds that drain into that portion of the Bay of Fundy.[122]

5.3 Conserving Linked Habitat for a Focal Species - Moose as an Example

The distribution of different classes of soil capability for ungulates, i.e., moose and deer, are shown in Figure 21[123]. The data are based on air photo interpretation, field surveys and vegetation and management analysis, and were originally collected in 1968 and updated until 1990[124]. Detailed explanations of methodology and summary reports relating to ungulates can be found through the Geogratis Canada website: http://geogratis.cgdi.gc.ca/.

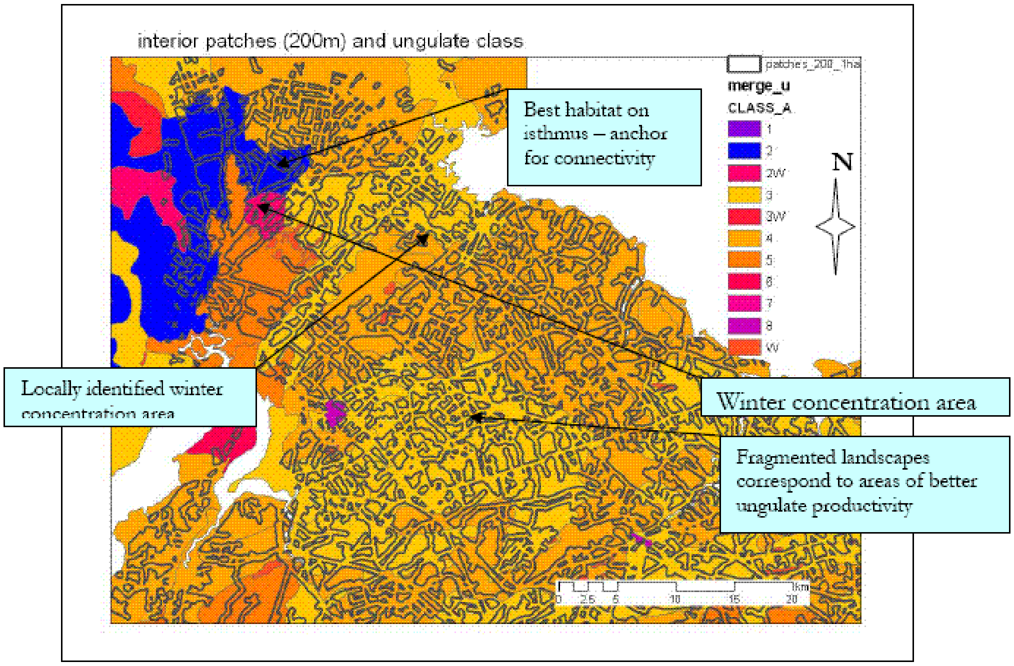


Figure 21 - Map illustrating the land capability for ungulates (i.e., moose and deer), based upon Canada Land Inventory Soil Capability for Ungulates assessments. Unfragmented patches from Figure 9 are outlined in gray. The boundaries defining blocks for each land class are not related to patches arising from Figure 10. Land classes are as follows: 1=no limitations on ungulate productivity; 2=ungulate productivity very slightly limited; 2W=class 2 winter concentration areas; 3=ungulate productivity slightly limited; 3W=class 3 winter concentration areas; 4=ungulate productivity moderately limited; 5=ungulate productivity moderately to severely limited; 6=ungulate productivity severely limited; 7=landscape characteristics not suitable for inhabitance by ungulates; 8=highly unsuitable for ungulates; W=open water. Subclasses are not included. *Data are courtesy of the Government of Canada through the Canada Land Inventory on-line mapping service of Geogratis. This map extends well beyond the project area to the south and east.*

Habitats are classified from 1 (highly suitable for ungulates) to 8 (highly unsuitable). Much of the isthmus falls into two capability classes, 3 or 4, which suggests that the area is suitable, but not highly productive for moose. Nevertheless, a large section of land on the southern portion of the isthmus in New Brunswick has high ungulate productivity, and winter concentration areas are present. This provides an excellent context for connectivity between moose in New Brunswick and Nova Scotia, as landscape- and regional-level connectivity for this species would allow animals in Nova Scotia to disperse or migrate to more suitable habitats in or across the isthmus.

One small, urban part of the isthmus, around Amherst, is highly unsuitable for ungulates (class 8). Interestingly, the wetland habitats do not seem to be overly suitable for ungulate productivity; however, these land use capabilities are based upon very old land data.

The distribution of large patches shown in Figure 21 relates in some way to the boundaries of different land classes, which may reflect past management of forested landscapes and cut boundaries (affecting the vegetative cover that was used to determine ungulate capability). Large patches are found in classes 2, 2W, 3 and 4, with roadways almost acting as borders between them.

Some of the most suitable ungulate areas in this part of Nova Scotia appear to be quite fragmented by roads, suggesting that they may be less suitable to ungulates, overall[125]. However, open areas can be important for the growth of shade intolerant browse species (see "Moose" section in Appendix 1 for details). This again supports the notion that connectivity between patches of suitable, undisturbed habitat is important, though the distribution of patches will dictate how they may be used. Perhaps the distribution of class 2, 2W, 3 and 3W habitats dictates a great deal about the way moose (and deer) tend to move across this landscape.

6. Climate Change – A Role for Isthmus Connectivity

Under certain scenarios that model the effects of climate change on present vegetation and forests in the region, the isthmus could become important for plants and animals migrating in and out of New Brunswick and Nova Scotia as a result of an increasingly warm climate (under one scenario) and changing biotic factors (i.e., favourable changes in habitat composition). It is postulated that the "relative mobility of different species and shifting climatic zones in relation to the position of the land bridge" was significant[126] after the disappearance of the Wisconsonian glacier in the region. With gradual warming since the last ice age, certain "southern species" were able to move into Nova Scotia via the isthmus (for example, porcupine, skunk and woodchuck).

Nova Scotia currently boasts 57 mammalian species, a number lower than other parts of north-eastern North America. Even though there is suitable habitat in Nova Scotia for these species, many have still not penetrated into this region[127]. The isthmus represents the only route by which some species could enter the province in the future. Some climate change researchers place Nova Scotia in a zone where a 20% increase in mammal diversity is anticipated by 2070, as a result of climate change[128]. It must be noted that an increase in mammal diversity is not a conservation goal – conserving the native species composition and ecological function is the main goal. However, this speculation strongly emphasizes the importance of thinking about the isthmus as the focal point of discussions and research surrounding wildlife migration along north-south corridors in landscapes. (Notwithstanding, it is a notion that could be negligible depending on the effects of rising sea levels.)

For northern species at the southern end of their range limits, however (e.g., lynx and marten), climate change is projected to severely compromise the extent of suitable habitat in the Northern Appalachians[129]. Moose in Nova Scotia are at the southern limit of their range, and as such may be susceptible to heat stress during the late winter and summer months, which when combined with a shortage of adequate cover habitat may influence moose decline[130]. In the face of climate change, Nova Scotia moose could face prolonged heat stress as a result of shorter winters and higher summer temperatures, though the actual effects on the regional climate are difficult at best to predict and it is difficult to consider indirect effects given current levels of uncertainty[131]. Ensuring a north-south dispersal corridor could be a key precautionary approach to the conservation of this provincially endangered species, especially given the uncertainty of habitat suitability under climate change scenarios.

Under the scenarios explored by the Intergovernmental Panel on Climate Change, one of the impacts in North America is expected to be some sea level rise. According to maps produced by the Government of Canada's Climate Change Impacts and Adaptation Program[132], the southern half of the isthmus is rated as having high sensitivity to sea-level rise, while the northern half is rated at medium sensitivity. This may reinforce the need to explore connectivity options in the northern, forested part, as those may be the most likely parts of the isthmus to remain above sea-level if (or as) climate change and associated impacts proceed.

7. Recommendations: What Needs to be Done

7.1 High Conservation Priorities to Facilitate Connectivity

Figure 22 depicts areas we conclude to have high priority for conservation to facilitate connectivity on the Chignecto isthmus. Each area is denoted by its own colour outline. Ground-truthing of these sites is required to determine their current state.

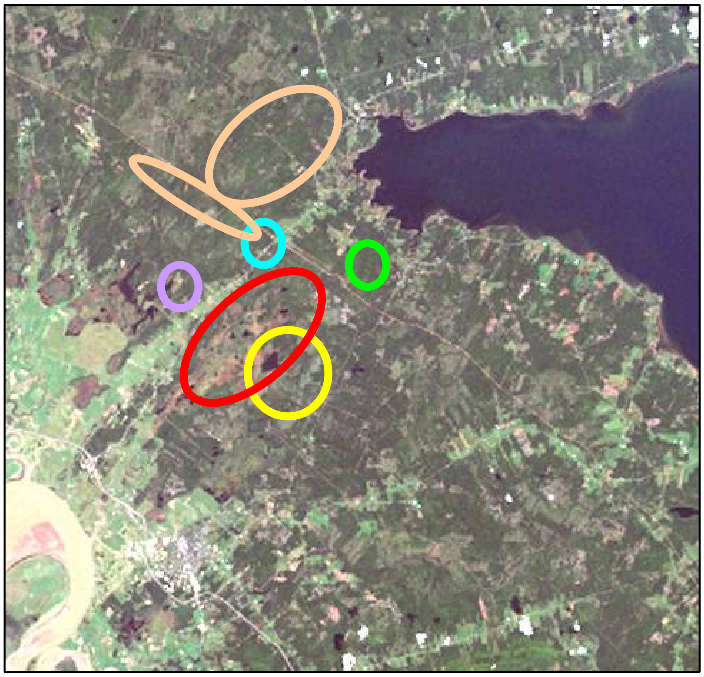


Figure 22 - High priority areas for facilitating connectivity on the Chignecto Isthmus. *LANDSAT image courtesy of NASA.*

[Turquoise] – This narrow section of contiguous forest along Highway 16 was identified as the highest priority area on the isthmus. Numerous contacts alluded to the importance of this spot as a path for wildlife movement (for example bear and moose) across the highway and thus between the provinces. Discussions are being held with a major landowner in this area to determine interest in stewardship activities.

[Beige] - These areas in New Brunswick are fragmented by timber extraction to some degree. According to the Wildlife Conservation Society's maps of human influence (section 5.3), these areas have been subjected to less human influence than those surrounding, increasing their value as wildlife habitat. There is no residential development inside these spaces and timber extraction mainly occurs beyond their borders, making them ideal stepping stones. J.D. Irving Ltd. owns a large parcel of forest land just north of these areas, which they manage for softwood plantations.

[Purple] – This small parcel of land on the edge of the Tintamarre National Wildlife Area has high value as a connective habitat between forest and wetland. It could serve as a stepping stone for wildlife moving from patches to the north to access the wetland water resource.

[Red] – This is the Missaguash/East Amherst Wildlife Management Area, a newly created conservation area that complements nearby wetland conservation areas. Management regulations have not yet been developed for this area, and it is entirely possible that resource extraction could take place under the Wildlife Management Area designation. Notwithstanding, all harvesting within zones 1, 2 or 3 of the North Tyndal Protected Water Area would be subject to approval.

[Yellow] – This is the North Tyndal Protected Water Area. The North Tyndal Well field represents a large, relatively intact habitat on the isthmus that could be a key component as part of a corridor for wildlife movement between the provinces. By ensuring that connectivity is maintained between this large area and other large tracts of forested habitat on the isthmus, through stepping stone networks and stretches of continuous forest cover, the passage (e.g., moose) and occupancy (e.g., northern flying squirrel) of a number of species may be possible over time. Also, given that water is easily accessible within this area, it represents potential habitat for a number of forest and wetland species, such as cavity-nesting waterfowl.

[Green] – The southeast slope of Uniacke Hill was identified as a winter moose concentration area, and in conjunction with the North Tyndal Protected Water Area and the Missaguash/East Amherst Wildlife Management Area, would serve to provide a connected seasonally important habitat for moose on the isthmus, with intact migration corridors. This could provide a basis for dispersing moose populations to use the isthmus in future.

7.2 Best Options for Connectivity

Figures 23 and 24 illustrate potential pathways for wildlife connectivity corridors between Nova Scotia and New Brunswick. The red lines on the map show areas where conservation attention could be focused to promote connectivity for terrestrial fauna, using the size of roadless patches as the main criterion. Based upon the information presented in the maps above, the paths are biased toward the northern part of the isthmus and were based on the location of roadless (relatively undisturbed) patches from Figures 10 and 11, a map-based review of habitat and land cover information in Figures 9 and 12, local knowledge on wildlife movement, and connectivity studies from Nova Scotia. It should be noted that these pathways are largely independent of road class, although some effort was taken to avoid the towns of Amherst and Sackville and the Trans-Canada highway on the southern side of the isthmus.

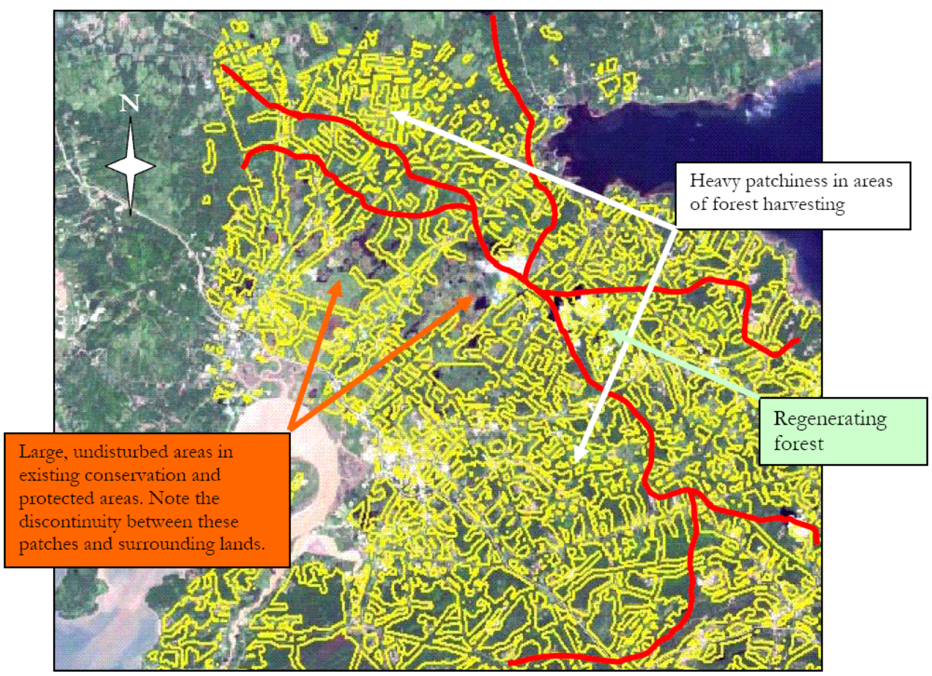


Figure 23. Proposed wildlife connectivity corridors superimposed on Figure 10, to show importance of large patches to landscape connectivity. The corridors are based on location of large patches, land cover observed within patches, local knowledge of wildlife movement, and review of academic studies on wildlife connectivity. The route was designed to avoid regenerating or cleared forest areas, shown in Figures 9 and 12.

The proposed paths of the corridors are quite perpendicular with respect to the major rivers draining the isthmus, a design that does not take into account the use of riparian areas and local wetland networks as movement corridors. Instead, we chose to focus on possible routes relating to connectivity at a landscape and regional level *across* the isthmus, again using the size of roadless patches as the main criterion. It should be noted that there are a variety of different routes that such corridors could take, and given the largely qualitative nature of this analysis, more study[133] will be required to identify an optimal pathway.

With both 200m and 600m buffers created around roads, the proposed connectivity corridors run predominantly between large 'roadless' patches. Given the distance between patches within the proposed corridor, it is possible that some wide-ranging wildlife could move across the landscape along such routes. For some species, such as northern flying squirrel or marten, it seems that roadless patches of suitable quality habitat may be too far apart for movement to occur (see Appendix 1 for details). In any case, not all species need to move regularly between patches and may instead inhabit them; their occurrence may more closely reflect the overall *amount* of habitat on the landscape, independent of its pattern[134]. Alternatively, species with larger home ranges may be affected by patchiness given their reluctance to move regularly between patches to fulfill foraging and resting requirements. Given the lack of empirical data on wildlife distribution and movement patterns across the isthmus, it is difficult to apply the results of other studies that provide threshold distances for movement between patches to the focal species.

Areas of regenerating forest, largely located between roadless or unharvested forest patches identified with the 200m buffer around roadways, were generally avoided in proposing routes for connectivity corridors. This decision relates to the notion that wildlife prefer protective cover for movement in lieu of crossing open spaces. In the case of ungulates, which forage on browse species typically found in open areas, the proximity of open areas, such as the Maritimes & Northeast Pipeline or regenerating forest sites, may facilitate use of the proposed corridors.

Many local residents strongly suggested that attention on corridor conservation be focused on a certain section of Trans-Canada Highway 16 (see Figure 23). The proposed pathway in each figure crosses the highway at the identified section, creating a sort of 'movement funnel' across the isthmus. It should also be noted that one of the suggested corridor pathways runs parallel and very close to the Maritimes & Northeast Pipeline 25m-wide open, right-of-way corridor. Though the pipeline corridor is narrow, its presence could affect the potential for some species requiring wide corridors for movement, i.e., bears (2.0km wide) and bobcats (2.5km wide) based upon home range size[135].

The second part of the corridor that runs along the coast of Baie Verte and also crosses Highway 16 was based upon information about moose presence in that area and the suggestion that moose, bears and deer travel along north-south routes in that area to gain access to the seacoast[136]. Likewise, the section of the corridor coming from the Shinimicas

River watershed is based upon speculation that this area is important for large mammals, given anecdotal reports of bear along the Northumberland Strait coast[137] and the proximity to large roadless patches.

In Figure 23, the proposed connectivity corridor has been adjusted based upon visual interpretation of land cover within the path of the original corridor illustrated in Figure 9. The path was adjusted from its original form to ensure connectivity between large patches of forested land shown in the LANDSAT image. Overall, it is better to ensure that the corridor connects the few remaining large patches, rather than a higher number of smaller

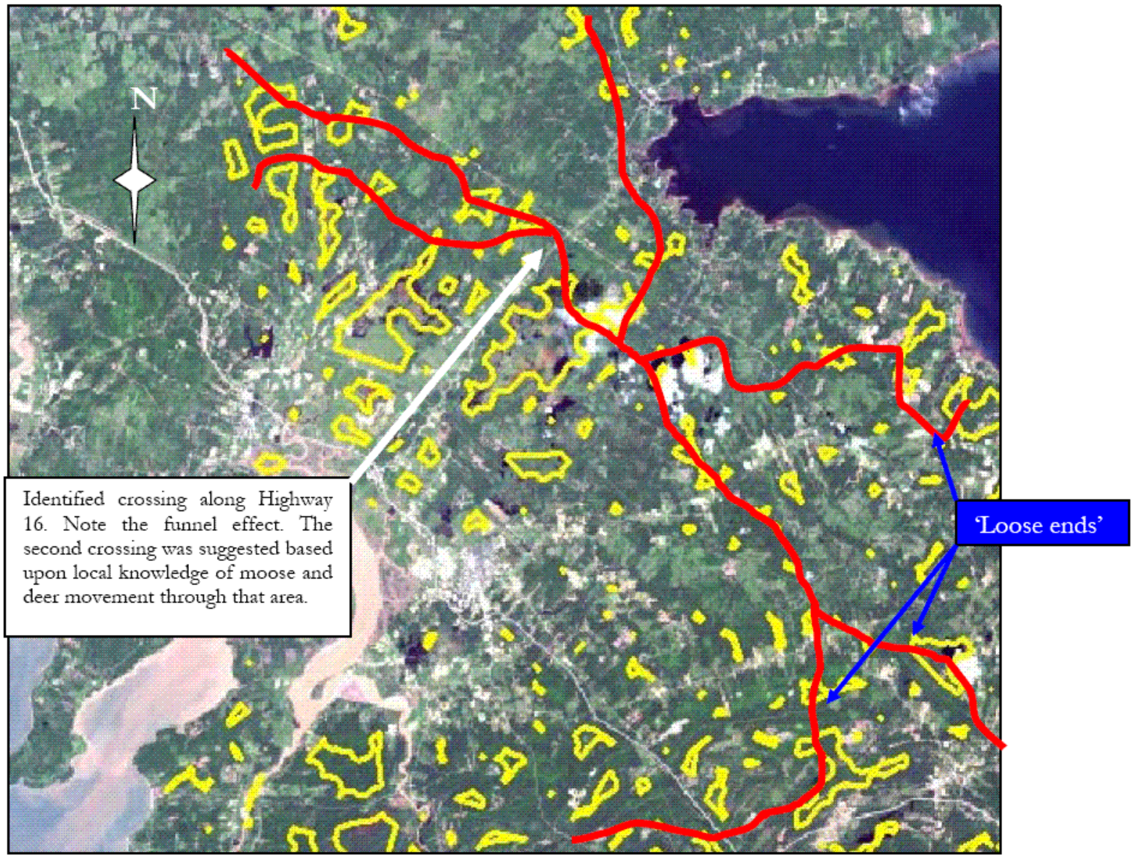


Figure 24 - Proposed routes for wildlife connectivity corridors based upon 600m buffer patches from Figure 11. Corridor routes have been slightly altered to capture remaining large roadless/unfragmented patches. Note the wildlife crossing point at Highway 16 and "loose ends" that permit these corridors to create connectivity with other populations in NS.

patches[138]. Based upon the concept of landscape connectivity[139], the spatial arrangement of the corridor and the patches it connects is also key, with "closer and larger" patches not broken by roads, waterways, clear-cuts or agriculture-improving connectivity[140]. We considered these factors where possible.

There are three important 'loose ends' on the Nova Scotia side of the proposed connectivity corridor (see Figure 24). These paths serve to connect our proposed corridor with the Cobequids moose population approximately 80km from the isthmus in north-central Nova Scotia[141]. Likewise, the bottom 'loose end' could indicate a route by which to connect moose on the isthmus with those in and around the Chignecto Game Sanctuary, approximately 25km south of Amherst.

As described in previous work, special management of moose habitats will be required in areas falling within the path of the connectivity corridor[142]. Accordingly, we suggest that special management extend to additional wide-ranging focal species identified as part of this exercise. It should be noted that based upon Figure 18, it appears that some of the larger Crown land blocks in Nova Scotia may coincide with a proposed connectivity corridor for the mainland population of moose (as shown in Appendix 1, Figure B, p.69), though this is difficult to determine based on the difference in scale. This area could be accessed along the pathways proposed in the connectivity corridors presented in Figures 19, 20, 22 and 23. In particular, this could provide some connectivity for the Cobequids moose population[143]. Nevertheless, there remains a question about how to connect to the Cobequids population across the Trans-Canada highway on the southern boundary of the figures.

Given the amount of landscape fragmentation caused by roads, it is possible that the movement of some wildlife could be limited, as some area-sensitive species will not use or move between patches that are too small. Figures 25 and 26 show the size of patches in hectares remaining after 200m and 600m buffers, respectively, were placed around the roads in Figure 9. Arrows (shown in blue) on each figure suggest pathways, biased to the northern portion of the isthmus, which could be important to the movement of some species between these patches. As in Figures 23 and 24, these pathways are based on qualitative analysis and are subject to a variety of factors influencing the behaviour of species that could follow such routes, not the least of which is habitat type, size and quality within and between the patches. The route of each pathway differs from those shown in Figures 23 and 24. That is because this analysis is only based upon patch size and does not include any visual interpretation of actual land cover.

The route shown in Figure 25 is more relevant to species that inhabit patches, or require connectivity at either local or landscape levels, such as small mammals and nesting songbirds. Patch sizes along the route range from 201 hectares to 4,366 hectares.

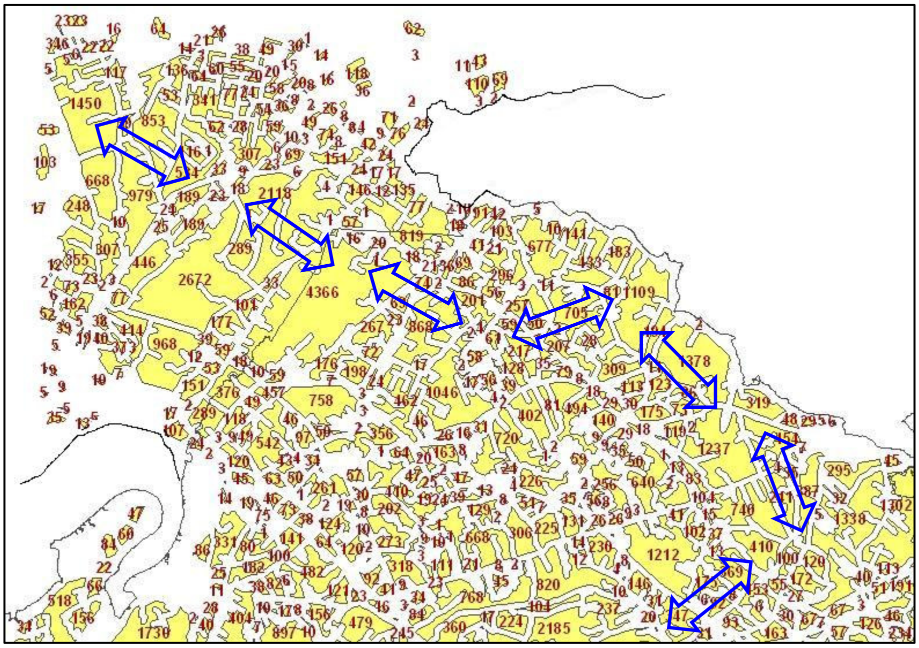


Figure 25 - Size of patches (ha) created through 200m buffer around roads in Figure 9. Blue arrows depict a possible pathway for wildlife connectivity, based solely upon patch size.

The route in Figure 26 relates mostly to species that require connectivity at broader landscape and regional levels. As in the earlier suggestions for wildlife connectivity corridors across the isthmus, additional work will have to be done to determine the actual distribution and movement patterns of wildlife on the isthmus. Patch sizes along this route range from 80 hectares to 2,302 hectares.

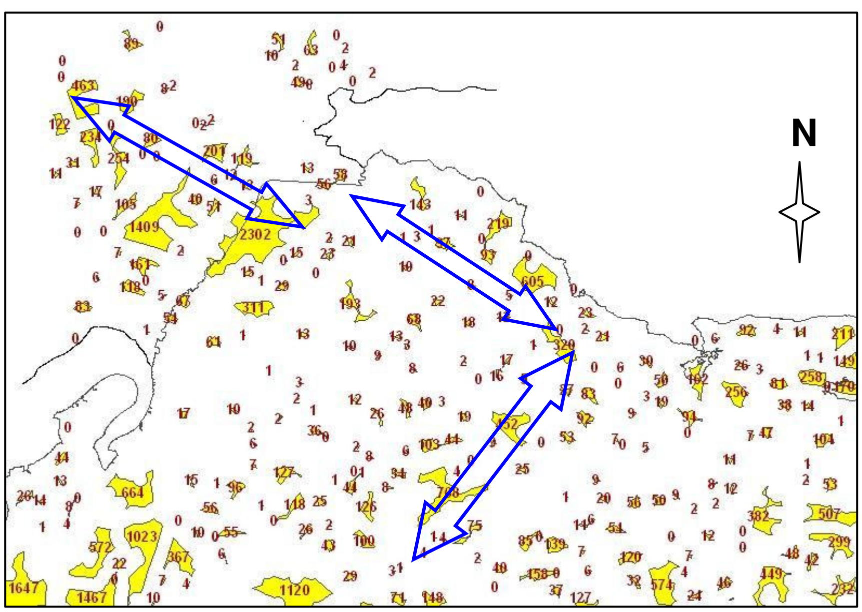


Figure 26 - Size of patches created by 600m buffers around roads in Figure 9. Blue arrows depict a possible pathway for wildlife movement based upon patch size only.

Regardless of patch size with either 200m or 600m buffers, the distance and quality of habitats between and within the patches will contribute greatly to their ability to be used by most species[144]. Also, movement will not necessarily be from largest patch to next largest patch in a logical fashion, and will be affected by a number of different environmental and ecological factors. Roads, as one source of fragmentation of the original landscape cover, have been suggested to cause habitat avoidance, disrupt natural interactions between animals and alter the natural behaviour of individual animals, amongst other affects[145].

7.3 Proposed Missaguash/East Amherst Wildlife Management Area

The proposed 3726 ha area should be given official designation as a wildlife management area, and should include the former Hackmatack Lake and Round Lake Game Sanctuary, in its entirety. This proposed WMA includes 422 hectares in New Brunswick that is owned by the province of Nova Scotia.

As a result of our recent efforts to assess conservation opportunities and challenges on the Chignecto isthmus, we conclude that numerous wildlife species serve to benefit from this designation, including terrestrial, arboreal and aquatic mammals, waterfowl, shorebirds, rare plants, reptiles, fish and amphibians.

- This area potentially serves as a key seasonal habitat for local moose. Based on 2001 Pellet Group Inventory data, moose are known to occur in this area of the province. Local residents and hunters confirm the presence of a moose winter concentration area north of the proposed wildlife management area on the southwest side of Uniacke Hill (straddling the Nova Scotia-New Brunswick border). Moose are known to move from upland winter concentration areas to lowland marshes and conifer stands in the spring and summer months. The location of the proposed wildlife management area thus facilitates movement of this species between seasonal habitats.
- Local residents, trappers and representatives of the Cumberland County River Enhancement Association indicate that aquatic habitats, particularly on the Nova Scotia side of the Chignecto isthmus, have been significantly degraded due to wetland channelization and siltation and deposition of sediments. These factors negatively alter shorebird foraging areas and detrimentally affect fish habitat. The degradation of inland waters throughout the Chignecto isthmus could potentially impact recovery efforts for Atlantic salmon stocks. In addition, declines and losses of endemic fish stocks, i.e., brook trout, have an impact on aquatic mammals, such as river otters. Local residents and trappers suggest that river otter populations have been in decline in recent years.
- Lakes within the proposed area are home to rare freshwater mussels (classified S1, or very rare), *Leptodea ochracea* or Delicate Lampmussel, that would be at risk of disappearance if development of this ecosystem were to occur. There is evidence to suggest that freshwater mussels originally colonized Nova Scotia using the rivers of the isthmus as a pathway[146].

Photo of the Portage Lakes and Beech Point areas of the upper Missaguash Marsh, where local contacts identified an area along Trans-Canada Highway 16 important to wildlife passage between Nova Scotia and New Brunswick. *Photo by: A. MacDonald, May 2005*

Although only 314 ha of the proposed area are categorized as "forested", forest and wetland species require the mosaic of habitats currently present. Precluding habitat fragmentation in this area is crucial, and land-use practices that would in any way create disjunct patches should be strictly limited. The Missaguash/East Amherst proposed wildlife management area represents a source habitat for a variety of local wildlife populations and thus should be maintained in a wilderness state. Its status as public land is also relatively rare on the isthmus, providing an opportunity to maintain habitat connectivity in a critical part of the isthmus over the long term.

Timber extraction is permitted to occur in Nova Scotia's wildlife management areas. CPAWS is proposing that forest harvesting, even if limited, should not occur in the Missaguash/East Amherst WMA. Timber extraction and associated activities could have a negative impact on surface freshwater and groundwater resources in the area. Likewise, timber extraction could fragment and degrade wildlife habitat on this important biological bridge connecting Nova Scotia to the rest of Canada.

7.4 Filling Gaps in Knowledge Related to Connectivity

In conducting this assessment of natural ecosystem connectivity on the Chignecto isthmus, we developed a sense of existing gaps in knowledge that should be addressed in order to maximize the natural value of this small, but crucial, landscape. The following points summarize our findings:

- There is a relative paucity of empirical data surrounding mammal, reptile and amphibian presence/absence and movement across the isthmus, and most of the element occurrence data available for the area is geographically biased to existing protected and conservation areas. More **extensive wildlife surveys and inventories in the Chignecto isthmus, especially in the forested landscapes,** would develop better element occurrence, presence/absence and local abundance data for the area. This would permit conservation stakeholders to more quickly identify the conservation potential of this landscape. Analysis of the amounts of habitats on the isthmus (especially for indicator species), in addition to the pattern of those habitats, would be useful for land management purposes.

- Local naturalist groups, such as the Chignecto Naturalists' Group, could **undertake Christmas Mammal Counts** to better qualify the importance of the isthmus as a corridor for wildlife movement and to identify species moving through the area.
- Provincial wildlife managers should work cooperatively to compile and compare non-avian wildlife data on the isthmus to **quantify the level of connectivity** associated with that landscape. This would also provide early warning mechanisms for losses of connectivity for particular species in relation to development or environmental changes in the area.
- The provincial departments of Natural Resources should analyze DNA samples for moose found within 100km of either side of the isthmus to determine if there is a **fourth isolated sub-population of moose** on the isthmus that moves back-and-forth between the provinces. It is not clear if DNA samples used for existing analyses of population connectivity were from New Brunswick moose near the NB/NS border area.
- It seems that little research has focused on the role of the isthmus under future climate change scenarios. Research on this theme should be undertaken soon to assess the potential for **new species immigration** into the province or losses of north-south migration routes for endemic species.
- Students and researchers should undertake direct study of mammal, reptile, amphibian, invertebrate and plant populations on the isthmus to provide empirically-based assessments of connectivity. Likewise, efforts could quantify the true species richness of the isthmus and establish benchmarks for future assessments of connectivity and fragmentation on the isthmus.
- Researchers (either governmental of non-governmental) need to determine land ownership patterns in priority areas for conservation and potential connectivity routes, as well as in areas where special elements occur. This would clarify priorities for landowner contact with respect to stewardship of key areas.

7.5 Suggestions for Planning and Conservation Strategies - Next Steps

1. CPAWS NB and CPAWS NS could bring together a steering committee of local stakeholders, government representatives, regional academics and CPAWS staff to oversee additional phases of this project. CPAWS staff could chair meetings of the steering committee to discuss progress on actions and recommendations stemming from this report. In addition, meetings would permit stakeholders to communicate and discuss new developments with respect to issues that could affect connectivity across the isthmus.

2. In order to consider the broader cross-border regional implications of community sprawl, planning commissions and municipalities in jurisdictions near or leading up to the border could coordinate some of their community planning goals and zoning plans. The maintenance of habitat connectivity could become a consideration in the siting of new developments, with community plans conserving key stepping stones of natural habitats in

the Chignecto isthmus corridor, and ensuring that new developments do not pinch off ecological connections across the isthmus.

3. NS and NB provincial government Departments of Transportation could avoid the key natural habitat linkages and wildlife corridors identified in this report, if new roads are constructed. Inter-provincial cooperation on the establishment of wildlife travel corridors under roads should also be considered, especially for roads that run in a north-south direction, effectively cutting across the entire isthmus.

Scientists working in the Greater Fundy Ecosystem suggest that in order to preserve ecological integrity, road densities should be no higher than 0.58 km/km^2. This compares to research on focal species connectivity in Nova Scotia that suggests road densities of lower than 0.60 km/km^2 reduce the negative impacts of fragmentation on wildlife populations and increase habitat quality. Our work shows that road densities on the Nova Scotian side of the isthmus are greater than either of these threshold values, but only when trails and logging roads are included. Future planning of roadways, including logging roads and trails, on the isthmus should avoid exceeding these values. Likewise, existing K-class logging roads and trails that are no longer needed could be decommissioned and allowed to revert to original habitat. These measures could serve to reduce the impacts of fragmentation and promote connectivity across the isthmus.

4. Those organizations that work with private landowners on conservations issues, such as land trusts and conservancies, the Fundy Biosphere Reserve Initiative, the Chignecto Agro Club, Ducks Unlimited and FSC certified forest managers, could raise the profile of habitat connectivity issues in the work they already do on the isthmus. They are in a good position to know about on-the-ground interests of isthmus landowners, and may be able to piece together connected parcels of stewardship lands.

5. Given the importance of continuous forest cover along wildlife movement corridors across the isthmus, or at least stepping stones of forest habitat, collaborative forestry strategies specific to the isthmus could be developed between large industrial foresters, woodlot owners, members of the Steering Committee and the provincial departments of Natural Resources.

6. Wildlife managers and biologists should be aware that there is a dearth of theoretical and empirical data illustrating the potential and/or actual movement of terrestrial wildlife across the borderlands. With strong potential for current and future species migrations relating to climate change and/or range expansion, it would be prudent to begin a program to monitor wildlife assemblages on the entire border area. Nova Scotia is unique in Canada as the province having only a narrow terrestrial connection to the rest of the continent, a small area across which all regional terrestrial ecological flows are directed. Given this circumstance, wildlife managers and planners do not have a precedent to follow with respect to thinking about connectivity and the need for comprehensive programs to monitor ecological integrity on the border. This is an opportune time to undertake collaborative measures to develop strategies and policies to preserve connectivity on the isthmus.

7. Strategies could be developed between the New Brunswick and Nova Scotia Departments of Natural Resources (wetlands, forestry and wildlife programs staff), the Canadian Wildlife Service, independent researchers and non-government organizations to coordinate wildlife conservation and habitat management efforts across the provincial border. There is a strong need for an inter-jurisdictional approach to wildlife management on the isthmus given the collection of different habitats so closely juxtaposed in this small landscape. The focus of these efforts should be to ensure that unfragmented, functional forested habitats are maintained on the isthmus in great enough supply that wildlife movement is not impeded. The Pollett River Watershed project of the Greater Fundy Ecosystem Research Group could be used as a model for this type of coordination.

8. The Town of Amherst should continue to acquire land within Zones 2 and 3 of the North Tyndal Protected Water Area. When reviewing plans for residential, forestry or agricultural use of those lands, the Well field Committee could consider additional measures to limit the impacts of any development on the connectivity of the well field to surrounding intact forest and wetland habitats.

9. Recovery efforts for regionally endangered species typically include input from all provincial governments, as well as the federal government. However, some endangered species in Nova Scotia are not listed in New Brunswick, e.g. moose. Directly across the border in New Brunswick, moose are considered to be plentiful and are actively hunted for a specific time each year. Given the need for greater connectivity between Nova Scotia and New Brunswick to maintain a viable moose population in Nova Scotia, the NS Mainland Moose Recovery Team should include representatives from the NB Dept. of Natural Resources, in order to ensure that opportunities to develop connectivity with moose in isthmian New Brunswick are not missed or overlooked. Regardless of the species in question, recovery teams in Nova Scotia could look at opportunities, where appropriate, for connectivity across the isthmus with larger sub-populations in other jurisdictions.

10. Wetland conservation and coastal zone management policies in New Brunswick provide a solid context for the conservation of such ecosystems in that province. In contrast, Nova Scotia is lacking a formal wetlands policy. Such a policy would help to expand current efforts to restore and conserve wetlands on the Nova Scotian side of the isthmus, which, in turn, would help to restore ecological integrity on the southern portion of the isthmus where the most significant human influence is concentrated.

11. Regional economic development strategies, particularly those relating to local tourism opportunities, could incorporate programs to promote the notion of the isthmus as a ‘crucial natural landscape’. Where practical, opportunities for sustainable, low-impact ecotourism could be developed to highlight the isthmus as a natural corridor. Perhaps interpretive tours exhibiting the unique natural history of the cross-border region could be developed.

Appendix 1 - Habitat and Connectivity Needs for Select Species

A. Habitat Fragmentation and Stepping Stones across the Isthmus

The distribution of small fragments of habitat, or "stepping stones", as a corridor across a landscape can allow wildlife to move between large areas of intact, suitable habitat, effectively creating connectivity[147]. A good example is a stream. Each stream-bank represents a large area of intact, suitable habitat; open water provides no means of crossing the stream, but stones aligned in the stream channel can be used as a path across the water. If the stones are too far apart, animals with a short leg-span or jumping distance will not be able to cross, though larger species will cross with little problem. Birds will cross the small stream channel easily, but if we expand the example to a large river, such as the Annapolis River in Nova Scotia, islands in the river channel become important as stop-over points for some birds.

Apply the above example to an area where a 100 ha section of forest has been cleared leaving small patches of 10 ha spaced at approximately 500m apart. Some species will cross the 500m gaps to travel between patches, and perhaps eventually across the entire cut area. For others, the distance of separation between each patch could prevent movement and lead to an "island effect"[148] or no movement at all through the landscape. This generally applies to some small mammals, songbirds, or even large carnivores such as lynx. Individuals 'stranded' in such patches may become more vulnerable to competition for food and space, predation, inbreeding, habitat degradation and negative influences from the surrounding landscape[149]. The number of patches can create a barrier to the dispersal of individuals. Research has shown that a higher number of smaller patches in a landscape can lead to more of the effects of fragmentation, and thus less connectivity, than fewer large patches across the same area[150].

"Stepping stone" patches are not just used by vertebrate animals, but also by insects, such as butterflies, and plants. The spacing between patches can be crucial in ensuring that plants and insects are able to recolonize sites in a landscape where they may have been lost[151].

Much of the woodland on the isthmus is fragmented by logging activity, roads and human developments, effectively creating patches of forest habitat across the landscape. Likewise, breaks in forest cover within riparian zones and channelization and damming of wetlands may limit the ability of mammals that frequent streams and wetlands, such as mink or river otters, to use and move through those habitats. Channelization and damming are historic features of the wetlands on the southern portion of the isthmus. By ensuring that patches of habitat are distributed at appropriate distances to act as "stepping stones" for species that are sensitive to the distance between patches, such as bobcats, Pileated Woodpeckers, river otters and flying squirrels, connectivity can be maintained across the isthmus. Raccoons, skunks and coyotes, all able to persist in areas of high patchiness (i.e., $<1km^2$ in size), are also shown to use corridors and could benefit from the maintenance of stepping stones[152]. It should be noted, however, that because large-bodied carnivores use more space and have low population densities, they are especially sensitive to the effects of isolation[153], so extra attention should be given to ensuring connectivity between patches for such species on the isthmus.

Quick facts about stepping stones as corridors

Studies of British red squirrels (*Sciuris vulgaris*) show that "stepping stones" of forested habitat allowed mixing and breeding, over 20 years, of individuals from populations that had previously been separated by up to 100km across a formerly intact forest[154].

Bobcats have been shown to use patches as small as 1.8km^2 in size, with a movement corridor arising when distances of 6m separated adjacent patches in an urban landscape. Fewer large patches seem to be more effective at achieving this than higher numbers of smaller patches[155]. Connectivity between patches appears to be critical to the persistence of bobcats in fragmented landscapes[156].

River otters inhabit and move along riparian edges and require vegetation that provides good escape cover, denning sites and resting areas. Likewise, deadfalls, snags and woody debris around aquatic habitats are important components of otter habitat[157], as are upland areas for resting and shelter and it is important to maintain corridors between these habitats and water in order to avoid habitat fragmentation[158]. Overland movement is also important during flooding and otters are known to use tributaries as corridors[159]. Channelization of wetlands and damming of rivers and streams[160] removes the vegetative cover essential in maintaining stream quality and protective cover, fragmenting riparian habitats and degrades habitat quality for otters. Water pollution and increased water temperature, due to loss of riparian cover, non-compliant agriculture and/or streamside development, are also particularly negative for otters, as these effects cause decreases prey species, such as fish and crustaceans.

Coyotes have been shown to use habitat patches in fragmented urban landscapes, with distances of 883m between patches and an approximate patch size of 1ha permitting individuals to use fragments as a corridor[161]. Given its ability to maximize use of fragmented landscapes, this species may serve to illustrate incidences of connectivity where other wide-ranging species are absent[162].

B. Connectivity on the Isthmus - Isthmus as Home

Interior Forest Birds and Mammals

Habitat needs: Interior forest bird species differ in their individual habitat needs depending on their behaviour and biology, though species preferring interior are generally intolerant of edge or transitional habitats, and are thus negatively affected by forest fragmentation[163]. Forest interior can be loosely defined as areas 100-200m from the forest edge. Forest patches between 100 and 400ha in size have been shown to be a threshold for the presence of "all forest-dependent" birds species, with patches between 50 and 75ha may provide marginal habitat for small populations of most interior forest species[164]. Forest structure and management considerations must encompass the needs of primary cavity-nesting species (e.g., woodpeckers), secondary cavity-nesters (e.g., some raptors and many songbirds), weak cavity-nesters (e.g., chickadees), open nest species (e.g., thrushes) and ground-nesters (e.g., Ovenbird or grouse).

Primary-, secondary- and weak cavity-nesting birds require certain forest types composed of suitable trees in which to excavate or colonize nest cavities. Such species are known to use dead snags and old, partially-alive conifers and deciduous trees for nesting, feeding and roosting (different trees for each[165]). In some cases, primary cavity-nesters may prefer living, large diameter aspen[166]. With respect to ground- and open-nesting birds, research in New Brunswick has shown that interior forest species such as Ovenbird, Blackburnian Warbler and Golden-crowned Kinglet respond negatively to the removal of large trees from intact forest habitats[167].

Home range: Home range sizes for birds are typically directly correlated to body weight, and thus for the most part, body size[168], so more 'massive' birds will tend to have larger home ranges[169]:

Blackburnian Warbler = 0.52 ha
Ovenbird = 1 ha
Pileated Woodpecker (primary cavity nester) = 130 ha[170]
Spruce Grouse = 13-33 ha[171]
American Kestrel = 140 ha
Least Flycatcher = 0.16 ha
Common Raven = 928 ha

Forest bird populations on the isthmus have been affected, both positively and negatively by a variety of factors (see Erskine and McManus, Jr. 2005[10] for an in-depth discussion). Populations of conifer-dependent interior forest species such as Boreal Chickadee, Golden-crowned Kinglet, Spruce Grouse, Pileated Woodpecker and possibly Ruby-crowned Kinglet have decreased on the isthmus over time as a result of prevailing timber harvest demands that target their habitats[172]. Similarly, some forest species have declined on the isthmus in the last 20 years because their previous abundance was related to the mid-1970s spruce budworm outbreak: Evening Grosbeak, Tennessee Warbler, Cape May Warbler and Bay-breasted Warbler[173]. Also in relation to loss of suitable habitat, populations of species such as Chimney Swift and Common Nighthawk, as well as the inland bog species Palm Warbler have decreased on the isthmus. Alternatively, there is evidence for increases - in some cases only temporary - in some species that prefer hardwood forest cover or shrubbery, as a result of the substantial loss of conifers during the spruce budworm outbreak: Ovenbird, Mourning Warbler, Canada Warbler, Least Flycatcher, Veery and Rose-breasted Grosbeak[174].

Habitat connectivity for forest birds can be thought of as a function of an individual's ability to successfully find territory, nest, forage and access cover and roosting areas in a fragmented forest landscape. It is established that fragmentation of forested habitats on breeding grounds has significantly contributed to the decline of many migratory birds, particularly in the case of area-sensitive species that cannot find suitable patches in relation to home range size[175]. These species may experience difficulty in foraging or finding mates in patches, avoid patches entirely or opt for the use of connecting corridors to move between habitat patches[176]. Some research has shown that habitat connectivity also facilitates between patch movements of adults in search of additional mating opportunities[177].

Northern Flying Squirrel

Habitat Needs: In the Maritimes, northern flying squirrels appear to be dependent on forest stands with older forest structural characteristics, including both coniferous and deciduous tree species, and varying sizes of snags, stumps, and decaying logs. Their abundance tends to be highest in mixed stands. These structural characteristics provide the conditions to support a wide range of food resources (e.g. fungi, lichens, birch seeds, beech nuts, insects, spruce cones) and nesting and predator-evasion / gliding opportunities[178]. Research suggests that in order to promote movement between "launch" and feeding trees, gaps in suitable forest cover should be no greater than 20m[179].

Home range: 2.75 ha for females, 12.49 ha for males

American Marten

Habitat Needs: Prefer old conifer-dominated forest in large stands (at least 500 ha in size), and are known to use mixed forests, especially if there is significant overhead cover and stand maturity (presence of snags and logs, different levels of vegetation - from shrubs to tall trees)[180]. Research suggests that protective cover improves hunting[181], though marten have been shown to cross straight through clear-cut areas (containing woody debris and cavities in snow) of up to 200m wide during the winter to access patches of suitable forest cover[182]. The same research concluded that marten would cross clear-cuts during the summer to access "uncut softwood islands" in the landscape, but supported the fact that marten are sensitive to fragmentation and alteration of forested habitats.

Home range: 4.4 km^2, with ranges reported from 0.1 to 2.3 km^2 for females and 0.1 to 7.6 km^2 for males[183], depending on the distribution of suitable habitat in a given landscape.

It is reasonable to conclude that forest fragmentation has decreased the amount of suitable habitat for forest-interior birds and mammals on the Chignecto isthmus. The current challenge is to assess the size and distribution of remaining patches in relation to the forest-interior species in decline. With this information, it will be possible to look at existing or potential opportunities for connectivity between patches as a means of promoting a healthy community of forest bird species across the isthmus. It should be noted, however, that Erskine and McManus, Jr.[10] provide distribution information for each bird species on the Northumberland Strait and Cumberland Basin sides of the isthmus, which should be used as a guide in establishing habitat conservation objectives for forest-interior birds across the isthmus. Given the current classification of forests, between 200 and 400 pairs of birds per km^2 may be expected to inhabit the mature spruce stands of the isthmus, while 400 to 800 pairs/km^2 may inhabit 20-30yr mixed conifer stands[184].

C. Connectivity through the Isthmus - Isthmus as Bridge

Nova Scotia conservation researchers have proposed Canada lynx, marten, moose and fisher, among others, as part of a suite of Nova Scotian focal species that are suitable for conservation efforts to capture "necessary ecosystem components" for many other species[185]. The following sections highlight aspects important to habitat connectivity for marten, moose and lynx, with examples of other species that require special attention on the isthmus.

Moose

Habitat needs: Moose use a variety of habitats throughout the year.

Winter concentration areas are generally softwood and mixed stands (approx. 10m high canopy with 50% closure) situated on the upper reaches of southwest facing slopes[186] where appropriate browse and cover species are available; deciduous browse species may include paper birch, yellow birch, pin cherry, aspen, red maple, mountain maple, striped (or moose) maple, willow and showy mountain ash[187], though in the eastern North American region, balsam fir, white birch and trembling aspen are suggested to be key browse species[188]. Several authors report that during the winter months, regenerating clear-cuts (12-15yrs old[189]) are "preferred" foraging habitats for moose, as deciduous browse species are typically readily available on those sites[190]. Cover habitat is important in facilitating thermo-regulation and movement in winter[191], especially at threshold snow depths (>100cm) when snow depth impedes movement in open areas[192]. Multi-scale habitat modelling done for the Tobeatic moose sub-population showed selection for open mixed stands with <40% "crown-closure" and avoidance of stands with >60% "canopy closure" in winter (January to April), as well as avoidance of wetlands and hardwood stands during that season[193], though shallower snow depths, exposure to parasites and different habitat quality in that part of the province may reduce the relevance of these results to other areas of Nova Scotia[194].

Moose in the Tobeatic area showed preference for softwood stands comprising shorter than average trees where a relatively more open canopy promoted growth of browse vegetation for winter foraging[195]. Other studies have suggested that in winter moose will use "uncut softwood islands" (most larger than 2 ha in area) for cover in large clear-cuts until snow depth and condition inhibit their ability to move across open areas[196] to access browse, an important spatial relationship for winter habitat[197]. It seems that moose tend to use open areas more than deer during the early winter months, when they can comparatively move more freely across the landscape[198]. Availability of winter ranges is crucial to adult and calf survival[199].

Open wetlands providing high-quality browse species are important to moose during the early spring months after winter reserves have been expended[200], and may be most important at a scale of up to 6km^2 [201]. Treed islands, peninsulas or open bogs with good forest cover make suitable calving areas in spring[202]. In general, mixed woods with water and open areas appear to be important during this time of year.

At all times of year, cover habitat seems to be very important, and habitat modelling suggests that softwood stands of low plant species richness were particularly important for moose (mainland population) in the Tobeatic[203]. Other research suggests that there is a preference for undisturbed mixed forest over hardwood stands, with partially harvested stands providing little optimal browse[204]. Summer habitats should consist of good canopy cover, to reduce heat stress, with edge or understory species available for browse[205]. Based upon studies from other regions, Snaith (2001)[205] summarized that moose require less cover type habitat in fall and early winter and continue to use edge and open habitats for browsing.

Home range: Recent study[206] of moose in mainland Nova Scotia show a mean home range value of 45.1 km^2.

Isthmus-specific issues

A good assortment of key moose habitats is present on the isthmus, represented in the abundance and diversity of wetland habitats, successional coniferous stands and upland mixed forests of different age classes. There also seems to be a good deal of potential cover habitat surrounding wetlands, complemented by growth of browse around existing timber extraction sites. One informant suggested that winter browse species may in fact be in short supply on the isthmus, at least for white-tailed deer[207]. Based on anecdotal evidence, it seems that the remote rail-bed of the former ship railway was once a key movement corridor for moose, until nearby forestry degraded the habitat[208]. A moose winter concentration area of approximately 23 km^2 is located on the southeast-facing portion of the upland mixed woods around Uniacke Hill (see Figure A) showing results of pellet group inventory surveys in that area), as well as two smaller areas located north of the isthmus on the Cape Tormentine headland[209]. Significant logging areas are present on the coniferous lowlands just below the south side of Uniacke Hill, which, though it may provide browse for moose in the short-term, could also increase the local presence of deer[210] and lead to additional poaching pressure.

Many authors have explored forestry practices in relation to wildlife habitat, though few local empirical studies indicate the best-case scenario for forest management and wildlife conservation, particularly with respect to moose, in Nova Scotia. Brannen (2004) showed that newly clear-cut areas have a negative affect on moose presence, with the extrapolation that *regenerating* cuts 10 to 30yrs in age would provide appropriate browse species[211], a feature that is needed in good proximity to other components of the moose habitat, i.e., shelter or cover. Young stands <40yrs in age may provide a good mix of shelter and browse[212]. Other studies[213] have indicated that suitable cover type habitat for moose tends not to develop until 30 yrs after forest clearing takes place.

Intact riparian corridors are also an important feature of suitable moose habitat. The loss of such areas may be a limiting factor in the recovery of moose (mainland population) in Nova Scotia, as like other large mammals, moose require the cooler microclimate of riparian corridors during the summer, and use such conduits to travel to winter concentration areas[214].

Forest and land-use practices and development on the isthmus should strive to maintain the following assortment of optimal habitat types[215] in order to promote local moose presence and facilitate movement across the isthmus:

- 40-50% "preferred forage area", or open mixed forest based on Brannen 2004.

- 5-15% "softwood forest cover"
- 35-55% "deciduous or mixed cover," consistent with Brannen 2004
- 5-10% "wetlands

Fragmentation of both deciduous and softwood forest habitats on the isthmus may have some impact on moose. Although there are suitable habitats, their overall structure and distribution in the landscape, especially with respect to roads and areas of human influence, may be unsuitable for moose. Road density (especially of permanent roads) is a significant factor that could affect the ability of moose to use the northern portion of the isthmus as habitat or as a dispersal corridor. At various scales, the length of primary and secondary roads in Nova Scotia decreases moose presence; even trails can affect moose presence at a 1km^2 scale[216]. Road density has also been negatively correlated to moose pellet presence[217], particularly when moose avoid habitats at road densities of 0.6km/km^2 [218]. Road density has been suggested to be more important than the composition of a habitat in determining moose presence[219] in landscapes already heavily modified by human activity. There are already several primary roads transecting the isthmus on both sides of the border: Leicester Road (NS), Amherst Head Road (NS), Brooklyn Road (NB), Aboushagan Road (NB), Trans-Canada Highway 16 (NB) and Tyndal Road (NS). The latter two roads are the main linear landscape features that transect the forest on the northern part of the isthmus, with highway 16 having a much higher level of traffic.

Another factor that could limit the productivity of moose on the isthmus is the local bear population. Most informants discussed the high number of bear in the area, stating it was not unusual to see several each season. Bear predation in the Tobeatic Wilderness Area, Nova Scotia, may be a cause of high calf mortality[220], and bears have been shown to account for up to 50% of moose calf mortalities in the first 45 days of life[221].

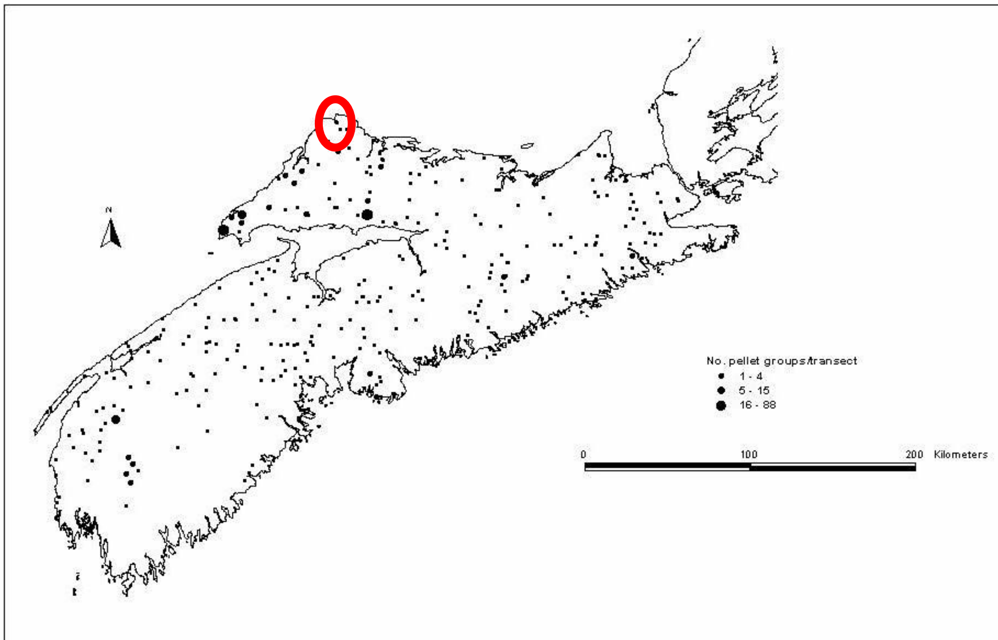


Figure 1-7. Number of moose pellet groups/transect counted in 2001 on provincial pellet group inventory transects.

Figure A - **2001 Moose Presence/Absence data (NSDNR).** Results of pellet group inventory surveys performed by NS Dept. of Nat. Res. in 2001 (reproduced by permission of D. Brannen). Red circle indicates probable Uniacke Hill winter concentration area. Similar data are not available for New Brunswick.

There are two core sub-populations of moose (mainland population) in Nova Scotia: the Tobeatic population and the Cobequids/Cumberland population. Given the current levels of productivity and low density in each population, respectively, Nova Scotia moose (mainland population) cannot reach adequate numbers to ensure "long-term viability"[222]. Hence, using moose pellet presence, habitat parameters and low road density as criteria, Snaith (2001) illustrated connectivity corridors between these populations, zones where land-use should be managed specifically to ensure opportunities to protect gene flow, migration and dispersal in the hopes of improving population viability. To promote connectivity, the corridor extends to the isthmus, as shown in Figure B, and extends into New Brunswick at the point just south of Uniacke Hill, where a winter concentration is known to exist. In this area, Snaith shows another core moose population[223]

Based upon the forestry activity shown in Figure 3 of the report, this corridor may be at risk of being degraded, though it is difficult to speculate the effect on moose without a more detailed assessment of that area at present. Unfortunately, current genetic studies of Nova Scotia's moose population suggest that there is only negligible gene flow and movement between the Cobequids/Cumberland moose population in Nova Scotia and moose in New Brunswick, with what appears to be very little gene flow between the New Brunswick and Guysborough populations[224].

Given the physiography of the of the isthmus landscape, and the knowledge that there is a moose winter concentration area on the Nova Scotia-New Brunswick border, suggests that there may be a small, local population of moose that inhabit the isthmian landscape across the border. It is very odd that moose sightings are so localized in this area of Nova Scotia and then become anecdotally abundant just across the border in New Brunswick. To better understand this disparity, a localized study of gene flow across the border should be conducted to assess the possibility of a separate, trans-boundary population. In fact, it has been suggested that a new core population area could exist across the isthmus based upon a variety of contributing factors[225] (see Figure C).

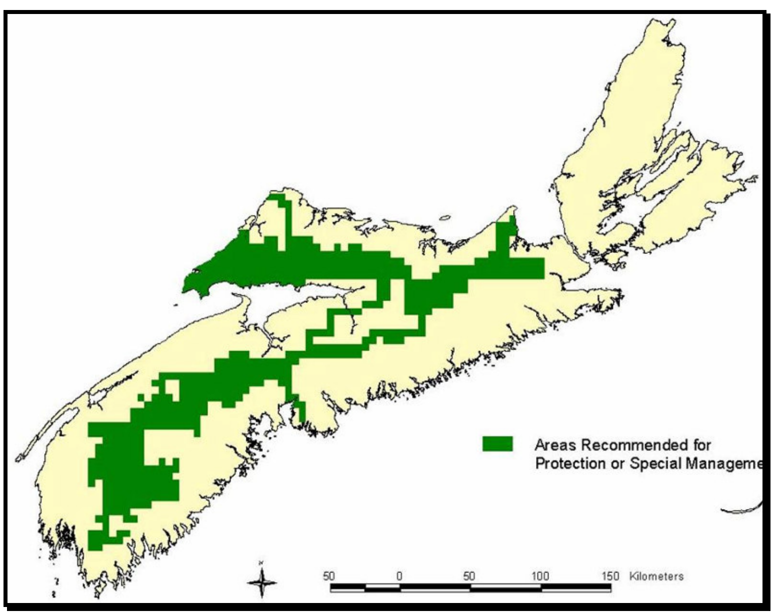


Figure B - Connectivity corridors for moose in Nova Scotia based on suitable habitat and moose presence data[226]

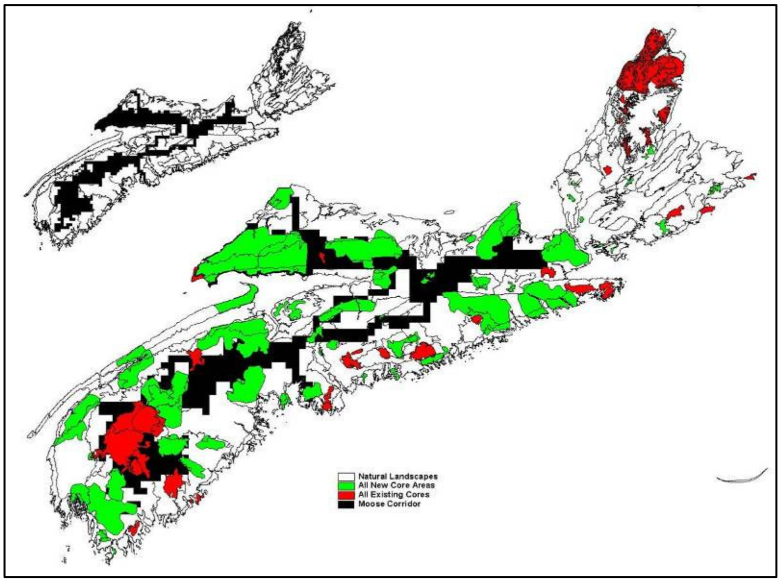


Figure C – Image of Snaith's moose connectivity corridors from Figure B, coupled with existing protected areas, as of 2001 (red), and Snaith's proposed core moose habitat areas (green)[226]. Note the location of a proposed core moose habitat on the isthmus.

Figure C shows proposed core moose habitat areas for Nova Scotia, with one such area occurring on the isthmus. The areas were proposed based upon a number of factors yielding optimal habitat suitability[227]. This proposed core area on the isthmus concurs with our presumption that there is a local population of moose that inhabit the isthmus between the provinces. However, based upon our coarse analysis of habitat for wide-ranging species, it would seem that better opportunities for a core moose habitat may be found on the northern, less developed portion of the isthmus.

Lynx

Habitat needs: Suitable denning habitats are important to persistence of lynx populations. Late-successional forest types or even regenerating stands >20yrs in age with an abundance of deadfalls and other woody debris are reported to provide suitable denning sites, cover and security[228]. Travel corridors of good cover need to link these patches with alternative den sites nearer to prey in the event that prey populations collapse[229]. Mature forests seem to be less important as denning habitat[230].

Overall, habitat use by lynx is dependent on the presence of suitable habitat for preferred prey species. Snowshoe hare and red squirrel as important prey species for lynx[231], particularly with changes in access to alternative prey species during the winter[232]. There is a general lack of research on prey species, but it seems that fox, northern flying squirrel, chipmunks, game birds and songbirds, muskrats, beavers, mice, voles and "a variety of ungulates" (caribou, deer and moose) are elements of the lynx diet in different parts of its range and throughout the year[233]. Although early-successional forests may provide good habitat for snowshoe hare in the short-term, other prey species prefer older forest types. The above cited research concludes that "old gap-phase" forests will provide a relatively greater diversity of prey species and thus are an important part of lynx habitat. In southern and warmer portions of their range, lynx may lose their anatomical competitive advantage over other predators given more frequent thaws during winter may lead to poor quality, crusted snow[234]. Competition with more flexible carnivores may be a limiting factor to lynx during prey population lows [235].

Home range: Like moose and bear, lynx are wide-ranging species with home ranges varying from 8 to 783km^2 [236], and movement distances of up to 1,100km recorded in the Yukon[237]. Male home ranges tend to be larger than those of females, though the home range size of each sex can increase greatly after crashes in prey populations[238]. Tracking studies in northern Maine suggest that lynx are able to cohabitate successfully, with overlapping home-ranges[239].

Isthmus-specific issues

There are currently no lynx known to be present on the isthmus, although long-distance dispersal through this area has been documented during snowshare hare population lows[240]. There are currently no lynx known to be present on the isthmus, though recent work by The Wildlands Project in the Northern Appalachian/Acadian Ecoregion presents an argument for maintaining connectivity potential between lynx populations on Cape Breton Island, Nova Scotia and larger populations in north-western New Brunswick, Maine and Gaspé, obligating the Chignecto isthmus as a corridor[241]. This work shows no high value lynx habitat on the Chignecto isthmus, and indicates that through various climate change scenarios under which snow depth, and thus prey species abundance, decrease over time, lynx presence on Cape Breton Island would decline significantly. In any case, this study highlights the importance of maintaining connectivity between disjunct populations, such as the Cape Breton Island example, and those to the north and west in order to maintain viability in the long-term.

Generally speaking, the presence of coyotes and bobcat throughout the areas between core lynx populations in the Maritimes could be problematic to the movement of lynx through areas of suitable connective habitat. However, given the range of movement recorded in other areas, it is reasonable to theorize that competition with other species, alone, would not prevent lynx from using the isthmus as a travel corridor. Lynx dispersal activity is tightly linked to the crash of snowshoe hare populations, when dispersal is highest, and is even considered a contributing cause in the decline of lynx populations after hare populations collapse[242].

There is evidence to suggest that lynx do not prefer open unforested, grassland or agricultural areas due to lack of security, cover and feeding opportunities[243]. This is an important factor to consider in the management of forested areas on the northern portion of the isthmus. Likewise, it is important to consider forest management practices that will not deter lynx from using the isthmus. It has been suggested that lynx will not cross clear-cuts greater than 100m in width, and significant delays (up to 25 yrs) in the appearance of snowshoe hare in clear-cuts[244] could greatly decrease local feeding opportunities. It has been recommended that up to 50% of dense stands (>2000 stems/acre) should be left unthinned to create optimal conditions for snowshoe hare[245]. Also recommended is that deadfalls and blow-downs should be maintained in at least 10% of the "suitable lynx habitat" in a given area, complemented by up to 60% of that habitat managed for travel cover; good travel cover has more than >30% canopy cover and stand density of at least 200 stems/acre[246].

Road density on the isthmus is another important consideration in discussing opportunities for lynx travel through this landscape. A threshold road density for lynx, among other species, may be 0.63km/km^2, similar to the density at which use of a habitat by moose is affected[247]. In fact, unwillingness of lynx to cross highways, avoidance of human developments, lack of hunting opportunities, vehicle mortality and increased competition with other predators have linked the effects of roads and trails with lynx decline in Nova Scotia[248]. As stated earlier, densities of roads, trails and logging paths on the isthmus range from 0.6 km/km^2 to greater than 3 km/km^2 in places[249]. When considering only the density of highways and primary roads[250], the isthmus provides suitable undisturbed space for lynx between the major roadways. To promote opportunities for lynx to use the isthmus as a corridor, efforts should be made to ensure that further roads and trails are not developed and that existing, little-used roads and trails are restored to original habitat.

Black Bear

Based upon interviews conducted for this project, local knowledge would suggest that local populations are robust and that there are very few barriers to bear movement across the isthmus. A cautionary note must be added that bears may be considered by local people to be abundant when they are seen more often, even though increased sightings may indicate that bears are being squeezed out to areas that are near human habitation (due to lack of habitat or food elsewhere). For a broader discussion of this issue, see Ray et al, 2005 [251]. It should be noted that this species is wide-ranging.

Habitat needs: Bear habitat use in south-eastern New Brunswick includes a wide variety of sites, including young softwood stands that provide good canopy cover and escape trees, stands affected by spruce budworm and possibly general avoidance of mature hardwood patches where beech bark disease may affect food supply[252]. Use of lowbush blueberry fields as a foraging habitat is also recorded. In general this species uses forested and shrubby habitats, as well as treed swamps and riparian areas[253]. Cover and hiding habitats are also important in reducing heat stress during the summer months and avoiding danger, and young successional forest cover may be used during this time[254]. Denning sites are variable and range from large cavities in trees, to rock crevices or undersides of logs, or even anthropogenic structures[255], and are typically located near water sources or conifer-dominated wetlands[256].

Home range: Home range size in less than optimal habitats in southeastern New Brunswick was found to range from 29.7 to 128.4km^2 [257], and over an even greater range between 15.1 and 369.2km^2 in a Quebec study[258].

Isthmus-specific issues

Based on the interviews and research done for this report, there is little concern at present as to the status of bear populations on the ithsmus. The mixture of suitable habitats from early successional to dense softwood forests, all close to wetland or swampy areas, would suggest that bears are able to persist in this landscape – especially given the presence of blueberry production in the region. However, important factors such as home range size and dispersal distance should be foremost in future management of black bear habitats.

Black bears have been shown to disperse distances of up to 120km through a variety of habitats[259]. Given that home range size seems to increase with decreasing habitat quality[260], and dispersal becomes more important as new home ranges are sought, intact corridors suitable for bear should be retained across the isthmus. The scenario for greater movement could be as follows: if current habitats become fragmented or reduced to the point where there are no areas of suitable size to accommodate black bear home ranges, local bear populations could encounter a problem. More importantly, given their ability to coexist with humans, drastic reductions in current habitat could increase interactions between humans and bears, as in the “garbage bear” scenario.

Road density is again an important consideration for bears, with avoidance of habitats near roads shown to range from a distance of 270m to nearly 1km, in the spring and fall seasons, respectively[261]. Tracking studies have also shown bears to avoid highways completely and only cross roads with infrequent traffic[262]. A threshold road density of 0.25km/km^2 for avoidance of habitat is recorded[263], which is exceeded on the isthmus with respect to all roads, trails and logging paths. However, when considering only the density of highways and primary roads[264], which may be more appropriate in relation to this situation, the isthmus provides suitable undisturbed space between the major roadways.

References Cited and Endnotes

[1] Fensome, R.A. and G.L. Williams (eds). 2001. The Last Billion Years: A geological history of the Maritime Provinces of Canada. Atlantic Geoscience Society Special Publication no.15. Nimbus Publishing, Halifax. 212p.
[2] Roland, A.E. 1982. Geological Background and Physiography of Nova Scotia. Nova Scotia Institute of Science. Ford Publishing Co., Halifax. 311p., cited in Maillet, J. 1997. An examination of the relationship between impoundment age and waterfowl and wetland avifauna use of 32 selected freshwater impoundments in the Chignecto border region. BSc (Honours) thesis. Mt. Allison University. April 1997.
[3] Roland 1982, Ramsay 1963 and Ganong, W. 1903. The vegetation of the Bay of Fundy salt and diked marshes: an ecological study. Botanical Gazette *36*: 161-186, as cited in Maillet 1997.
[4] Canada Department of Agriculture. 1973. The Soils of Cumberland County Nova Scotia. Nova Scotia Soil Survey Report 17. 148p.
[5] Aalund, H. and R.E. Wicklund. 1950. Soil Survey Report of Southeastern New Brunswick. Dominion Department of Agriculture. 3rd ed. Fredericton, NB. 109pp.
[6] Can. Dept. Agr., 1973.
[7] Tony Erskine, personal communication, 2005; Can. Dept. Agr., 1973.
[8] Neily, P.D., Quigley, E., Benjamin, L., Stewart, B. and T. Duke. 2003. Ecological Land Classification for Nova Scotia, Volume 1 - Mapping Nova Scotia's Terrestrial Ecosystems. Nova Scotia Department of Natural Resources Renewable Resources Branch. Report DNR 2003 –2. 83p.
[9] Environment Canada. 2004. Canadian Climate Normals 1971-2000. Sackville, NB.
[10] As described in Erskine, A.J. and R. McManus, Jr. 2005. Bird status changes – and changes in environment – in the Chignecto Isthmus region of Atlantic Canada. Canadian Wildlife Service Technical Report Series No. 430 Atlantic Region. Vi+167pp.
[11] Neily et al, 2003.
[12] This is actually the NSDEL equivalent of NSDNR's ecodistricts, though it includes surface vegetation cover. The two classification schemes comprise the same area on the NS side of the isthmus. A landscape ecosystem is defined as "a group of biotic communities, together with their environment, occurring over a particular portion over the landscape and held together by some common physical or biotic feature." (from Nova Scotia Department of Environment and Labour. 2002. Natural Landscapes of Nova Scotia: Summary Descriptions. Protected Areas Branch, NSDEL,Halifax. 103pp.)
[13] Ecosystem Classification Working Group. 1996. An ecological land classification system for New Brunswick. New Brunswick Dept. of Natural Resources and Energy, Fredericton. 94p.
[14] Neily et al, 2003.
[15] Neily et al, 2003; Erskine and McManus, Jr., 2005.
[16] Loucks. O. L. 1959-60. A forest classification for the Maritime Provinces. Proc. N.S. Inst. Sci. 25: 85-167, as cited in Canada Department of Agriculture. 1973. The Soils of Cumberland County Nova Scotia. Nova Scotia Soil Survey Report 17. 148p.
[17] Rowe, J.S. 1972. Forest Regions of Canada. Canadian Forestry Service. Pub. No. 1300. Information Canada, 0ttawa. 168pp.
[18] Taken and adapted from Erskine, A.J. and R. McManus, Jr. 2005. Bird status changes – and changes in environment – in the Chignecto Isthmus region of Atlantic Canada. Canadian Wildlife Service Technical Report Series No. 430 Atlantic Region. Vi+167pp.
[19] Environment Canada. 2003. Ramsar: Chignecto National Wildlife Area. http://www.atl.ec.gc.ca/wildlife/ramsar/chignect.html
[20] Harry Thurston, personal communication, 2005.
[21] Fensome and Williams (eds), 2001.
[22] Browne, S. and D. S. Davis (Eds). 1996. "T4.3 Post-glacial Colonization by Animals." *In* The Natural History of Nova Scotia. V.1. Topics and Habitats. Nova Scotia Museum. Nova Scotia. 3pp.
[23] Ibid.
[24] Browne, S. and D. S. Davis (Eds). 1996. "T11.8 Land Mammals." *In* The Natural History of Nova Scotia. V.1. Topics and Habitats. Nova Scotia Museum. Nova Scotia. 7pp.
[25] Fensome and Williams (eds), 2001.
[26] Browne, S. and D. S. Davis (Eds). 1996. "T4.2 Post-glacial Colonization by Plants." *In* The Natural History of Nova Scotia. V.1. Topics and Habitats. Nova Scotia Museum. Nova Scotia.
[27] Entire sectioned summarized from Natural History of Nova Scotia 1994
[28] R. Hall, personal communication, 2005.
[29] Marc Spence, personal communication, 2005.
[30] Tony Erskine, personal communication, 2005.

[31] Maillet, J. 1997. An examination of the relationship between impoundment age and waterfowl and wetland avifauna use of 32 selected freshwater impoundments in the Chignecto border region. BSc (Honours) Thesis. Mt. Allison University. April 1997.
[32] Thurston, H. 2004. A Place Between the Tides: A Naturalist's Reflections on the Salt Marsh. Greystone, Toronto. 233p.
[33] BoFEP. 2003. *Living Lightly on Land and Water: Native people on the Bay of Fundy*. Fundy Issues #24 Autumn 03
[34] Don Colpitts, personal communication, 2005.
[35] Erskine and McManus, Jr., 2005; Smith and Mackinnon, 1995. Browne, S. and D. S. Davis (Eds). 1996. "T12.10 Plant and Resources." *In* The Natural History of Nova Scotia. V.1. Topics and Habitats. Nova Scotia Museum. Nova Scotia. 8pp.
[36] Erskine and McManus, Jr., 2005.
[37] Smith, A. and C. Mackinnon. 1995. Yorkshire 2000: Signposts Along Tantramar's Past. http://heritage.tantramar.com/signposts.html. Accessed on 5 May 2005.
[38] Erskine and McManus, Jr., 2005; Browne, S. and D. S. Davis (Eds). 1996. "T12.10 Plant and Resources." *In* The Natural History of Nova Scotia. V.1. Topics and Habitats. Nova Scotia Museum. Nova Scotia. 8pp.
[39] Erskine and McManus, Jr., 2005.
[40] Statistics Canada. 2001. "Community Highlights" for Amherst (Town) Nova Scotia, Cumberland (Subdivision C), Westmorland (Parish) New Brunswick, Sackville (Parish) New Brunswick and Sackville (Town) New Brunswick. National Census Data. Extracted 10 May 2005 from http://www12.statcan.ca/english/profil01/PlaceSearchForm1.cfm.
[41] Using data taken from Statistics Canada 2001.
[42] It should be noted, however, that Cumberland County (census district C) represents almost 60 per cent of the total population used in the above calculation, and the geographic area encompassed by the portion of Sackville Parish south of the town of Sackville is not addressed in this report.
[43] NSDNR. 2001. Tidnish Dock Provincial Park. Information brochure.
[44] Harry Thurston, personal communication, 2005.
[45] NSDNR. 2001. Tidnish Dock Provincial Park. Information brochure.
[46] Erskine and McManus, Jr., 2005.
[47] Marc Spence, personal communication, 2005. Graham Forbes, personal communication with Sue Browne of CPAWS NS, 2003.
[48] Erskine and McManus, Jr., 2005.
[49] Marc Spence, personal communication, 2005; Erskine and McManus, Jr., 2005.
[50] Erskine and McManus, Jr., 2005.
[51] Pulsifer, M. 1992. The eastern cougar in Nova Scotia. NSDNR Conservation 16(2&3): Page number not known.
[52] Canadian Endangered Species Conservation Council. 2001. Wild Species 2000: The General Status of Species in Canada. CD Version.; NSDNR. 2002. Results for "Extirpated/Extinct" wildlife. General Status of Wild Species in Nova Scotia database. URL: http://www.gov.ns.ca/natr/wildlife/genstatus/ranks.asp. Accessed 20 May 2005.
[53] Ross Hall, personal communication, 2005.
[54] Marc Spence, personal communication, 2005.
[55] Dillon Consulting Ltd. 2004. Heritage Gas Amherst High Pressure Steel Pipeline Registration and Environmental Assessment. Proponent: Heritage Gas, Dartmouth, NS. 18pp.
[56] Dillon Consulting Ltd. 2004.
[57] Browne, S. and D. S. Davis (Eds). 1996. "T11.6 Shorebirds and Other Birds of Coastal Wetlands." *In* The Natural History of Nova Scotia. V.1. Topics and Habitats. Nova Scotia Museum. Nova Scotia. 5pp.
[58] Environment Canada, 2003. RAMSAR database: Chignecto National Wildlife Area. www.atl.ec.gc.ca/wildlife/ramsar/chignect.html. Accessed 10 May 2005.
[59] Environment Canada. 2003. Ramsar: Chignecto National Wildlife Area. http://www.atl.ec.gc.ca/wildlife/ramsar/chignect.html
[60] Krista Baker, personal communication, 2004.
[61] Erskine, A.J. 1992. Atlas of Breeding Birds of the Maritime Provinces. Nimbus/Nova Scotia Museum (Halifax). 270p.
[62] Cape Jourimain Nature Centre. 2005. "The Ecosystems." http://www.capejourimain.ca/home/interpretation/index.html Accessed 12 May 2005.
[63] Marc Spence, personal communication, 2005.
[64] NSDNR. 1999. Amherst Shore Provincial Park. Information brochure.
[65] Stefen Gerriets, personal communication, 2005.
[66] NSDNR. 2005. Review of Provincial Wildlife Management Areas and Game Sanctuaries Information Sheet: Hackmatack and Round Lakes Game Sanctuary. Online version 18 January, 2005. 1p.
[67] Patterson, R. and B. Pitman. 2004. Freshwater website: Water quality (Source water protection case studies – Amherst, Nova Scotia). Environment Canada. http://www.ec.gc.ca/water/en/manage/qual/case/e_amherst.htm
[68] Jason Macdonald, personal communication, 2005.
[69] Patterson and Pitman. 2004; North Tyndal Protected Water Area Designation and Regulations. N.S. Reg. 200/1992.

[70] Bird Studies Canada, BirdLife International and Canadian Nature Federation. Important Bird Areas of Canada On-line Site Catalogue. http://www.bsc-eoc.org/iba/site.jsp?siteID=NS002. Accessed May 2, 2005.
[71] Austin-Smith, Peter. 1998. Tantramar Dykeland Wildlife Habitat - Status Report. Canadian Wildlife Service, Sackville, NB.
[72] Diane Amirault, personal communication, 2005.
[73] Marc Spence, personal communication, 2005; based on NSDNR. 2001. NS Pellet Group Inventory Data. Wildlife Division, Kentville, NS.
[74] Beazley, , K.F., Snaith, T.V. MacKinnon, F. and D. Colville. 2004. Road density and potential impacts on wildlife species such as American moose in mainland Nova Scotia. Proc. N.S. Inst. Sci. 42(2): 339-357.
[75] Simberloff, D. and J. Cox. 1987. Consequences and costs of conservation corridors. Conservation Biology 1: 63-71.
[76] Adapted from Noss, R.F. 1991. Wilderness recovery: Thinking big in restoration ecology. The Environmental Professional 13:225-234., as cited in Groves, C.R. 2003. Drafting a Conservation Blueprint: A Practitioner's Guide to Planning for Biodiversity. The Nature Conservancy. Island Press, Washington D.C. Page number not known.
[77] Adapted from Bennett, A. 1999. Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation. IUCN World Conservation Union, Switzerland. 164pp., as cited in Groves, 2003.
[78] Mark Gloutney, personal communication, 2005; Harry Thurston, personal communication, 2005
[79] MacKinnon, C.M., Daury, R.W. and R.J. Hicks. 1991. Seabird and Seaduck Movement Through the Northumberland Strait, 1990. Technical Report No. 130 Canadian Wildlife Service, Atlantic Region.
[80] MacKinnon et al, 1991.
[81] Rosenburg, K.V. and Raphael, M.G. 1986. Effects of forest fragmentation on vertebrates in Douglas-fir forests. In: J. Verner, M.L. Morrison, and C.J. Ralph (eds.) *Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates*. Madison, Wisconsin: University of Wisconsin Press, pp. 327-329; and Wilcox, B.A. and Murphy, D.D. 1985. Conservation strategy: The effects of fragmentation on extinction. *American Naturalist* 125:879-887, as cited in Woodley, S. and G. Forbes. 1998. Chapter 8 - Conclusion: State of the Greater Fundy Ecosystem. In S. Woodley, G. Forbes and A. Skibicki (eds). State of the Greater Fundy Ecosystem. GFE Research Project, University of New Brunswick, Fredericton. Page number not known; Keitt, T.H., D.L. Urban, and B.T. Milne. 1997. Detecting critical scales in fragmented landscapes. Conservation Ecology [online]**1**(1): 4.; Memmott, J. 2002. Habitat Fragmentation. http://www.bio.bris.ac.uk/research/community/habitatfragmentation.html. Accessed 15 May 2005; Fahrig, L. and Merriam, G. 1985. Habitat Patch Connectivity and Population Survival. Ecology 66(6): 1762-1768, as cited in Brannen, D.C., 2004. Population parameters and multivariate modelling of winter habitat for moose (*Alces alces*) on mainland Nova Scotia. M.Sc. Thesis. Acadia University. 123pp.
[82] Melanson, G.P. and B.E. Cramer. 1999. Landscape heterogeneity, connectivity and critical landscapes for conservation. Diversity and Distributions. 5(1/2). 27-39. Special Issue: Diversity, Stability and Conservation of Mediterranean-type Ecosystems in a Changing World.
[83] Taylor, P.D., Fahrig, L. and K.A. With. Unpublished. Landscape Connectivity: A return to the basics. Book chapter submitted for publication. Target publication unknown.
[84] Forman, R.T.T. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge University Press, Cambridge, and Forman, R.T.T., Friedman, D.S., Fitzhenry, D., Martin, J.D., Chen, A.S. and L.E. Alexander. 1997. Ecological effects of roads: toward three summary indices and an overview of North America. In : Canter, K. (ed) Habitat fragmentation and infrastructure. Minister of Transport and Public Works and Water Management, Delft, Netherlands. 40-54p., as cited in Beazley et al, 2004.
[85] Summarized based upon citations in Beazley et al 2004.
[86] Seiler, A. 2001. Ecological effects of roads: a review. Introductory Research Essay. Department of Conservation Biology. Uppsala, Sweden. 40pp., as cited in Brannen, 2004.
[87] Beazley et al 2004.
[88] NSDNR. 2005. Moose-vehicle collision data for Nova Scotia. Prepared by Vince Power, Large Mammal Technician
[89] All local contacts interviewed noted this anecdotal evidence.
[90] Taylor et al unpublished.
[91] Cornell Lab of Ornithology. 2005. Birds in Forested Landscapes; Andren 1995, cited in Bayne and Hobson 1998 http://www.birds.cornell.edu/bfl/gen_instructions/fragmentation.html
[92] Erskine 1992
[93] Hames, S. 1998. BFL Analyzes Early Results. Birdscope 12(2): 14-16.
[94] Bayne, E.M. and K.A. Hobson. 1998. The effects of habitat fragmentation by forestry and agriculture on the abundance of small mammals in the southern mixcdwood boreal forest. Can J. Zool. 76: 62-69.
[95] N.S. Reg. 166/2002
[96] N.S. Reg. 200/1992
[97] J. Macdonald and R. Patterson, personal communication, 2005.

[98] NS Dept. of Environment and Labour. 2001. Preliminary Assessment of Eigg Mountain/James River Study Area, Antigonish and Pictou Counties, Nova Scotia. NSDEL Protected Areas Branch, Halifax, NS
[99] Beazley, K.F., Snaith, T.V., MacKinnon, F. and D. Colville. 2004. Road density and potential impacts on wildlife species such as American moose in mainland Nova Scotia. Proc. N.S. Inst. Sci. 42(2): 339-357.
[100]M. Betts, personal communication with R. Clowater and A. MacDonald, 2005.
[101]Ibid.
[102] Based upon interpretation of Beazley et al, 2004.
[103] Adapted from the Anonymous. 2001. "Riparian Areas for Wildlife" The Nebline. October 2001. 5pp.
[104] Naiman, R.J., Decamps, H. and M. Pollock. 1993. The Role of Riparian Corridors in Maintaining Regional Biodiversity. Ecological Applications, 3(2):209-212.
[105] *Fischer and Fischenich 2000*
[106] Gibson and Pittway 1996
[107] N.S. Reg. 166/2002
[108] Watercourse and Wetland Alteration Regulation - Clean Water Act, N.B. Reg. 90-80, consolidation 2004.
[109] Sanderson, E.W., M. Jaiteh, M.A. Levy, K.H. Redford, A.V. Wannebo, and G. Woolmer. 2002. *The human footprint and the last of the wild. BioScience* 52: 891-904
[110] Woolmer, Gillian. 2005. *Northern Appalachians - Human Footprint of the Chignecto Isthmus, Draft Version 0.1, April, 2005.* PowerPoint presentation prepared for CPAWS NB and CPAWS NS. Wildlife Conservation Society Canada. Toronto.
[111] Carroll, Carlos, PhD. 2005. Carnivore Restoration in The Northeastern U.S. and Southeastern Canada**:** A Regional-Scale Analysis of Habitat and Population Viability for Wolf, Lynx, and Marten, Report 2: Marten and Lynx Viability Analysis. Wildlands Project - Special Paper no.6. The Wildlands Project, Richmond, VT, USA.
[112] Based upon review of geographic information accessed in January 2005 through the on-line Data Locator application of the Nova Scotia Geomatics Centre, Amherst, NS.
URL: http://gov.ns.ca/GeoNova/home/products/softpage/data_locator.asp.
[113] Randy Tattrie (NSDNR), personal communication, 2005.
[114] Based upon Nova Scotia Dept. of Natural Resources. 2004. "Introduction: Land Use Categories." Integrated Resource Management website. URL: http://gov.ns.ca/natr/irm/default.htm. Accessed April 2005.
[115] Crooks 2000.
[116] For more information, see: Alexander, S.M. and N.M. Waters. 2000. The effects of highway transportation corridors on wildlife: A case study of Banff National Park. Transportation Research Part C 8: 307-320.
[117] Centre for Disease Control and Prevention. 2000. Update: Raccoon rabies epizootic – United States and Canada, 1999. Morbidity and Mortality Weekly Report 49(2): 31-35.
[118] Matt Betts, personal communication, 2005.
[119] Betts, M.G., Knox, J. and Forbes, G. (2002). A landscape ecological approach to private woodlot planning in New Brunswick. Natural Areas Journal 22(4): 311-317
[120] Based upon our review of local knowledge surrounding wildlife distribution in the area.
[121] See Appendix I for a short discussion relating to this point.
[122] The Proposed Fundy UNESCO Biosphere Reserve Initiative. 2005. Fundy Biosphere Reserve Initiative Planning Group, New Brunswick.
[123] Natural Resources Canada. 2005. On-line Mapping - Land Capability for Ungulates. Canada Land Inventory on Canadian Geographic Information Systems website. GIS layers 021H, 021I and 011E. URL:
http://geogratis.cgdi.gc.ca/clf/en?action=entrySummary&entryId=8390&entryType=productCollection&keymap=multicli.
Accessed March 2005.
[124] Natural Resources Canada. 2005. Canada Land Inventory – Land Capability for Ungulates. Canadian Geographic Information Systems website. URL:
http://geogratis.cgdi.gc.ca/clf/en?action=entrySummary&entryId=8390&entryType=productCollection&keymap=multicli.
Accessed March 2005.
[125] Based upon Beazley et al, 2004.
[126] Natural History of Nova Scotia, 1994.
[127] Natural History of Nova Scotia, 1994.
[128] Humphries, M.M., Umbanhowar, J. and K.S. McCann. 2004. Bioenergetic Prediction of Climate Change Impacts on Northern Mammals. Integr. Comp. Biol. 44: 152-162.
[129] Carroll, Carlos, PhD. 2005. Carnivore Restoration in The Northeastern U.S. and Southeastern Canada**:** A Regional-Scale Analysis of Habitat and Population Viability for Wolf, Lynx, and Marten, Report 2: Marten and Lynx Viability Analysis. Wildlands Project - Special Paper no.6. The Wildlands Project, Richmond, VT, USA
[130] Snaith 2001
[131] Houghton et al 1998 cited in Humphries et al 2004

[132] Climate Change Impacts and Adaptation: A Canadian Perspective. 2004. *Eds:* Donald S. Lemmen and Fiona J. Warren. Climate Change Impacts and Adaptation Directorate, Natural Resources Canada. Ottawa, Ontario.
[133] Additional study topics should include actual surveys of wildlife presence and movement at the landscape and regional level, as well as assessments of current habitat structure and distribution, both west-to-east and north-to-south across the isthmus. Up-to-date habitat quality and distribution for focal species should be assessed; and, an inventory of landownership should be conducted to determine the opportunity for private land stewardship initiatives along this or other optimal pathways for a wildlife connectivity corridor.
[134] Matt Betts, personal communication, 2005.
[135] As summarized in Shafer, C.L. 2001. Inter-reserve distance. Biological Conservation 100: 215-227.
[136] Marc Spence, personal communication, 2005.
[137] Robert Anderson, personal communication, 2005; Harry Thurston, personal communication, 2005.
[138] With, K.A. 1997. The application of neutral landscape models in conservation biology. Conservation Biology 11(5): 1069-1080; www.ecologyandsociety.org
[139] See Taylor et al, Unpublished for an explanation of the importance of functional versus structural connectivity and the spatial distribution of patches across a landscape in promoting connectivity.
[140] for points except for "clear-cuts" refer to Gustafson, E.J. and R.H. Gardner. 1996. The effect of landscape heterogeneity on the probability of patch colonization. Ecology 77: 94-107, as cited in Taylor et al, Unpublished.
[141] The Cobequids population in described in both Snaith, 2001 and Brannen, 2004.
[142] Ibid.; Dennis Brannen, personal communication, 2005.
[143] Snaith, 2001.
[144] Taylor et al, Unpublished; Keitt, T.H., D.L. Urban, and B.T. Milne. 1997. Detecting critical scales in fragmented landscapes. Conservation Ecology [online]**1**(1): 4. Available from the Internet. URL: http://www.consecol.org/vol1/iss1/art4/
145 Jalkotzy, M.G., Ross, P.I. and M.D. Nasserden. 1997. The effects of linear developments on wildlife: a review of selected scientific literature. Arc Wildlife Services Ltd., prepared for Canadian Association of Petroleum Producers, Calgary, as adapted and cited in Beazley et al, 2000
[146] Davis, G.M. 1984. Molecular genetics of peripheral populations of Nova Scotian Canada Unionidae Mollusca Bivalvia. Biol. Journal of the Linnean Society 22(2): 157-185.
[147] Noss, R.F., Quigley, H.B., Hornocker, M.G., Merrill, T., and P.C. Paquet. 1996. Conservation Biology and carnivore conservation in the Rocky Mountains. Conservation Biology 10: 949-963, as cited in Tigas, L.A., Van Vuren, D.H. and R.M. Sauvajot. 2002. Behavioral responses of bobcats and coyotes to habitat fragmentation and corridors in an urban environment. Biological Conservation 108: 299-306.
[148] MacArthur, R.H. and E.O. Wilson. 1963. An equilibrium theory of insular zoogeography. Evolution 17: 373-387.
[149] Fahrig, L. and G. Merriam. 1994. Conservation of fragmented populations. Conservation Biology 8(1): 50-59.
[150] With, K.A. 1997. The application of neutral landscape models in conservation biology. Conservation Biology 11(5): 1069-1080; www.ecologyandsociety.org
[151] Weber, T. 2003. Chapter 2 - Maryland's Green Infrastructure Assessment: A comprehensive strategy for land conservation and restoration. Maryland Dept. of Natural Resources, Landscape and Watershed Analysis Division. 46p.
[152] Crooks, K.R. 2000. Relative sensitivities of mammalian carnivores to habitat fragmentation. Conservation Biology 16(2): 488-502.
[153] Ibid.
[154] Hale, M.L., Lurz, P.W.W., Shirley, M.D.F., Rushton, S., Fuller, R.M. and K. Wolff. 2001. Impact of landscape management on the genetic structure of red squirrel populations. Science 293, 21 Sept.: 2246-2248.
[155] Crooks, 2000.
[156] Olsen, T.A. and G.R. Hess. 1998. Focal species selection for conservation in a suburbanizing, forested landscape. Draft document, Regional Planning for Wildlife in the Triangle. G.R. Hess, North Carolina State University, Raleigh. URL: http://www4.ncsu.edu/~grhess/research/regplan/focal.html
[157] Ontario Ministry of Natural Resources. 1986. Guidelines for providing furbearer habitat in timber management. 2nd Draft. MNR# 51601. No publication location listed.
[158] Ibid.
[159] Tango, P.J. 1986. Home range of reintroduced river otters in West Virginia. M.S. Thesis, West Virginia University. 113 pp., as cited in Corrigan, M. 2002. A Preliminary Report on the Feasibility of River Otter Reintroduction in New Mexico. Report prepared for New Mexico River Otter Working Group. Taos, New Mexico. URL: http://www.amigosbravos.org/projects/riverotter/FeasibilityStudyMegancorrigan. Accessed 05 May 2005.
[160] Olsen and Hess, 1998; OMNR, 1986.
[161] Crooks, 2000.
[162] Ibid.

[163] Summarized from Eastern Ontario Model Forest. 2005. "Wooded Interior by Watershed." http://sof.eomf.on.ca/Biological_Diversity/Ecosystem/Fragmentation/Indicators/Interior/i_wooded_interior_by_watershed_e.htm. Access 12 May 2005.
[164] Environment Canada, 2004, as cited in Eastern Ontario Model Forest, 2005.
[165] As explained in Schroeder, R. L. 1983. Habitat suitability index models: Pileated Woodpecker. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.39. Washington, DC. 15pp.
[166] Martin, K. and J.M. Eadie. Nest webs: A community-wide approach to management and conservation of cavity-nesting birds. Forest Ecology and Management 115: 243-257; Parker, G. and D. Doucette. GFE Research Projects 2001.
[167] Universite de Moncton. 2005. "Tolerance thresholds: a new conservation tool." Living Landscapes 1. 4pp.
[168] Schoener, T.W. 1968. Sizes of feeding territories among birds. Ecology 49(1): 123-141.
[169] Unless otherwise cited, each home range as cited in Schoener 1968.
[170] Schroeder, 1983.
[171] Turcotte, F., Courtois, R., Couture, R. and J. Ferron. 2000. Impact à court terme de l'exploitation forestière sur le tétras du Canada (Falcipennis canadensis). Can. J. For. Res. 30(2): 202-210
[172] Erskine, A.J. and R. McManus, Jr. 2005. Bird status changes – and changes in environment – in the Chignecto Isthmus region of Atlantic Canada. Canadian Wildlife Service Technical Report Series No. 430 Atlantic Region. Vi+167pp.
[173] Ibid.
[174] Ibid.
[175] As summarized in Fraser, G.S. and B.J.M. Stutchbury. 2004. Area-sensitive forest birds move extensively through forest patches. Biological Conservation 118: 377-387.
[176] Sieving, K.E., Willson, M.F., De Santo, T.L., 1996. Habitat barriers to movement of understory birds in fragmented south-temperate rainforest. The Auk, 944–949; Desrochers, A., Hannon, S.J., 1997. Gap crossing decisions by forest songbirds during the post-.edging period. Conservation Biology 11(5), 1204–1210; Belisle, M.A., St. Clair, C.C., 2001. Cumulative effects of barriers on movements of forest birds. Conservation Ecology 5 (2) [online] URL:. Available from http://www.consecol.org/vol5/iss2/art9; Belisle, M., Desrochers, A., Fortin, M.J., 2001. Influence of forest cover on the movements of forest birds: a homing experiment. Ecology 82, 1893–1904, as cited in Fraser and Stutchbury, 2004.
[177] Norris, D.R. and B.J.M. Stutchbury. 2001. Extraterritorial movements of a forest songbird in a fragmented landscape. Conservation Biology **15:** 729-736.
[178] Gerrow, S., Flemming, S. and T. Herman. 1997. Habitat Characteristics and Home Ranges of Northern Flying Squirrel in Fundy National Parks and the Greater Fundy Ecosystem. Greater Fundy Ecosystem Research Group Case Studies. Fredericton, NB.
[179] Bourgeois, M.C. 1997a. Fractal analysis of movement patterns used to compare American Marten response to different habitat characteristics. MSc thesis, Acadia University. Wolfville, N.S.
[180] Bourgeois, M.C. 1997b. American Marten Response to Forest Characteristics. Greater Fundy Ecosystem Research Group Case Studies. Fredericton, NB.
[181] Bourgeois, 1997a.
[182] Soutiere, E. C. 1979. Effects of timber harvesting on marten in Maine. J. Wildl. Management 43: 850-860.
[183] Ibid.
[184] Browne, S. and D. S. Davis (Eds). 1996. "T11.2 Forest and Edge-habitat Birds" *In* The Natural History of Nova Scotia. V.1. Topics and Habitats. Nova Scotia Museum. Nova Scotia. 4pp.
[185] Beazley, K.F. 1997. Ecological considerations for protected area system design. Proc. N.S. Inst. Sci. 41: 59-76, Beazley, K.F., 1998. Focus-species approach for trans-boundary biodiversity management in Nova Scotia. Linking Protected Areas With Working Landscapes Conserving Biodiversity. Proceedings of the Third International Conference on Science and Management of Protected Areas. (Wolfville, NS, 12-16 May.) Munro, N.W. and J.H. Willison (eds). SAMPAA Wolfville, NS. 755-771, and Beazley, K.F. 2001. A focal-species approach to maintaining biodiversity in Nova Scotia. Natural Areas Journal. In press (when cited), as cited in Snaith, 2000.
[186] Prescott, W.H. 1968. A study of Winter Concentration Areas and Food Habits of Moose in Nova Scotia. Unpublished M.Sc. Thesis. Acadia University, Wolfville, NS.
[187] As reported by Raymond, K.S., Servello, F., Griffith, B. and W.E. Eschholz. 1996. Winter foraging ecology of moose on glyphosate-treated clearcuts in Maine. J. Wildl. Management 60(4): 753-763; Prescott, 1968.
[188] Pimlott, D. H. 1961. The ecology and management of moose in North America. Terre Vie 2: 246-265, as cited in Dodds, D. G. 1974. Distribution, habitat, and status of moose in the Atlantic provinces of Canada and northeastern United States. Naturaliste canadien 101: 51-65.
[189] Monthey, R.W. 1984. Effects of timber harvesting on ungulates in Northern Maine. J. Wildl. Management 48: 279-285.
[190] Peek, J.M., Ulrich, D.L. and R.J. Mackie. 1976. Moose habitat selection and relationships to forest management in northeastern Minnesota. Wildl. Monographs 48: 65pp, Telfer, 1978 and Monthey 1984, as cited in Raymond et al, 1996; Monthey, R.W. 1984. Effects of timber harvesting on ungulates in Northern Maine. J. Wildl. Management 48: 279-285.

[191] Brannen, D.C., 2004. Population parameters and multivariate modelling of winter habitat for moose (Alces alces) on mainland Nova Scotia. M.Sc. Thesis. Acadia University, Wolfville, N.S.; and Snaith, T.V. 2001. The status of moose in mainland Nova Scotia: Population viability and habitat suitability. MES Thesis. Dalhousie University, Halifax, N.S.
[192] Des Meules, P. 1962. Intensive study of an early spring habitat of moose (Alces alces americana Cl.) in Laurentides Park, Quebec. Proc. Northeast Wildl. Conf., Monticello, New York. 12pp.
[193] Brannen, 2004.
[194] Tony Nette (NSDNR), personal communication, 2005; Dennis Brannen, personal communication, 2005.
[195] Brannen, 2004.
[196] Monthey, R.W. 1984. Effects of timber harvesting on ungulates in Northern Maine. J. Wildl. Management 48: 279-285.
[197] Telfer, E. S. 1974. Logging as a factor in wildlife ecology in the boreal forest. For. Chron. 50: 186-190.
[198] Telfer, E. S. 1970. Winter habitat selection by moose and white-tailed deer. J. Wildl. Management 34(3): 553-558.
[199] VanHorne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Management 47: 893-901, as cited in Brannen 2004.
[200] Hauge, T.M. and L.B. Keith. 1981. Dynamics of moose populations in northeastern Alberta. J. Wildl. Management 45: 573-597.
[201] Brannen, 2004.
[202] As summarized by Snaith, 2001.
[203] Brannen, 2004.
[204] Monthey, R.W. 1984. Effects of timber harvesting on ungulates in Northern Maine. J. Wildl. Management 48: 279-285. Monthey, R.W. 1984. Effects of timber harvesting on ungulates in Northern Maine. J. Wildl. Management 48: 279-285.
[205] Snaith, T.V. 2001. The Status of Moose in Mainland Nova Scotia: Population Viability and Habitat Suitability. Masters Thesis, Dalhousie University, Nova Scotia. 143pp
[206] Brannen, 2004.
[207] Don Colpitts, personal communication, 2005.
[208] Robert Anderson, personal communication, 2005.
[209] Mark Spence, personal communication, 2005.
[210] Interpretation based upon Dodds, 1974.
[211] Based upon extrapolations from Hundertmark, K., W. Eberhardt and R. Ball. 1990. Winter habitat use by moose in southeastern Alaska: implications for forest management. Alces 26:108-114 and Thompson, M., J. Gilbert, J. George Matula and K. Morris. 1995. Seasonal habitat use by moose on managed forest lands in northern Maine. Alces 31:233-245, as cited in Brannen, 2004.
[212] Brannen, 2004.
[213] Telfer, E.S. 1970. Winter habitat selection by moose and white-tailed deer. J. Wildl. Management 34: 553-558, as cited in Snaith, 2001.
[214] Bancroft, R. 2005. "Legislation and Value of Riparian Areas." Role of Parks and Protected Areas in the Working Forest Landscape. (Halifax, N.S., 22 March 2005). Nova Forest Alliance/Parks Canada conference, Halifax, NS.
[215] Allen, A.W., Jordan, P.A., and J.W. Terrell. 1987. Habitat suitability index models: moose. Lake Superior region. US Department of the Interior Biological Report 82(10.155): 1-47, as cited by Snaith, 2001.
[216] Brannen, 2004.
[217] Snaith, 2001, and Beazley et al, 2004.
[218] As reported by Forman, R.T.T., Friedman, D.S., Fitzhenry, D., Martin, J.D., Chen, A.S. and L.E. Alexander. 1997. Ecological effects of roads: toward three summary indices and an overview of North America. In Canter, K. (ed) Habitat Fragmentation and Infrastructure. Min. of Transport and Public Works and Water Management, Delft, Netherlands, 40-54p.
[219] Snaith, 2001.
[220] Brannen, 2004.
[221] Ballard, W.B. and V.V. Ballenberghe. 1997. Predator/Prey Relationships. In: Franzmann A.W., C.C. Schwartz, editors. Ecology and Management of the North American moose. 1st ed. Washington: Smithsonian Institution Press, as cited in Brannen, 2004.
[222] Snaith, 2001.
[223] Ibid.
[224] Ball, M. and P. Wilson. 2003. Genetic Analysis of the Endangered Nova Scotia Moose Populations. Project Progress Report, July 2003. Natural Resources DNA Profiling and Forensic Centre. Peterborough, Ontario.
[225] Snaith, 2001.
[226] Taken from Snaith, 2001 with permission.
[227] See Snaith, 2001 for a detailed explanation.
[228] Crammon, H. 2003. Ghost of the north Maine woods: Canada Lynx rediscovered. JDI Forest Research Spring 2003,1p; Buskirk, S.W., Ruggiero, L.F., Aubry, K.B., Pearson, D.E., Squires, J.R. and K.S. McKelvey. 1999. Comparative ecology of

lynx in North America. Chapter 14 In Ruggiero, L.F., Aubry, K.B., Buskirk, S.W., Koehler, G.M., Krebs, C.J., McKelvey, K.S., and J.R. Squires. 1999. Ecology and conservation of lynx in the United States. General Technical Report RMRS-GTR-30WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station; Mowat, G., Poole, K.G. and M. O'Donoghue. 1999. Ecology of Lynx in Northern Canada and Alaska. Chapter 9 In Ruggiero, L.F., Aubry, K.B., Buskirk, S.W., Koehler, G.M., Krebs, C.J., McKelvey, K.S., and J.R. Squires. 1999. Ecology and conservation of lynx in the United States. General Technical Report RMRS-GTR-30WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

[229] Koehler, G.M. and K.B. Aubry. 1994. Lynx. Pp. 74-98 In L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski (tech eds). The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. U.S. Dept. of Agriculture, Forest Service, Gen. Tech. Rep. RM-254; Mowat et al, 1999.

[230] Mowat et al, 1999.

[231] Hall, E. R. 1981. The mammals of North America. John Wiley and Sons, New York.

[232] Buskirk et al, 1999.

[233] Buskirk et al, 1999; Saunders, J. K. 1963a. Food habits of lynx in Newfoundland. Journal of Wildlife Management 27:384-390, Bergerud, A. T. 1971. The population dynamics of the Newfoundland caribou. Wildlife Monographs 25: 1-55, Parker, G. R., J. W. Maxwell, L. D. Morton, and G. E. J. Smith. 1983. The ecology of the lynx (Lynx canadensis) on Cape Breton Island. Canadian Journal of Zoology 61: 770-786, Stephenson, R. O., D. V. Grangaard, and J. Burch. 1991. Lynx, Felis lynx, predation on red foxes, Vulpes vulpes, caribou, Rangifer tarandus, and Dall sheep, Ovis dalli, in Alaska. Canadian Field-Naturalist 105: 255-262 and Poole, K. G. 1992. Lynx research in the Northwest Territories, 1991-92. Report number 68, NWT Renewable Resources, Yellowknife. Unpublished Manuscript, as cited in Mowat et al, 1999.

[234] Buskirk et al, 1999.

[235] Ibid.

[236] Berrie, P. M. 1974. Ecology and status of the lynx in interior Alaska. Pages 4-41 In R. L. Eaton (ed). The world's cats. Volume 1. World Wildlife Safari, Winston, OR, as cited in Mowat et al, 2000.

[237] Mowat, G. 1993. Lynx recruitment in relation to snowshoe hare density. M.Sc. Thesis, University of Alberta, Edmonton, as cited in Koehler, G.M. and K.B. Aubry. 1994. Lynx. Pp. 74-98 *In* L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski (tech eds). The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. U.S. Dept. of Agriculture, Forest Service, Gen. Tech. Rep. RM-254.

[238] Mowat et al, 1999.

[239] Crammon, 2003.

[240] Ray, J.C., John F. Organ, and Michael S. O'Brien. 2002. Canada Lynx (Lynx canadensis) in the Northern Appalachians: Current Knowledge, Research Priorities, and a Call for Regional Cooperation and Action. Report of a meeting held in Portland, Maine, April, 2003. Wildlife Conservation Society.

[241] Carroll, C. 2005. Carnivore Restoration in the northeastern US and southeastern Canada. A regional-scale analysis of habitat and population viability for wolf, lynx and marten. Report 2: lynx and marten viability analysis. The Wildlands Project Special Paper no. 6. 46pp.

[242] Mowat et al, 1999.

[243] Summarized in U.S. Fish and Wildlife Service and National Marine Fisheries Service. 1998. "Lynx." Endangered Species Consultation Handbook. 37001-37002pp.; Halfpenny, J. and E.A. Biesiot. 1986. A field guide to mammal tracking in North America. Johnson Books, Boulder, CO. 161 pp., cited in Washington Department of Natural Resources. 1996a. Lynx habitat management plan for Department of Natural Resources managed lands. Unpubl. Rpt., Washington Department of Natural Resources, Olympia, as cited in Murray, D.L., Boutin, S. and M. O'Donoghue. 1994. Winter habitat selection by lynx and coyotes in relation to snowshoe hare abundance. Canadian Journal of Zoology 72: 1444-1451.

[244] Koehler and Aubry, 1994.

[245] Ibid.

[246] United States Department of Agriculture. 1994. Wolverine, lynx, and fisher habitat and distribution maps, draft hierarchical approach and draft conservation strategies. Unpublished memo from Western Forest Carnivore Committee Chairperson Bill Ruediger (U.S. Dept. of Agriculture, Forest Service, Northern Region, Missoula, Montana) to Forest Supervisors (R-1), Regional Foresters (R-2, R-4, R-5, and R-6), and cooperating agencies (state and federal). September 14, 1994. Analysis excerpted from Buecking, 1998.

[247] Woodley, S. 2000. (Parks Canada, Ottawa), personal communication, no date, as cited in Beazley et al, 2004.

[248] O'Neil, P. 2000. Treasures of the wild: Standing guard over Cape Breton's disappearing lynx and pine marten. The Cape Bretoner 8: 16-18, Buskirk, S.W., Ruggiero, L.F. and C.J. Krebs. 2000. Habitat fragmentation and interspecific competition: implications for lynx conservation. http://www.Fs.fed.us/rm/pubs/rmrs_gtr30/lynx/chap4.pdf and Jalkotzy, M.G., Ross, P.I., Nasserden, M.D. 1997. The effects of linear developments on wildlife: a review of selected scientific literature. Arc Wildlife Services Ltd., prepared for Canadian Association of Petroleum Producers, Calgary, AB, as cited in Beazley et al, 2004.

[249] Based on Beazley et al, 2004.

[250] Beazley et al, 2004.
[251] Ray, J.C. In press. Sprawl and highly mobile or wide-ranging species. In: Nature in Fragments: The Legacy of Sprawl (E. A. Johnson & M.W. Klemens, eds.), Columbia University Press, New York, NY.
[252] Chamberland, P. 1997. Black Bear (*Ursus americanus*) habitat ecology as related to aspects of forest management in southern New Brunswick. M.Sc. Thesis. Acadia University, Wolfville, N.S.
[253] Manville, A.M. 1983. Human impact on the black bear in Michigan's lower peninsula. Int. Conf. Bear Res. and Mgmt. 5: 20-33, cited in US Forest Service. No date. Biologic Data and Habitat Requirements – Wildlife Species: Ursus americanus. URL: www.fs.fed.us/database/feis/wildlife/mammal/uram/biological_data_and_habitat_requirements.html. Accessed 20 April 2005.
[254] Samson, C. 1995**.** Écologie et dynamique de population de l'ours noir dans une forest mixte protégée du sud du Québec (Canada). Ph.D. Thesis. Laval University, Québec, Québec. 201**pp.**, as cited in Chamberland, 1997.
[255] In US Forest Service. No date.
[256] Manville, A.M. 1986. Den selection and use, and winter movements of black bears in Michigan's northern lower peninsula. Proc. 7th International Conf. Bear Res. And Mgmt. Abstract, as cited in Rogers, L.L. and A.W. Allen. 1987. Habitat suitability index models: Black bear, Upper Great Lakes Region. US Dept. of the Interior, Fish and Wildlife Service, Research and Development, Washington, DC. Biological Report 82(10.144).
[257] Chamberland, 1997. See Ref 252.
[258] Samson 1995, as cited in Chamberland 1997.
[259] Simberloff, D., Farr, J.A., Cox, J. and D.W. Mehlman. 1992. Movement corridors: Conservation bargains or poor investments? Conservation Biology 6(4): 493-504.
[260] Chamberland, 1997.
[261] Jalkotzy et al 1997, as cited in Beazley et al, 2004.
[262] Brody, A.J. and M.R. Pelton. 1989. Effects of roads on black bear movements in western North Carolina. Wildlife Society Bulletin 17: 5-10, as cited in Beazley et al, 2004.
[263] Jalkotzy et al 1997, as cited in Beazley et al 2004
[264] Beazley et al, 2004.