

Message from the Chair of Canada MAB

This co-operative study not only illustrates in a factual and interesting way changes in landscape and habitat that have been taking place in different parts of Canada, and provides information about how different human activities and policies have affected the land and many of its resources, but it is also a successful and in many ways a pioneering example of how a number of different institutional interests and responsibilities, each working within their respective areas of competence, can pull together toward a common objective of finding out what is happening, over time, to our country.

The Biosphere Reserve Landscape Change Project grew from an original "common sense" proposal by John Whitaker, a member of the Riding Mountain Biosphere Reserve Committee in Manitoba, who, as a farmer near a National Park in an area of impending resource exploitation, had a "ground level view" of the changes that had happened to the land about him during the past century and a concern about its future. Biosphere Reserves are an activity within the Man and the Biosphere Programme (MAB) of the United Nations Educational, Scientific and Cultural Organization UNESCO, which since 1971 has been providing a focus and international co-ordination for research, monitoring, demonstration and education related to the characteristics and values of natural ecosystems and natural resources, and the impacts of human activities on them. Biosphere Reserves, in particular, are places designed for conservation and study of examples of natural landscapes and ecological function, over time, in as natural condition as possible; for providing information on the effects of socio-economic activities on biological systems; and for identification, development, and demonstration of practices that are ecologically, economically and culturally sustainable. Mr. Whitaker proposed that a useful contribution to the objectives of Biosphere Reserves would be to gather data on the historical changes of land-use in or around the six Biosphere Reserves that then existed in Canada. This proposal fitted well with a commitment in a Memorandum of Co-operation between the MAB programmes of Mexico, the USA and Canada - signed by the Honourable John Fraser, former Chair of Canada MAB - that each country would prepare land-use cover maps of its Biosphere Reserves, as a contribution to the United Nations Land-Use Cover Project. The Canadian Biosphere Reserves Association accepted the proposal and with the co-operation and support of the Ontario Ministry of Environment and Environment Canada, the study reported herein is the result.

The studies reported in the following pages are each different, determined by the availability of data and focussed on selected important or indicative changes in each Biosphere Reserve examined. A variety of techniques and methodologies was used. The individual studies do not lend themselves to an overall summary of the nature or extent of change; but collectively they show the remarkable changes that have occurred in various parts of the country, especially during the last century. They suggest that the changes are continuing, and that the nature of the changes is changing. They lead the researchers and the readers -- and we hope, the policy-makers -- to ask some important questions about our values and the future of our country. References to the technical details of each study are given.

Canadians, in general, are a people dedicated to bringing about change. Blessed to find ourselves in a country with abundant natural resources but an environment where it takes some effort and ingenuity to live comfortably, those of us whose forebears have come here in the past three centuries, or have recently arrived, have developed the habit of viewing successful change as an altering of the state of Nature for short term human ends, and of using increasing amounts of natural resources for the benefit of increasing numbers of people. For much of our recent history, many Canadians have looked upon the changes that they have made in the landscape and biosphere as signs of progress and a source of pride. The limitations of the resources, and the cumulative ecological effects of making incremental and apparently small changes in the natural systems have been of little concern. The Biosphere Reserve Landscape Change Project documents in a systematic way the progressive and net effects in some selected measurable characteristics, of changes that most of us have been aware of in our local experience but have not assessed in larger perspective.

This modest study helps us view examples of the development of our country in a geographical and a time dimension, and should help us think about its future. It is also an example of the value and the opportunities of the UNESCO MAB programme and Biosphere Reserves to provide information, and location of research and information that will contribute to public awareness, improved development and management practices, and long range policies for our country.

E.F. Roots, Acting Chair, Canada MAB

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Biosphere Reserves in Canada

What is a World Biosphere Reserve?

Biosphere Reserves are areas of terrestrial or coastal ecosystems, which are internationally recognized within UNESCO's Man and Biosphere Program for promoting and demonstrating a balanced relationship between people and nature. Presently there are 368 Biosphere Reserves in 91 countries.

Biosphere Reserves are designed to meet one of the most challenging issues that the World is facing as we begin the 21st century: How can we conserve the diversity of plants, animals and micro-organisms which make up our living biosphere and maintain healthy natural ecosystems while, at the same time, meet the material needs and aspirations of an increasing number of human beings. Biosphere Reserves have been designed as tools for reconciling and integrating the conflicting interests and pressures that characterise landscape planning today.

Each Biosphere Reserve is intended to fulfil three basic functions, which are complementary and mutually reinforcing.

- a conservation function - to ensure the conservation of landscapes, ecosystems, species and genetic variation.
- a development function - to promote, at the local level, economic development that is culturally, socially and ecologically sustainable.
- a logistics function - to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development.

Fully functioning Biosphere Reserves conserve natural and cultural diversity, exemplify or demonstrate models for land management and approaches to sustainable development, and support research, monitoring, education and training.

How are Biosphere Reserves Organized?

The configuration of land use within a biosphere reserve (see Figure 1) can vary greatly. However, each biosphere reserve must have one or more relatively undisturbed and protected "core" areas which conserve significant ecological features and functions. Buffer areas around the cores may be used in ways that do not impact on the protected areas.

Protected Core Area

➡ minimal disturbance, legal protection

Buffer Zone

➡ some resource benefit

Transition Zone

➡ co-operative management activities

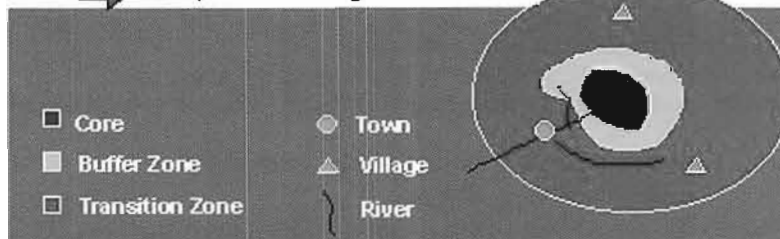


Figure 1 - Land-Use Configuration of Biosphere Reserves

In October 1995, the Honourable John Fraser, Chair of Canada MAB, signed a Memorandum of Co-operation along with the MAB programs of the United States and Mexico. The Memorandum included the commitment for Canada to make available land cover maps from Canada's Biosphere Reserves. Two years later, a partnership centred around the Canadian Biosphere Reserve Association (CBRA) initiated the Biosphere Reserve Landscape Change Project as part of a multi-year plan to develop an integrated data/information management system common to the Biosphere Reserves in Canada.

Based on discussions with the Biosphere Reserves, the EMAN Co-ordinating Office of Environment Canada and the Land-Use Policy Branch of the Ontario Ministry of Environment, the Project was designed to prepare landscape change analyses using existing data including original land survey records, air photos, satellite imagery or some combination of all three.

The Canadian Biosphere Reserve Association pursued this initiative to demonstrate the ability of the Biosphere Reserves to address common national issues and to develop solutions for application within Biosphere Reserves and elsewhere. The EMAN Coordinating Office of Environment Canada provided each of six of Canada's Biosphere Reserves with a recent graduate funded by Environment Canada's Youth Employment Strategy, who was used as the resource for the Project.

The Project started with a workshop co-sponsored and co-organized by the Land-Use Policy Branch of the Ontario Ministry of the Environment and the EMAN Co-ordinating Office of Environment Canada.

The workshop brought together the Science Horizon youth from each Biosphere Reserve to:

- explore and develop common landscape change protocols for Canadian Biosphere Reserves;
- train Science Horizon youth in the protocols through demonstrations involving experts in historical records, air photo interpretation and earth observation;
- undertake assessments of each Biosphere Reserve in terms of their needs with respect to landscape change information (what has been done, what is needed);
- address what is feasible for each Biosphere Reserve given technological, temporal and financial constraints; and
- set out a strategy to deliver the project.

Each Science Horizon youth undertook their component of the Project using the training provided at the workshop and local resources. Each of the studies was undertaken with a different set of local objectives, locally-available technologies, and locally-available resources. Therefore, each study was significantly different, yet followed the same steps to completion.

Each Biosphere Reserve conducted the study by:

1. determining whether work had been completed on land survey records, air photo or satellite interpretation and, if so, acquired the work;
2. seeking land survey records, air photos and satellite imagery as far back in time as possible;
3. evaluating the expertise of their Science Horizon youth and partners assisting the Biosphere Reserve, e.g. National Parks, Universities and Colleges;
4. selecting a study area appropriate for the information sources; where applicable, mapped and classified land survey records, digitized and classified air photos, digitized and classified satellite imagery;
5. analyzing landscape changes based on the mapping;
6. drafting reports on causes and implications of landscape changes; and
7. submitting a final report to the Canadian Biosphere Reserve Association and Environment Canada.

Summaries of these final reports follow as the main body of this report.

Six of Canada's Biosphere Reserves participated in a Landscape Change Project on the use of historical survey records, air photos or satellite imagery, or some combination of all three. The objectives of the analyses were:

- ❶ To test approaches to landscape change analysis within diverse landscapes and environments across Canada;
- ❷ To highlight the dramatic changes that humans have brought on the landscape since European settlement through landscape change data and information;
- ❸ To provide government agencies and others with landscape change data and information to better inform their decision making; and
- ❹ To provide Biosphere Reserve communities with some understanding of the natural environments that surround them (and how these environments have been changing) toward further developing each community's "sense of place". A community's "sense of place" is in part awareness of the local environment and a shared history of the area, but also involves something more in terms of individual values and feelings towards the land or values attributed to the elements of the land.

Each of the studies was undertaken with a different set of local objectives, available technologies, and available resources. Their results reflect these differences. Each study has great value individually, yet certain patterns emerge across all the studies as noted below.

Table 1 - Summary of Geographical Area and Time Periods for Landscape Change Studies at Canada's Biosphere Reserves

Biosphere Reserve	Total Area Studied	Time Changes Examined	Main Approach
Waterton	795 km ² in southwestern Alberta	logging since 1950s Roads 1951-1997	aerial photos satellite imagery road/trail digital data clearcut digital data
Niagara Escarpment	corridor stretching 725 km in southwestern Ontario	regional 1976-1995 area study 1974-1994	aerial photos satellite imagery baseline digital data
Long Point	270 km ² on shore of Lake Erie in southern Ontario	presettlement 1985-1990	land survey digital base maps
Charlevoix	148.52 km ² located east of Quebec City Quebec	1970-1990	ecological forestry maps
Riding Mountain	144 km ² in Manitoba	1873, 1948, 1993	land survey aerial photos topographic maps satellite imagery
Mont St. Hilaire	~ 150 km ² in southwestern Quebec	1761, 1815, 1839, 1867, 1932, 1963, 1993	topographical maps (recent ones draw from aerial photos)

Landscape Change at Canada's Biosphere Reserves

Since European human settlement in the 1700s and 1800s, resource development and growing human populations are the major drivers of landscape change at Biosphere Reserves. Many of the major landscape changes took place in the early days of European settlement, yet significant

Other lands within a biosphere reserve are used, often intensively, for a variety of human purposes. This mix, or mosaic of land-uses, provides opportunities to discover some of the cumulative consequences of a particular land-use or resource management practice by making selective comparisons with site conditions in the undisturbed core areas. Sometimes, lands outside the core and buffer areas of a biosphere reserve are referred to as the zone of cooperation, the zone of influence, or the "transition" areas of a biosphere reserve.

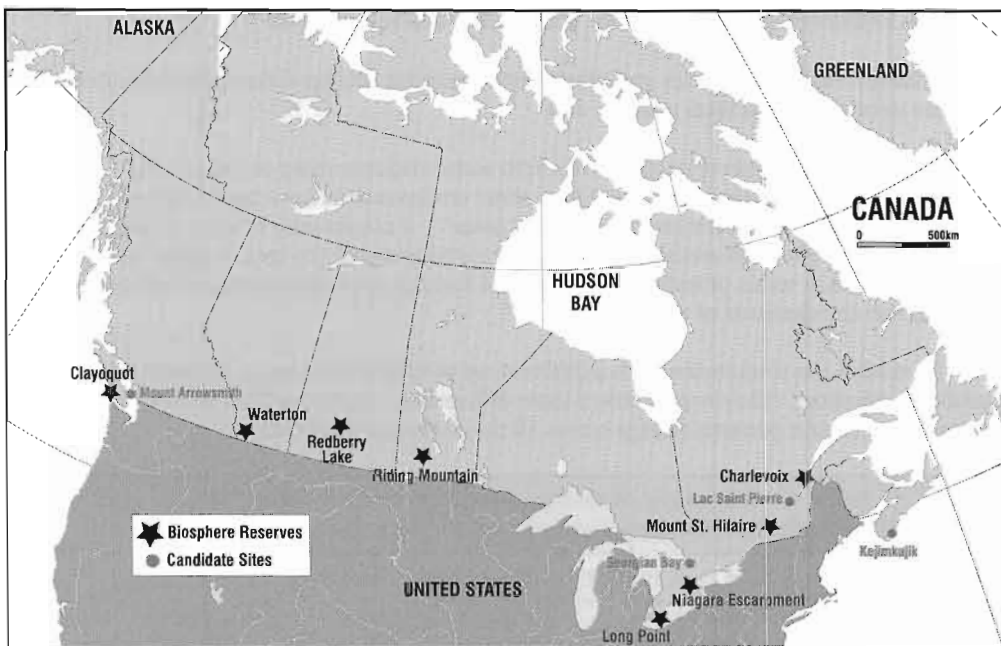


Figure 2 - Map of Canada's Biosphere Reserves and Candidate Sites

Overview of Canadian Biosphere Reserves

Since 1978, eight areas in Canada have been internationally recognized as World Biosphere Reserves: Mont St-Hilaire (Quebec, 1978); Waterton (Alberta, 1979); Long Point (Ontario, 1986), Riding Mountain (Manitoba, 1986); Charlevoix (Quebec, 1989); Niagara Escarpment (Ontario, 1990); Clayoquot Sound (British Columbia, 2000) and Redberry Lake (Saskatchewan, 2000). The success of biosphere reserves in Canada is dependent on a broad and diverse network of volunteers reflective of each community across a range of age groups, cultures, and interests.

The Biosphere Reserve network in Canada continues to grow. The communities of several ecologically unique areas in Nova Scotia, Quebec, Ontario, and British Columbia are currently preparing nomination papers for submission to UNESCO in order to join the Biosphere Reserve network.

Habitat Fragmentation, Loss and Degradation at Canada's Biosphere Reserves

Resource development and human settlement at Biosphere Reserves have significantly fragmented wildlife habitats, thus threatening wildlife populations (as illustrated through the results of the Biosphere Reserve landscape change studies) such as: the grizzly bear (Waterton Biosphere Reserve), caribou (Charlevoix Biosphere Reserve) and the scarlet tanager (Niagara Escarpment Biosphere Reserve). These species reflect the impacts of landscape change as indicators of overall wildlife habitat decline. Carolinian tree species are also under threat in the Long Point Biosphere Reserve.

Protected areas provide an opportunity to support wildlife populations, but when particular species require more undisturbed area than the protected areas can provide, then certain wildlife become threatened. For example, parts of the Niagara Escarpment Biosphere Reserve, although not experiencing overall forest area decline, are experiencing more forest fragmentation resulting in smaller forest patch sizes. The smaller fragments and increased forest edge (due to changing shapes) threaten the scarlet tanager, a bird species requiring large, undisturbed forests.

The Need for Environmental Planning and Management

Additional resource development and human settlement at Biosphere Reserves requires thoughtful planning and environmental management to define the appropriate uses of the land.

Specific human activities that continue to threaten the natural environment can be curtailed without disturbing main economic drivers of the community. For example, at the Waterton Biosphere Reserve, the threat to the grizzly bear results from the ongoing use of recreational off-road vehicles on forestry roads - not necessarily the forest harvesting activities themselves.

Planners and environmental managers associated with the Niagara Escarpment Biosphere Reserve have come to understand the importance of monitoring at various scales: the regional level (greater than 1:250,000), the area level (1:50,000 - 1:15,000), and the site level (plot monitoring). The Niagara Escarpment Biosphere Reserve Landscape Change Study illustrated that the regional level monitoring provided an assessment of the significant landscape patterns and trends, and identified the areas of significant ecological importance with respect to human development pressures. The area level monitoring provided an ability to link the cause (human development) with the ecological effect (forest fragmentation) - see above. And the site level monitoring targeted specific threats identified in the regional and area monitoring.

Options for Landscape Change Studies: Land Surveys, Aerial Photos or Satellite Imagery

Historical land surveys are valuable in describing pre-settlement land cover. Land surveyor records consist of point source descriptions of forest cover that the land surveyor recorded along concession lines. These land surveyor records can be mapped to provide a valuable picture of pre-settlement land cover. For example, Mont St. Hilaire Biosphere Reserve was able to use land surveyor and topographical maps from 1761, 1815, 1839, 1867 and 1914 of the Richelieu area for early estimates of forest cover. Recent topographical maps are also valuable as Long Point Biosphere Reserve demonstrated in their use of topographical maps from 1985 and 1990 to compare forest cover with earlier land surveys.

Aerial photos are particularly useful in describing land cover over the past 50 years. The photos are usually black and white stereo images at 1:15,000 representing summer seasonal resolution. For example, Riding Mountain Biosphere Reserve used air photos from 1928/9, 1948/9, 1970, and 1986 of the Regional Municipality of Clanwilliam for identifying land cover.

Satellite imagery is valuable for describing recent (last 25 years) land cover, but it is expensive to purchase images and then have them interpreted. For example, Waterton Biosphere Reserve used a 1996 SPOT satellite image for land cover.

Landscape Change Study

changes are still occurring today. Landscape changes include: removal of forests; conversion of grasslands and draining of wetlands in order to convert land for agricultural purposes; and building of houses, roads and other infrastructure to support the material well-being of human populations.

Conversion of landscapes for agriculture happened primarily during the early days of European settlement while development of human infrastructure has occurred more recently. Most of the ongoing landscape changes today are the result of forest fragmentation due to tree harvesting, house construction for an expanding human population at Biosphere Reserves, and the regeneration of abandoned agricultural lands to forests.

Regeneration of forested lands is occurring in areas where agricultural production is being abandoned. In many cases, the soils of these lands are not sufficient (and perhaps never were sufficient) for successful agricultural production. Observations from the Charlevoix Biosphere Reserve study indicate that years of agricultural production have depleted the soil quality even further, thus constraining regeneration of native forests.

Table 2 - Summary of Key Pressures Driving Landscape Changes at Canada's Biosphere Reserves

Biosphere Reserve	Key Pressure Driving Landscape Change	Impacts	Specific Findings
Waterton	Road development associated with industrial activity (seismic activity/gas wells/pipelines/logging) Off-road vehicle use Logging	Wildlife species more vulnerable to legal and illegal hunting; disturbed ranges. Habitat degradation (soil compaction, reduced cover, disturbed ranging patterns) Habitat degradation (loss and/or fragmentation)	grizzly bear elk grizzly bear elk grizzly bear elk
Niagara Escarpment	Mineral extraction (above Escarpment) and Clearing for agricultural activity (below Escarpment); urban development Clearing for agricultural activity; urban development	Forest fragmentation with declining forest interior and increasing nest predation and parasitism. Forest fragmentation leading to the spread of invasive plants.	scarlet tanager wood thrush european buckhorn
Long Point	House or cottage development	Forest fragmentation with declining forest interior.	Neotropical migrants
Charlevoix	Abandoned agricultural areas House or cottage development	Forests re-establishing to create different habitats at a slow rate due to soil degradation in fallow. Altering natural landscape	change in species change in greenspace patterns
Riding Mountain	Clearing for agricultural activity	Habitat loss and fragmentation, increased conflicts between wildlife and adjacent land owners resulting in wildlife decline and genetic isolation.	wolves moose elk
Mont St. Hilaire	Clearing and drainage of swampy land for agricultural activity Reforestation of unsuitable agricultural land House or cottage development; road and railway development	Forest fragmentation Forest regrowth Forest fragmentation, pollution and barrier to ecological processes	change in greenspace patterns change in greenspace patterns change in greenspace patterns

Chacune des six réserves canadiennes de la biosphère a participé à un projet sur la transformation du paysage au moyen de l'utilisation de relevés historiques, de photographies aériennes ou d'imagerie satellite ou d'une combinaison de ces trois procédés. Ces analyses avaient pour objectif:

- ❶ d'expérimenter différentes méthodes d'analyse de la transformation du paysage sur divers paysages et environnements au Canada;
- ❷ de mettre en évidence les transformations spectaculaires apportées aux paysages par les humains depuis la colonisation européenne, à l'aide de données et d'information sur la transformation du paysage;
- ❸ de transmettre aux organismes gouvernementaux et autres des données et de l'information sur la transformation du paysage afin d'éclairer leur prise de décision, et
- ❹ de mieux faire comprendre aux communautés des réserves de la biosphère les environnements naturels qui les entourent et les transformations qu'ils ont subies afin d'instiller dans chaque communauté «une notion de lieu». Dans plusieurs études, on suggère que cette notion de lieu fait, en partie, référence à une sensibilisation à l'environnement local et à une histoire partagée de la région, mais qu'elle inclut également un élément supplémentaire en terme de valeurs et de sentiments individuels à l'égard de la terre ou des valeurs attribuées aux éléments de la terre.

Chacune des études entreprises visait une série d'objectifs locaux, de technologies et de ressources disponibles différents. Leurs résultats font état de ces différences. Chaque étude a une grande valeur individuelle; on a cependant pu dégager certaines tendances, comme on le décrit dans le présent sommaire.

Transformations du paysage dans les réserves canadiennes de la biosphère

La mise en valeur des ressources et l'établissement humain sont les principaux moteurs de la transformation du paysage dans les réserves de la biosphère depuis la colonisation européenne. Bon nombre des transformations majeures du paysage sont survenues au début de la colonisation européenne, bien que d'importantes transformations aient encore lieu aujourd'hui. Ces transformations incluent la déforestation, la conversion des prairies et l'assèchement des terres humides dans le but de convertir la terre à des fins agricoles, ainsi que la construction de maisons, de routes et autres infrastructures dans le but d'assurer le bien-être matériel des populations humaines.

Tableau 1-Sommaire de la zone géographique et des périodes du temps pour des études sur les transformations du paysage des réserves de la biosphère au Canada

Réserve de la biosphère	Superficie totale étudiée	Transformations examinées	Principale méthode
Waterton	795 km ² dans le sud-ouest de l' Alberta	Exploitation forestière depuis les années 1950 Routes 1951-1997	Photos aériennes Imagerie satellite Données numériques sur les routes/sentiers Données numériques /coupes à blanc
Escarpement du Niagara	Corridor s'étendant sur 725 km dans le sud-ouest de l'Ontario	Étude régionale 1976-1995 Étude du territoire 1974-1994	Photos aériennes Imagerie satellite Données numériques de référence
Long Point	27 000 ha sur les rives du lac Érié dans le sud de l'Ontario	Antérieure à la colonisation 1985-1990	Relevés Cartes numériques
Charlevoix	148,52 km ² à l'est de la ville de Québec (Québec)	1970-1990	Cartes forestières écologiques Relevés
Riding Mountain	144 km ² au Manitoba	1873, 1948, 1993	Photos aériennes Cartes topographiques Imagerie satellite
Mont-Saint-Hilaire	~ 150 km ² dans le sud-ouest du Québec	1761, 1815, 1839, 1867, 1932, 1963, 1993	Cartes topographiques (cartes récentes faites à partir de photos aériennes)

Quantitative versus Qualitative Landscape Change Studies

There is great value in conducting both quantitative and qualitative land-use change studies. For example, quantitative analysis using a functional geographic information system (GIS) allows for proper inventory, management, analysis and multi-function query abilities such as that used by the Riding Mountain Biosphere Reserve. Qualitative analysis, using the "map and crayons" approach, was applied by Charlevoix Biosphere Reserve. Although less technologically-driven and statistically-sure, the Charlevoix approach still provides valuable estimates and insights about changes in land cover.

Table 3- Summary of Methods Used for Biosphere Reserve Landscape Change Study

Method	Strengths of Method	Weaknesses of Method	Biosphere Reserve Using Method
Land Surveys	Historical data	Less accurate due to individual bias of surveyor	Mont St. Hilaire, Long Point
Aerial Photos	Subject to availability along certain flight lines	Relatively recent Niagara Escarpment	Riding Mountain, Waterton,
Satellite Images	Accurate	Recent, expensive	Waterton, Niagara Escarpment

Next Steps and Conclusions

The partners of this project will use the results and lessons learned from the study in different ways. Maps generated from this study have been shared at events of Biosphere Reserves and partners. Riding Mountain and Mont St. Hilaire Biosphere Reserves are planning to import this information into local management agencies to guide decision-making towards sustainability consistent with a community's sense of place. Each Biosphere Reserve plans to expand and build upon the initial work done as part of this study. The EMAN Coordinating Office, Environment Canada will be using the study and lessons learned to develop a landscape change indicator for use at other EMAN sites as part of an early warning system of ecological changes across Canada. The Ontario Ministry of the Environment will be sharing the protocols and lessons learned with their clients and partners including municipalities, non-government organizations and Conservation Authorities.

Table 4 - Summary of Techniques Used for Biosphere Reserve Landscape Change Study

Technique	Strength	Weakness	Biosphere Reserve using technique
Map and crayons	Inexpensive, low-technological requirements or expertise	Time consuming less accurate, non-quantifiable	Charlevoix
Geographic Information Systems	Comprehensive, database creation, querying capabilities	Expensive, high technological and expertise requirements	Riding Mountain, Waterton, Long Point, Niagara Escarpment, Mont St. Hilaire
FRAGSTATS	Analytical tool for assessing fragmentation of forests	GIS and expertise required	Niagara Escarpment

The Biosphere Reserve Landscape Change Project demonstrated significant insights about the changes that humans have brought on the landscape since European settlement may be documented from existing landscape data and information. These studies have provided a view of the changing natural environment in and around Biosphere Reserves and have provided information to Biosphere Reserve communities to help refine their "sense of place". Further application of the combined techniques from all of these studies is recommended to continue adding to the picture of landscape and associated ecological changes at Biosphere Reserves and elsewhere in Canada.

Les territoires protégés permettent de soutenir la faune sauvage, mais lorsqu'une espèce en particulier a besoin d'un territoire intact plus grand que ce que le territoire protégé peut offrir, certains animaux sont alors menacés. Par exemple, dans certaines parties de la réserve de la biosphère de l'Escarpe du Niagara, bien qu'on n'y ait pas observé de réduction globale de la région forestière, on note une plus grande fragmentation qui se traduit par des territoires forestiers plus petits et de formes différentes. Le rétrécissement de ces fragments et l'accroissement de l'orée de la forêt (attribuable à la modification des formes) menacent le tangara écarlate, une espèce d'oiseau qui a besoin de milieux forestiers non perturbés de grandes dimensions.

La planification et la gestion de l'environnement sont absolument nécessaires

La mise en valeur de ressources additionnelles et les établissements humains dans les réserves de la biosphère requièrent une planification et une gestion environnementales réfléchies, dans le but de définir les utilisations les mieux appropriées de la terre.

Les activités humaines spécifiques qui continuent de menacer l'environnement naturel peuvent être freinées, sans pour autant nuire aux principaux moteurs économiques de la communauté. Par exemple, dans la réserve de la biosphère de Waterton, la menace faite à l'ours grizzly découle de l'utilisation continue de véhicules tous terrains dans les chemins forestiers – et pas nécessairement des activités d'exploitation forestière elles-mêmes.

Les planificateurs et les gestionnaires de l'environnement associés à la réserve de la biosphère de l'Escarpe de Niagara en sont arrivés à comprendre l'importance de la surveillance continue à des échelles diverses : au niveau régional (plus grand que 1:250,000), du secteur (1:50,000 - 1:15,000), et du site d'observation de parcelles de terrain. Leur étude sur les transformations du paysage a démontré que la surveillance continue à un niveau régional permettait d'effectuer une évaluation des tendances et caractéristiques importantes du paysage et d'identifier les secteurs revêtant une importance écologique significative, en ce qui touche les pressions exercées par le développement humain. La surveillance continue au niveau du secteur a permis d'établir un lien entre la cause (le développement humain) et l'effet écologique (fragmentation de la forêt) – voir plus haut. La surveillance continue au niveau du site a permis de cibler les menaces spécifiques qui avaient été préalablement identifiées au cours de la surveillance continue au niveau régional et du secteur.

Options aux fins des études sur la transformation du paysage : relevés, photographies aériennes ou imagerie satellite

Les relevés historiques servent à décrire la couverture terrestre avant la colonisation. Les relevés des arpenteurs-géomètres consistent en descriptions ponctuelles des transformations de la couverture forestière enregistrées à différents moments par l'arpenteur. Ces relevés peuvent être cartographiés de façon à présenter un portrait de la couverture forestière antérieure à la colonisation. Par exemple, dans le cas de la réserve de la biosphère du Mont-Saint-Hilaire, on a pu utiliser les relevés d'arpentage et les cartes topographiques de 1761, 1815, 1839, 1867 et 1914 de la région du Richelieu pour obtenir des estimations de la couverture forestière de l'époque. Les cartes topographiques récentes sont également utiles. Les cartes de 1985 et 1990 ont notamment servi à comparer la couverture forestière aux relevés antérieurs.

Les photographies aériennes se révèlent particulièrement utiles pour décrire la couverture forestière des cinquante dernières années. Les photos sont généralement des images stéréo en noir et blanc à 1:15 000 représentant une résolution estivale. Par exemple, dans le cas de la réserve de la biosphère de Riding Mountain, on s'est servi de photos aériennes datant de 1928-1929, de 1948-1949, de 1970 et de 1986 de la municipalité régionale de Clanwilliam afin d'identifier la couverture forestière.

L'imagerie satellite est utile pour décrire une couverture forestière récente (des 25 dernières années), mais le coût d'achat et d'interprétation de ces images est très élevé. Ainsi, dans le cas de la réserve de la biosphère de Waterton, on a utilisé une image satellite SPOT de 1996 afin de déterminer la couverture forestière.

Étude de Transformations du paysage

La conversion des paysages à des fins agricoles est principalement survenue au début de la colonisation européenne, alors que la mise en place de l'infrastructure humaine s'est produite plus récemment. La majeure partie des transformations en cours aujourd'hui sont le résultat de la fragmentation de la forêt attribuable à l'exploitation forestière, à la construction de maisons due à l'expansion de la population dans les réserves de la biosphère et de la régénération de terres agricoles abandonnées en forêts.

La régénération des terres boisées se produit dans des secteurs où la production agricole a été abandonnée. Dans de nombreux cas, la qualité du sol de ces terres n'est pas suffisante (ou ne l'a peut-être jamais été) pour une production agricole rentable. Les observations réalisées dans le cadre de l'étude sur la réserve de la biosphère de Charlevoix indiquent que des années de production agricole ont fini par épuiser encore davantage la qualité du sol, limitant ainsi la régénération des forêts naturelles.

Fragmentation de l'habitat, perte et dégradation dans les réserves canadiennes de la biosphère

La mise en valeur des ressources et les établissements humains dans les réserves de la biosphère ont entraîné la fragmentation des habitats fauniques, menaçant ainsi la faune sauvage, comme l'illustrent les résultats des études sur les transformations du paysage des réserves de la biosphère, notamment : de l'ours grizzly (Waterton), du caribou (Charlevoix) et du tangara écarlate (Escarpeement du Niagara). Ces espèces reflètent les répercussions de la transformation du paysage et rendent compte du déclin de l'habitat faunique. Des espèces d'arbres de la forêt carolinienne sont également menacées dans la réserve de la biosphère de Long Point.

Tableau 2 -Sommaire des principales tensions causant la transformation du paysage des réserves de la biosphère au Canada

Réserve de la biosphère	Principales tensions causant la transformation du paysage	Répercussions	Conclusions spécifiques
Waterton	Aménagement des routes associé à l'activité industrielle (activité sismique/puits de gaz/pipelines /exploitation forestière)	Faune plus vulnérable à la chasse légale et illégale; terrains perturbés	ours grizzly caribou
	Véhicules tous terrains	Dégradation de l'habitat (compactage du sol, couverture réduite, perturbation du territoire)	ours grizzly caribou
	Exploitation forestière	Dégradation de l'habitat (perte ou fragmentation)	ours grizzly caribou
Escarpeement du Niagara	Extraction de minéraux (au-dessus de l'Escarpeement) et déboisement à des fins agricoles(sous l'Escarpeement); développement urbain	Fragmentation de la forêt - rétrécissement des zones intérieures et hausse de la prédation des nids et du parasitisme	tangara écarlate grive des bois
	Déboisement à des fins agricoles; développement urbain	Fragmentation de la forêt causant la propagation de plantes envahissantes	merprun commun
Long Point	Construction de maisons ou de chalets	Fragmentation de la forêt et rétrécissement des zones intérieures	migrants néotropicaux
Charlevoix	Zones agricoles abandonnées	Réorganisation des forêts en vue de créer des habitats différents à cause de la dégradation du sol	changement au niveau de l'espèce
	Construction de maisons ou de chalets	Modification du paysage naturel	changement au niveau des espaces verts
Riding Mountain	Déboisement à des fins agricoles	Perte d'habitat et fragmentation, hausse des conflits entre la faune et les propriétaires des terrains adjacents entraînant le déclin de la faune et l'isolement génétique	loup original caribou
Mont St. Hilaire	Déboisement et assèchement de terres humides à des fins agricoles	Fragmentation de la forêt	changement au niveau des espaces verts
	Reforestation de terres agricoles inadéquates	Renouvellement de la forêt	changement au niveau des espaces verts
	Construction de maisons ou de chalets; aménagement de routes et de voies ferrées	Fragmentation de la forêt, pollution et obstacle aux processus écologiques	changement au niveau des espaces verts

Waterton Biosphere Reserve Landscape Change Study

What are the study objectives?

The purpose of the Waterton Biosphere Reserve Landscape Change Study was to analyze the cumulative impacts of human activities - logging, road and off-road vehicle use, seismic activity, gas production and transport - on the habitat of grizzly bear and elk populations of southwestern Alberta.



Figure 3 - Grizzly bear (*Ursus arctos*)

Grizzly bears (see Figure 3) were selected for the study for the following reasons: (i) their binational importance; (ii) the relative importance of southwestern Alberta to the grizzly bear distribution throughout Canada and the United States; (iii) their large habitat requirements allow them to serve as effective umbrella species to implicitly indicate effects on the habitat of a wide range of other species; and (iv) the grizzly has frequently been identified as an animal of great socio-economic value to humans and as a symbol of wildness and harmony.

The grizzly bear population in Canada is presently listed as 'vulnerable' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and is on the 'blue' list in Alberta, meaning it is suspected to be a vulnerable species. The grizzly bear is already listed as 'threatened' in the United States meaning it cannot be legally hunted and its status requires specific habitat protection measures. In Canada, however, this species is subjected to hunting as well as to habitat alienation and fragmentation. A 1990 COSEWIC status review of grizzly bear habitat in Canada showed that greater than 60 percent is vulnerable or threatened and all is considered at risk. Grizzly bears require large tracts of continuous wilderness habitat with minimal human disturbance due to their low reproduction and migration capabilities. In areas where human activity continues to encroach upon grizzly bear habitat the possibility of maintaining large tracts of wilderness is disappearing. Therefore, there is cause for concern.

Elk (see Figure 4) were selected for the study for the following reasons: (i) elk are quite sensitive to human presence; elk are important prey species and are seen as keystones in the survival of carnivores such as wolf, cougar and bear; (iii) elk are highly valued by humans both for hunting and viewing; and (iv) when on private lands, elk can compete with humans for livestock forage and crops.



Figure 4 - Elk (*Cervus elaphus*)

Southwestern Alberta provides a favourable habitat for elk, where they thrived until the late 1870s. Following the settlement of Europeans, elk were extirpated in southwestern Alberta due to over-hunting and disease introduced by cattle. Elk were re-established in the early 1910s and numbered over 3000 by 1953. The elk populations in southwestern Alberta are limited by habitat loss and hunting pressures, and are considered one of the most sensitive species to human disturbance. Currently, their populations are being 'managed' to reduce conflict with ranchers. The Waterton Biosphere Reserve Landscape Change Study focussed on the decline in habitat potential which may not relate to immediate impacts on elk given their current low numbers.

What is the study area?

The Waterton Biosphere Reserve centred its landscape change study on the Castle region of southwestern Alberta (see Figure 5). The Castle Region is comprised of 795 square kilometers of forest reserve land in southwestern Alberta. It is bounded on the east by the Municipal District of Pincher Creek, on the west by the Alberta-British Columbia border and on the south by Waterton Lakes National Park. The study area follows the watershed boundaries of the Carbondale and Castle Rivers.

Etude de Transformations du paysage

Études quantitatives sur la transformation du paysage par rapport à des études qualitatives

La tenue d'études quantitatives et qualitatives sur l'évolution de l'utilisation des sols s'avère très utile. Ainsi, une analyse quantitative effectuée à l'aide d'un système fonctionnel d'information géographique (SIG) permet un inventaire, une gestion, une analyse et des capacités d'interrogation multifonction, telles que celles utilisées par la réserve de la biosphère de Riding Mountain. Une analyse qualitative, faite au moyen de crayons et de carte, a été utilisée dans le cas de la réserve de la biosphère de Charlevoix. Bien qu'elle soit moins avancée sur le plan technique et moins sûre statistiquement parlant, la méthode utilisée à Charlevoix permet tout de même de fournir des estimations utiles sur les transformations subies par la couverture forestière.

Tableau 3 Sommaire des méthodes utilisées dans l'étude sur les transformations du paysage

Méthode	Atouts de la méthode	Faiblesses de la méthode	Réserve de la biosphère utilisant la méthode
Relevés	Données historiques	Moins précise à cause de la partialité de l'arpenteur	Mont St. Hilaire, Long Point
Photos aériennes	En fonction de la disponibilité	Relativement récente	Riding Mountain, Waterton, Escarpement du Niagara
Imagerie satellite	Précise	Récente, coûteuse	Waterton, Escarpement du Niagara

Prochaines étapes et conclusions

Les partenaires de ce projet utiliseront les conclusions et les leçons tirées de l'étude de diverses façons. Les cartes tracées lors de la réalisation de cette étude ont été partagées au cours d'événements touchant les réserves de la biosphère et entre les partenaires. Les réserves de Riding Mountain et de Mont-Saint-Hilaire prévoient transmettre cette information à des agences locales de gestion afin d'orienter la prise de décision en vue de la durabilité, pour qu'elle soit conforme avec la notion communautaire de lieu. Chaque réserve de la biosphère prévoit poursuivre le travail initial entrepris dans le cadre de cette étude et s'en inspirer. Le bureau de coordination de la surveillance écologique (BCSE) s'appuiera sur cette étude et les leçons qu'on peut en retirer afin d'élaborer un indicateur de transformation du paysage susceptible d'être utilisé dans d'autres sites du Réseau d'évaluation et de surveillance écologiques (RESE), dans le cadre d'un système d'alerte rapide des changements écologiques au Canada. Le ministère de l'Environnement de l'Ontario compte partager les protocoles et les leçons apprises avec ses clients et partenaires, y compris les municipalités, les ONG et les responsables de la protection de la nature.

Tableau 4-Sommaire des techniques utilisées dans l'étude sur les transformations du paysage

Technique	Atout	Faiblesse	Réserve de la biosphère utilisant la Technique
Carte et crayons	Peu coûteuse, n'exige pas de compétences spécialisées	Fastidieuse, moins précise, non quantifiable	Charlevoix
Systèmes d'information géographique	Exhaustive, création d'une base de données, capacités d'interrogation	Coûteuse, exige une grande compétence technologique	Riding Mountain, Waterton, Long Point, Mont St. Hilaire, Escarpement du Niagara
FRAGSTATS	Outil analytique servant à l'analyse de la fragmentation des forêts	SIG, exige des compétences spécialisées	Escarpement du Niagara,

Le Projet sur la transformation du paysage dans les réserves de la biosphère a permis de recueillir d'importants renseignements sur les transformations que les humains ont fait subir au paysage depuis la colonisation européenne et que l'on peut retirer des données et de l'information existantes sur l'utilisation du sol. Ces études ont brossé un portrait de la transformation de l'environnement naturel à l'intérieur et autour des réserves de la biosphère et de fournir de l'information aux communautés des réserves de la biosphère afin de les aider à préciser leur «notion de lieu». Il est recommandé de continuer à utiliser toutes les techniques appliquées dans le cadre de ces études afin de continuer de recueillir de l'information sur la transformation du paysage et les changements écologiques connexes dans les réserves de la biosphère et ailleurs au Canada.

Waterton Biosphere Reserve Landscape Change Study

The Castle region is under increasing human pressure. The area is used intensively for logging, recreation (motorized and non-motorized vehicles), natural gas extraction and cattle grazing. The Southern Bow-Crow forest, of which the Castle is a part, is the narrowest strip of forest land along the Rocky Mountains, being only 15-35 kilometres in width. The West Castle and South Castle Valleys, along with the Flathead River Valley in British Columbia, are the sole north-south running valleys contained wholly within the southern Rocky Mountains. The area contains wilderness corridors crucial for large carnivore movement between the United States and Canada. Fragmentation of these passages could lead not only to fractured habitat within the Castle but also to the isolation of the grizzly bear in the U.S. state of Montana from other populations in Canada. Possible extinction of the isolated population of U.S. grizzly bear could occur as it has been stated that "the most critical habitat for the long term persistence of the grizzly bear in the U.S. may occur in Canada".

What are the methods used in the landscape change study?

The study combined an extensive literature search with use of aerial photos, satellite imagery and geographic information systems to detect spatial/temporal landscape changes in southwestern Alberta. The analysis focused on:

- a comparison of road and trail development between 1951 and 1997; and
- a comparison of logging activity in each of the Carbondale, West Castle and South Castle watersheds.

Using 1951 air photos analyzed through a spectroscope, roads were digitized against a geo-corrected 1996 SPOT satellite image (10 metre resolution). A second theme of current roads, trails (including seismic lines) was derived from the original digital files of the Castle Access Management Plan as provided by the Rocky Mountain Ecosystem Coalition. Increase in total road/trail surface and changes in road density were calculated in ARC/INFO (a Geographic Information System provided by ESRI Canada Ltd.). Alberta Vegetation Inventory data secured through the Alberta Conservation Data Centre was searched for clearcuts and overlaid upon the SPOT image in each of the focus watersheds – West/South Castle and Carbondale. Analysis for clearcut size, edge effect, and total amount of clearcut was generated for each of the three valleys. Plots were generated using facilities at the Geography Department, University of Calgary.

What are the results and implications of the study? And lessons for Waterton Biosphere Reserve and other decision-makers?



Figure 6 - Freshly Cut Timber Logs

Logging

Timber extraction in the Castle region occurs unevenly in each of the three major river valleys (see Figures 7 and 8). According to an analysis of Alberta Forestry data, of the almost 10,000 hectares (ha) that has been logged in these watersheds, about 83 percent (8,302 ha) has occurred in the Carbondale, 8 percent (808.7 ha) has occurred in the South Castle and 9 percent (888.6 ha) has occurred in the West Castle. Despite the heavy activity in the Carbondale, the latter two valleys are relatively intact. It is in these two valleys, the South Castle and West Castle that opportunities exist for improved practices and restoration based upon the findings of this study.

Timber harvesting has the potential to affect wildlife adversely but can be managed to minimize negative impacts and even provide some benefits. Impacts may include animal avoidance of areas during active logging; habitat alteration leading to a decline in use and eventual habitat loss; fragmentation of habitat if the clearcut area impedes movement by wildlife; stress due to noise or human presence which may affect survival and reproduction; increased human-bear interactions at logging camps which may lead to habituation and food conditioning if humans are careless or uneducated about the consequences; and roads which allow for increased human

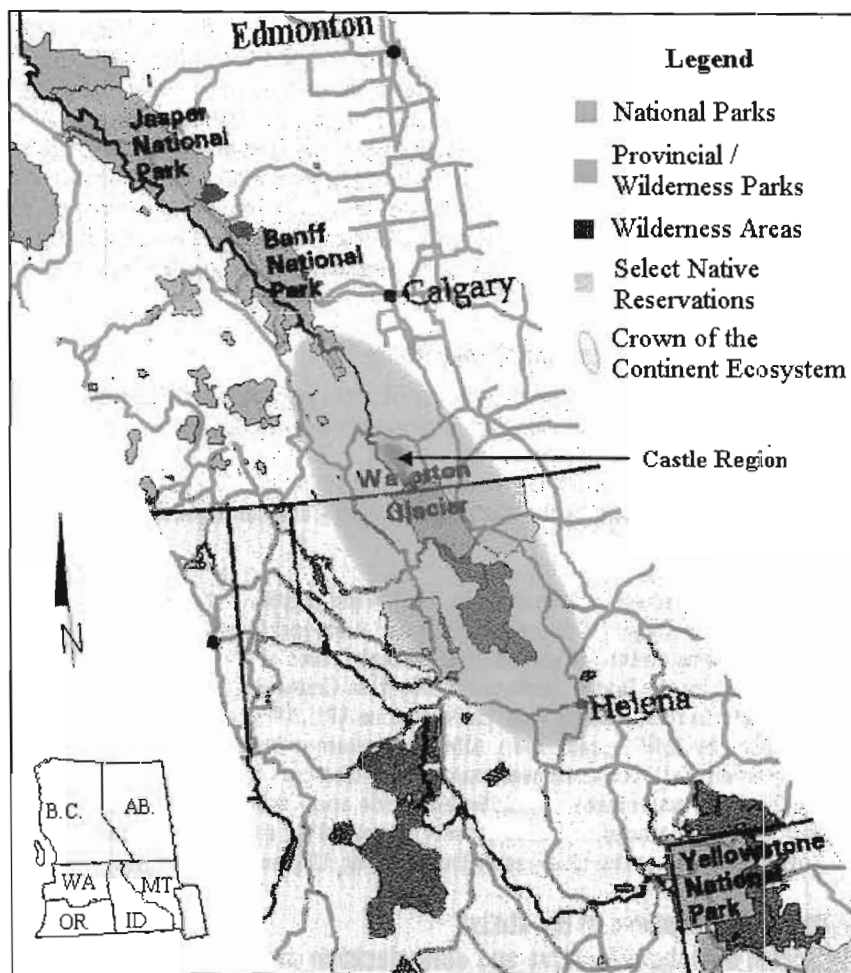


Figure 5 - Castle Region of Southwestern Alberta

The Castle Region consists of a diversity of ecological types including grassland and aspen parkland, montane, subalpine and alpine. The largest is the subalpine area, which occupies approximately 50 percent of the region. The montane area is important winter range for species such as elk. The subalpine area is important summer range for both elk and grizzly bears.

With the diversity of habitats available, the Castle Region also has a rich diversity of plant and animal species, including 824 vascular plant species - 75 of which are considered rare. The Region houses the largest stands of whitebark pine, an important food source for grizzly bears, in the province outside of Waterton Lakes National Park. Some of the area's larger mammal inhabitants include Rocky Mountain Bighorn Sheep, Wolverine, Elk, Moose, Cougar, Canada Lynx, Gray Wolf, White-tailed Deer, Mule Deer, Black Bear and Grizzly Bear. Two species of reptiles - the wandering garter snake and the plains garter snake - and four species of amphibians, including the spotted frog which may be at risk, are present in the area. Bird diversity in the region is also quite high including birds of prey, water-birds, songbirds, woodpeckers, kingfishers and upland birds. Various species of fish are present in the waterways of the Castle Region although overfishing, habitat degradation and stocking with non-native game species (rainbow and brook trout) has had a detrimental effect on the populations of native species, such as bull and cutthroat trout and mountain whitefish.

Waterton Biosphere Reserve Landscape Change Study

Roads and Access

Analysis of air photos reveals that, by 1951, roads and trails penetrated the Gardiner, Lost and Lynx Creek headwaters of the Carbondale and were just being introduced to the South and West Castle valleys. The density of roads present in the Castle Region has increased substantially since 1951 (see Figures 9 and 10). There are estimates of 463 kilometres of open roads in the Castle Region of which 41 kilometres are industrial access roads, only 5 kilometres are major haul roads and the remaining 417.9 kilometres are abandoned and off-road vehicle-created roads. The road density in the Castle Region is 0.912 kilometres/square kilometre, a density that researchers estimate is responsible for at least a 25 percent habitat loss for elk. Unfortunately, these roads often follow valley bottoms through the banks of rivers which are inherently good habitat for grizzly bears. This leads many researchers to describe construction and post-logging (or natural gas extraction) management of roads as the largest barrier to elk and grizzly bear management. Many species, including grizzly bear and elk, avoid roads and habitat adjacent to roads. The habitat loss extends beyond the physical dimensions of the road itself since wildlife avoids the habitat near and around roads as well. Researchers have found that grizzly bears avoid areas within 900 meters of roads and elk reduce their use of habitat 800 metres from the road edge.



Figure 9 - Roads in the Castle Region 1951

Therefore roads that are constructed for the logging industry and left open for vehicle access following operations may decrease the use of clearcut areas by grizzly bears, even if favourable plant material is available as a food source. This leads to what scientists call "effective habitat loss" or an unwillingness of animals to use otherwise suitable habitat.

A serious negative impact of roads is the potential for greater access into remote areas. This increased access results in an increase in wildlife species' susceptibility to legal and illegal hunting. Between 1972 and 1984, 70-75 percent of all grizzly bear kills in Alberta – including legal, illegal and management removal – were within one kilometre of roads.

Off-Road Vehicles

There are approximately 1,645 off highway vehicles registered in Alberta, the majority of which are snowmobiles, followed by all-terrain vehicles and motorbikes. This is a completely new impact that did not exist in 1951. Although roads did exist up the Carbondale, and West Castle



Figure 7 - Forest harvesting in the West/South Castle Watersheds



Figure 8 - Forest harvesting in the Carbondale Watershed

access into previously remote areas. Potential adverse impacts may be reduced by adjusting the timing and spacing of logging operations; improving the post-logging treatment of slash and soil; and reclaiming access roads to deter motorized traffic. If procedures are implemented with concern for wildlife then it is possible that the post-logging environment, especially in the absence of a natural fire regime, could increase the carrying capacity for bears in the region. The same would hold true for elk.

Waterton Biosphere Reserve Landscape Change Study

Cumulative Impacts

The impacts of all of the human activities in the Castle Region must be assessed cumulatively over time and space as this reflects what the wildlife will be exposed to. Wide-ranging animals such as grizzly bears could be exposed to several human activities within the course of a day, especially during the time of year when they are more mobile in search of food. It has been described above that both elk and grizzly bears are sensitive to human encroachment in their habitats. It appears that there is ongoing degradation of habitat occurring in the Castle Region. Each industry enters the wilderness, performs its function – be it seismic exploration or timber removal – and leaves. But the habitat that is left differs from the habitat present prior to disturbance. Seismic roads are left, timber hauling roads remain open and cutblock areas may or may not be treated with respect for wildlife needs in mind. This is the new 'habitat' which wildlife must adapt to. If wildlife cannot adapt, then that area is no longer available to them. As pieces of wilderness are lost, the remaining ecosystem becomes less able to support the species it once could. Following the resource industry's encroachment into the wilderness, off-road vehicle recreational activities increase. Once off-road vehicle users access previously untouched areas of the Castle Region, further trails are established along with campsites. Some of these users may be hunters who are now able to reach areas in a couple of hours, that before have taken a couple of days on foot. Game species, such as grizzly bear and elk, are no longer safe in these areas which were previously difficult for humans to access.

What are the next steps?

This study into landscape change begs several questions. Are we content with having elk forced out into their prairie conflict with ranchers or can we improve habitat enabling elk to return to previous levels of viability? With respect to grizzlies: Does the Alberta public care if grizzly bears exist in the southern part of the province? Do we have an obligation to complement, not hinder, recovery efforts in the United States?

If the public supports grizzly bear conservation then human activity in these corridors must be controlled to prevent fragmentation. If we can conserve habitat for the larger carnivores, such as the grizzly bear and wolf, then it is likely that habitat will be conserved for most other vertebrate species as well. The plight of the grizzly bear in the Castle Region will be an indicator of its future in North America.

valleys in the early fifties, use was largely confined to these roads. Not only did roads and motorized trails expand dramatically by 1997 (see Figures 9 and 10), often these are just staging points for off-road activity which permeates 'buffer' zones around them. This recreational activity will likely increase in Southern Alberta as most of Kananaskis Country to the north of the Castle Region, with the exception of McLean Creek, has been closed to off-road vehicles. A steward report for the Castle Region in 1996 showed 16 of 22 examined trails having recent off-road vehicle use; with over half of these being heavily damaged

The effects of off-road vehicles go beyond indirect habitat loss for wildlife due to avoidance. Heavy off-road vehicle use can completely eliminate vegetation directly and indirectly by crushing and soil compaction. This alters habitat by reducing the food and cover available for wildlife. In the winter, snowmobiles can alter the under-snow environment affecting plant growth and the survival of small mammals. Snowmobiles can also cause problems for elk on their wintering range when they are more sensitive to disturbance. Snowmobile tracks allow wolves to access and hunt deep snow country where isolated wintering herds of elk are located. The lack of wolves in the Castle system currently renders this impact moot.



Figure 10 - Roads in the Castle Region 1997

Seismic Activity/Gas Wells/Pipelines

Although the study has focussed on forestry and roads rather than petroleum developments, the latter is strongly associated with motorized access. Hence, a study of impacts from petroleum development was included to complement the analysis.

There are 72 natural gas wells presently in or near the Castle Region, located primarily within the Front Range. Seismic activity started in approximately 1953 after the introduction of roads for logging and fire-fighting purposes. Roads were left open, facilitating access for motorized vehicles into previously undisturbed remote areas. Increased access following natural gas extraction activity may have greater negative consequences for wildlife than the more direct impacts of the industry itself (exploration via seismic lines; drilling and subsequent operation of gas wells). However, all of these activities, both direct and indirect, have effects on the use of the Castle Region by wildlife.

Niagara Escarpment Biosphere Reserve Landscape Change Study

What are the study objectives?

The Niagara Escarpment Landscape Change Study synthesized land-use change information for the Escarpment, and identified linkages between different scales of analysis - regional level, area level, and site level. Cumulative environmental effects are usually landscape level phenomena. Understanding the survival of a species in the landscape involves addressing the survival in a regional context. A species' persistence is directly related to habitat size, shape, proximity and connectivity of the landscape. In

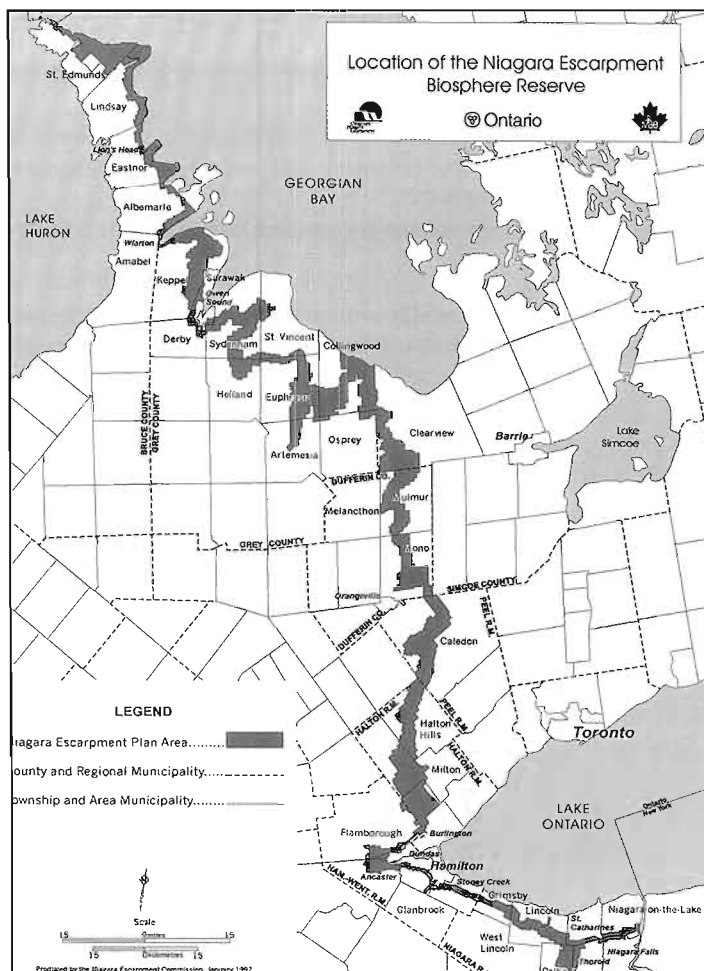


Figure 11 - Niagara Escarpment Biosphere Reserve

turn, these landscape patterns are influenced by land-use change. The objective of the study was to determine land use change at the regional and area scale on landscape patterns and associated cumulative effects on the landscape and two species – the wood thrush and the scarlet tanager.

What is the study area?

Located in southern Ontario, the Niagara Escarpment Biosphere Reserve is a largely forested corridor extending for 725 km from the Niagara River to the tip of the Bruce Peninsula (see Figure 11). The area is characterized by a diversity of microclimates created by changes in relief across the scarp, orientation of cliff and talus slopes, cold air drainage conditions along valleys, and the presence of caves and springs. As a result, the Escarpment supports diverse plant and animal communities.

Human activities have affected the health of most of the Escarpment to varying degrees. Activities such as aggregate resource extraction and farming have altered the natural landscape. There is increasing demand for permanent residences, especially along the southern portion of the Niagara Escarpment because of the beauty of the Escarpment landscape and its proximity to major urban centres. The beauty and accessibility of the Escarpment (via the Bruce Trail) also attracts a wide range of recreational users.

Recommendations for further study

The study revealed that a lot more can be completed with existing data and literature. Our overarching questions are:

- To what degree do the Castle, Flathead and Wigwam drainages each contribute to dispersal and viability of large mammals throughout the Rockies of BC, Alberta and Montana?
- To what relative degree do varying human activities cumulatively affect this dispersal and viability?
- To what degree do these varying activities affect the biodiversity or species richness in this region?
- How much of this region is available habitat for bear and elk relative to rock and ice?
- Given deficiencies in provincial vegetation inventory data, what is the true history of logging in the area and what are its impacts?
- What trails and roads are missing from current government files and what is their relative use and impacts?

Some of these questions can be answered readily with available data whilst others require new transboundary partnerships between museums, governmental agencies, scientists and conservationists.

To obtain the complete and original study titled Threats and Opportunities: The Elk and Grizzly of the Castle Region, Southwestern Alberta, write to the Miistakis Institute for the Rockies c/o Biological Sciences, University of Calgary, 2500 University Drive NW, Calgary, Alberta, CANADA T2N 1N4.

Niagara Escarpment Biosphere Reserve

Area Level

Using an area level analysis, forests can be broken down into groupings of vegetation (i.e. deciduous, coniferous, or mixed) and the connectivity of forested areas can be examined. Area level analysis is directed at monitoring the cumulative effects of land-use change, that is, the sum of human impacts over space and time. The Abiotic, Biotic, and Cultural Resource (ABC) Survey Method for cumulative effects monitoring of landscape conditions was applied in a section of the Halton Region - a section selected as a result of the regional level analysis (see Figure 13).

The cumulative effects of land-use change (1974-1994) in the north part of the Region of Halton were examined. The 76,000 hectare study area included portions of the Town of Halton Hills, the Town of Milton and the Hilton Falls Complex, which is the largest wooded corridor within the southern Niagara Escarpment - an area designated as "environmentally sensitive". Baseline data for the 1994 conditions were provided in digital format by the Ontario Ministry of Natural Resources. This information was digitized from 1:10,000 Ontario Base Map (OBM) sheets. Classification of land-use type, physiognomic grouping of vegetation, and forest patches was primarily based on aerial photographs (1:20,000 for 1994 and 1:15,000 for 1974). ArcInfo was the geographic information system used in the study to generate two final maps: one where landscape and land-use change resulted in positive cumulative effects (e.g. increased habitat for indicator species such as the Scarlet Tanager); and the other showing negative cumulative effects (e.g. conversion of a forest stand to an agricultural area).

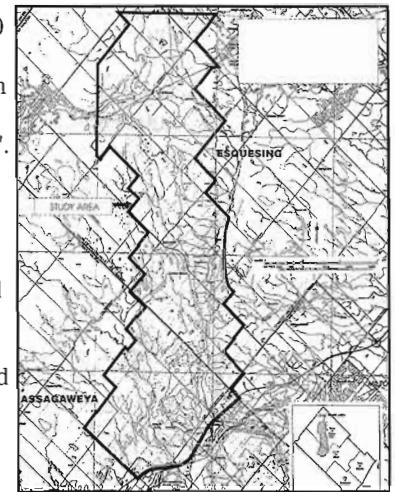


Figure 13 - Halton Area of Southern Niagara Escarpment Biosphere Reserve

Site Level

Within the southern portion of the Niagara Escarpment, a forest biodiversity monitoring plot was established in the Hilton Falls Conservation Area in 1996 using methods developed by the Smithsonian Institution's Monitoring and Assessing Biodiversity program (see Figure 14). The Hilton Falls Conservation Area was chosen as a "control site" as it is located at the northern limit of the richest ecosystem in Canada - The Carolinian Zone - and it contains species with both northern and southern ranges. The transitional area where it is located (between two ecological regions created by climatic influences and physiognomic factors) is known as an "ecotone". Ecotonal areas are particularly important for monitoring climatic influences on vegetation and changes in species ranges.

The Canadian Wildlife Service of Environment Canada studied the effects of forest fragmentation on neotropical migrant birds in forests of different sizes along the Niagara Escarpment. The Hilton Falls tract (>1200 ha) was the largest connected forest area used in the study. As part of this study, the nesting productivity of the Wood Thrush was monitored in the Hilton Falls Conservation Area and the surrounding forest. The Wood Thrush is a neotropical migrant of conservation concern provincially where it has experienced long-term population declines.

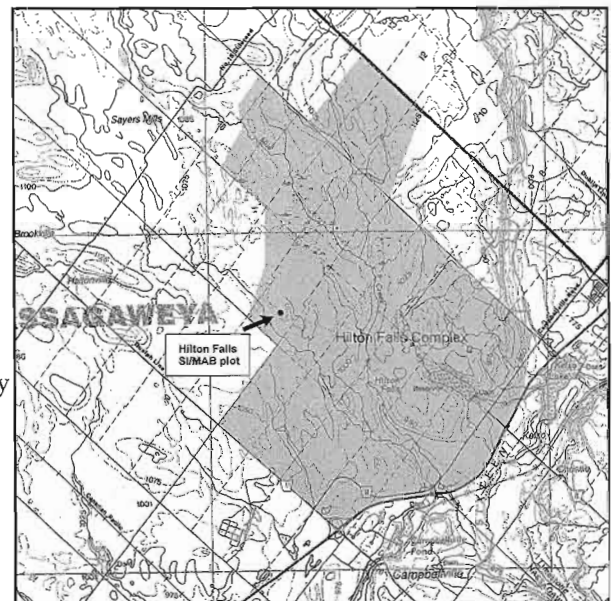


Figure 14 - Location of SI/MAB Plot at Hilton Falls Complex of Southern Niagara Escarpment Biosphere Reserve

What are the methods used in the landscape change study?

Regional (Landscape) Level

Regional landscape change analysis was conducted by Geomatics International in 1997 providing a broad overview of land-use information and landscape change along the southern Niagara Escarpment (see Figure 12) over a 20 year period (1976-1995). As part of the regional level analysis, five sub-areas characterized by distinct land-use pressures which comprise the southern Niagara Escarpment were examined: the Niagara Peninsula East; the Niagara Peninsula West; Hamilton-Dundas-Burlington corridor; the Halton Region; and the Region of Peel. The Niagara Peninsula is dominated by agricultural activities, including tender fruits and row cropping.

The major form of land-use in the Hamilton-Dundas-Burlington corridor is high intensity urban activities, while the Halton and Peel Regions are dominated by rural and recreational development.

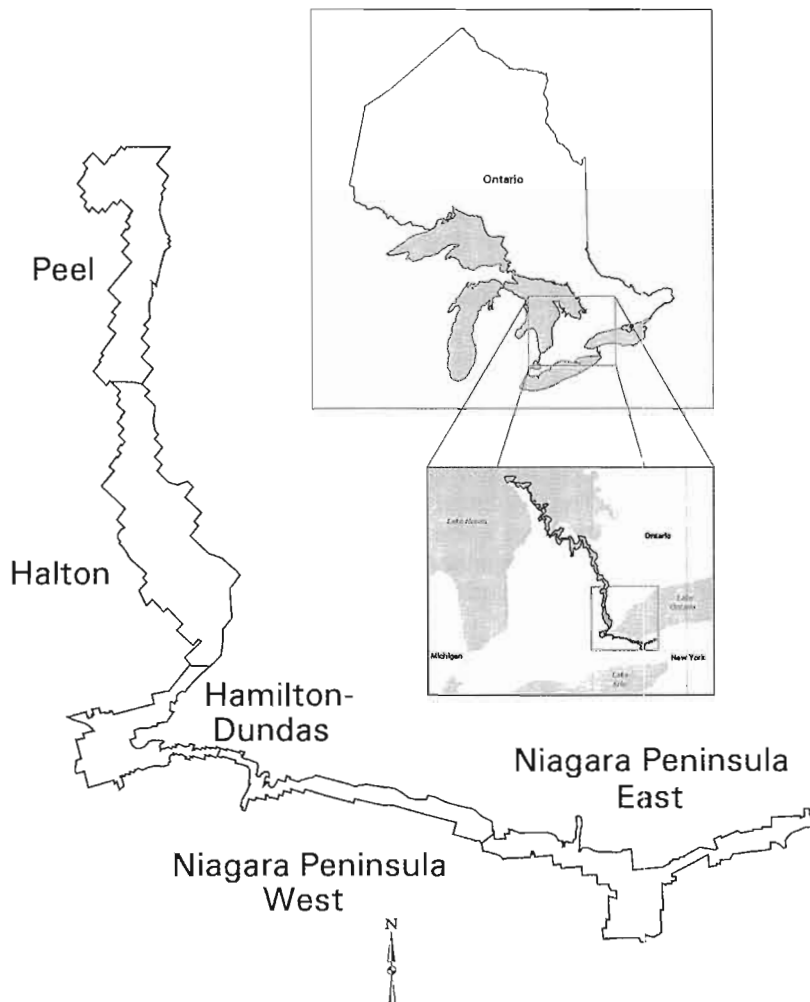


Figure 12 - Southern Niagara Escarpment Biosphere Reserve

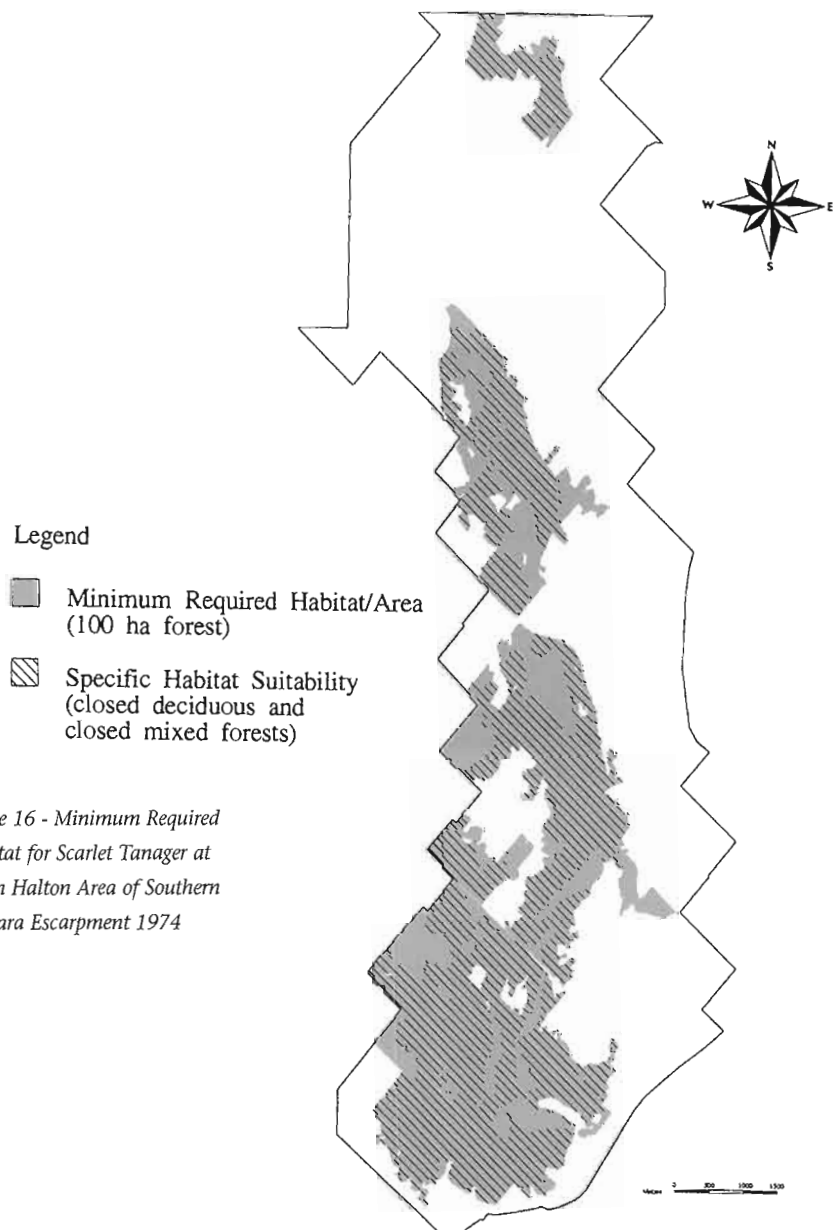
Analysis involved classifying and analyzing satellite imagery to determine the effects of development on the natural landscape in terms of total area of forests, fragmentation, and connectivity. FRAGSTATS, a program used to quantify forest patches in terms of size, shape, density, nearest neighbour, core area, edge habitat, etc., was used to determine forest fragmentation for the entire southern portion of the Niagara Escarpment and the five regional sub-areas.

Niagara Escarpment Biosphere Reserve

Area

Regional analysis for the southern Niagara Escarpment identified that there is a rapid decline in forest interior habitat. Regional sub-area analysis revealed that the Halton Region has the largest forested area, the highest number of forest patches, and the highest amount of forest interior habitat within the region.

Forest cover in the north Halton study area increased from 3,545 hectares in 1974 to 3,696 hectares in 1994 - a 4 percent increase mainly associated with minor size increases in shrubland, open mixed, and woodland vegetation types at the outer boundaries of forests. Connections between the forests were poor or non-existent. Less than 50 percent of the major woodlands (>100 hectares) and large forests (20 - 100 hectares) provided interior habitat conditions. All of the medium and small forests were entirely composed of edge habitat.



What are the results and implications of the study? And lessons for Niagara Escarpment Biosphere Reserve and other decision-makers?

Regional

Agricultural land-use within the Niagara Escarpment decreased from approximately 41 percent (~24391 hectares) in 1976 to 40 percent (23804 hectares) in 1995. Forested areas accounted for 43 percent (~25500 hectares) of the total land cover in 1976, and increased to 44 percent (~26132 hectares) in 1995. Other classes that showed an increase in area between 1976 and 1995 include urban land cover (~2073 hectares to 2973 hectares) and recreational areas (~426 hectares to 1040 hectares).

Although the forested area increased between 1976 and 1995, a higher number of forest patches was found in the 1995 image (898 patches) compared to the 1976 image (827 patches). Overall, the southern Niagara Escarpment landscape in 1995 consisted of more numerous, smaller patches of forest with a greater variability in size than the landscape in 1976, leading to the conclusion that the forested landscape is now more fragmented.

In addition to a more fragmented forest, the actual shape of each forest patch increased in irregularity from 1976 to 1995. Patch shape is important for determining the amount of core forest (100 metres from forest edge) necessary to support certain plants and animal species away from disturbance. In 1976, more than half of forest area was core forest (100 metres from forest edge) while in 1995, core forest was only 39 percent. This decline in the amount of forest interior habitat may represent one of the most serious threats affecting forest interior species such as the Scarlet Tanager (see Figure 15).



Figure 15 - Scarlet Tanager (*Piranga olivacea*)

Niagara Escarpment Biosphere Reserve

Site

Of the total number of species identified in the forest biodiversity monitoring plot, over 90 percent were native, which is a relatively high proportion compared to most natural areas in southern Ontario. Species composition and the size of canopy trees in the plot suggest that the community is a secondary successional forest. The canopy was dominated by sugar maple (*Acer saccharum*), which is typically associated with the later stages of succession. Floristic quality assessment of the plot revealed that several species (e.g. lobed woodsia, showy orchid, and white wood aster) are significant in that they are habitat specific and sensitive to disturbance.



Figure 18 - European Buckthorn (*Rhamnus cathartica*)

Several introduced species were present in the plot which may pose a threat to its native quality. Of particular concern is the European buckthorn (*Rhamnus cathartica*) (see Figure 18), which is an aggressive invader that has the ability to out-compete native species and become a local dominant. Scientists recommend that this species be carefully monitored.



Figure 19 - Woodthrush (*Hylocichla mustelina*)

Wood Thrush (see Figure 19) nesting success was nearly twice as high in large woodlots than in small woodlots. Nest destruction by predators was the main cause of poor Wood Thrush reproduction in all forest sizes - although parasites reduced the productivity of nests that escaped predators. The rate of parasitism was significantly lower in medium and large woodlots. More than 60 percent of the nests within 50 metres of the edge were parasitized. There were no parasitized nests observed >300 metres from the forest edge. The results suggest that further fragmentation of large woodlots would increase predation and parasitism.

Wood Thrushes in large woodlots produced an average of 1.55 female young, which is above the 1.06 young required for population replacement. In small woodlots, productivity levels were below the replacement value. Hilton Falls, which was the largest woodlot in the study, was identified as an important regional population source for Wood Thrushes in southern Ontario.

Integrated Analysis

Regional analysis provided a broad overview of landscape patterns across the southern Niagara Escarpment and identified changes in landscape conditions between 1976 and 1995. In 1995, the southern Niagara Escarpment was characterized by more numerous, smaller forest patches compared to forests in 1976. Of the five regional sub-areas, Halton Region was identified as having the highest forest cover and the greatest amount of forest interior habitat. However, temporal analysis of the Halton sub-area showed that the amount of interior forest habitat is rapidly decreasing. An increase in extraction activities was identified as the most significant landscape change between 1976 and 1995. Recreational development was also identified as an expanding land-use.

Regional analysis is useful for assessing overall trends and landscape patterns. At this level of analysis, it was identified that the Halton Region is ecologically important in terms of forest habitat but is subject to increasing development pressures. More detailed area level analysis was used to link the cause (development) with the ecological effect (forest fragmentation) and to assess the cumulative effects of landscape change.

Within the southern Niagara Escarpment, area level analysis focused on the north section of the Halton Region. The results showed that less than half of the larger woodlands and large forests in the study area provide forest interior conditions. Mineral extraction was found to be the most significant impact on interior forest patterns above the Escarpment, with agriculture as the main factor influencing these patterns below the Escarpment.

A decrease in forest interior area due to decreased size of forests and more irregular forest patch shapes (see Figures 16 and 17) is a negative change for indicator species such as the Scarlet Tanager (see Figure 15). The Scarlet Tanager is a forest interior species that requires large (>100 ha), undisturbed, mature to semi-mature deciduous forests. This species is particularly sensitive to disturbances associated with edge effects.

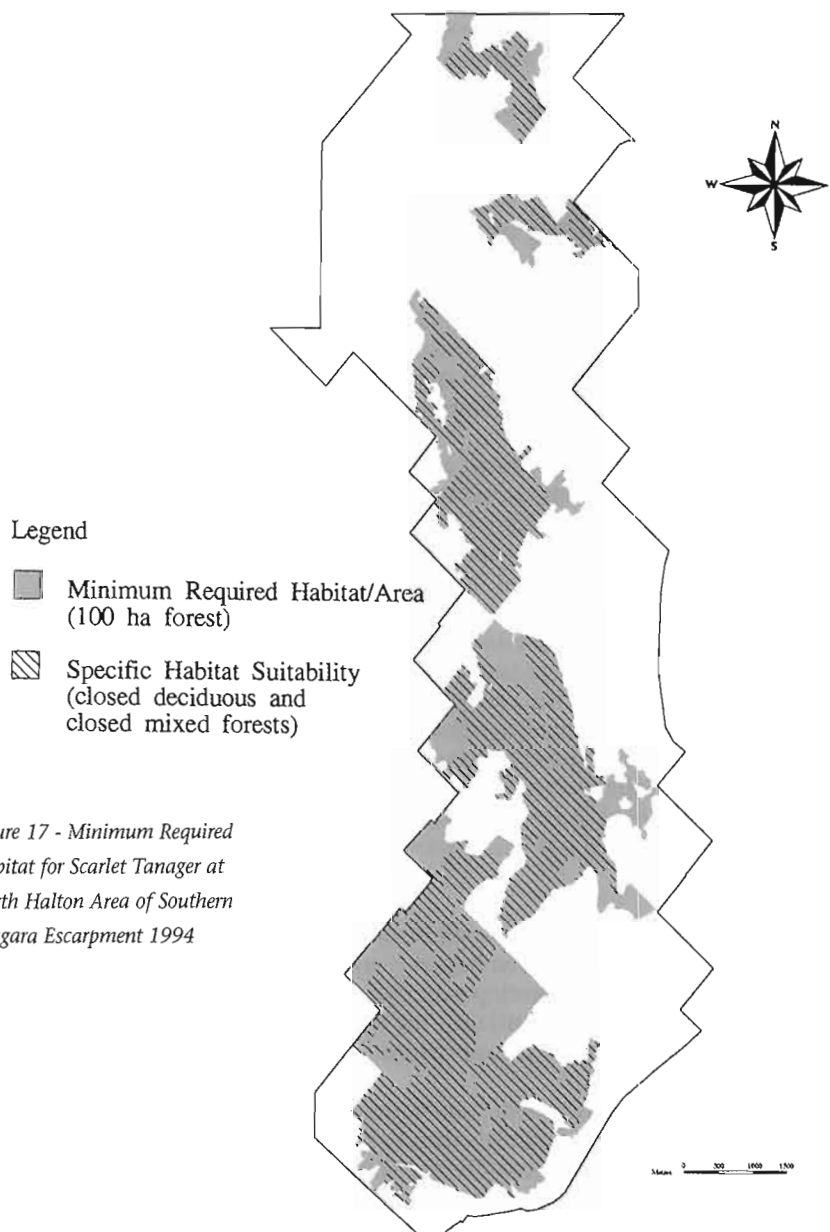


Figure 17 - Minimum Required Habitat for Scarlet Tanager at North Halton Area of Southern Niagara Escarpment 1994

Long Point Biosphere Reserve Landscape Change Study

What are the study objectives?

The focus of the Long Point Biosphere Reserve Landscape Change Study is on forest cover change in both quantity and quality. More forest does not necessarily equate with better forests. Studies have shown that many factors aside from just the size of a forest have an impact on its quality or its ecological integrity.

It is well recognized by ecologists that the impacts of housing within and around forests have a strong influence on the quality of the forests for birds. Researchers have found that the presence of housing has a strong negative relationship with forest interior bird species, particularly long distant migrants, independent of forest size.

The quality of the forest also is negatively influenced when the proportion of edge increases relative to the interior. Many aspects of the edge are detrimental to forest dwelling species. Nest predation from mammal predators such as squirrels, raccoon, mice, opossum and cats, and avian predators such as Blue Jays, American Crows, and Common Grackles have been demonstrated to occur more frequently near the forest edge as opposed to the forest interior. Hydro right-of-ways also have major effects in that forest birds, particularly many long-distance migrants, avoid the band of forest adjacent to a cleared right-of-way to a distance of at least 120 metres. Thus the phenomena associated with the visible edge penetrate deep into the forest.

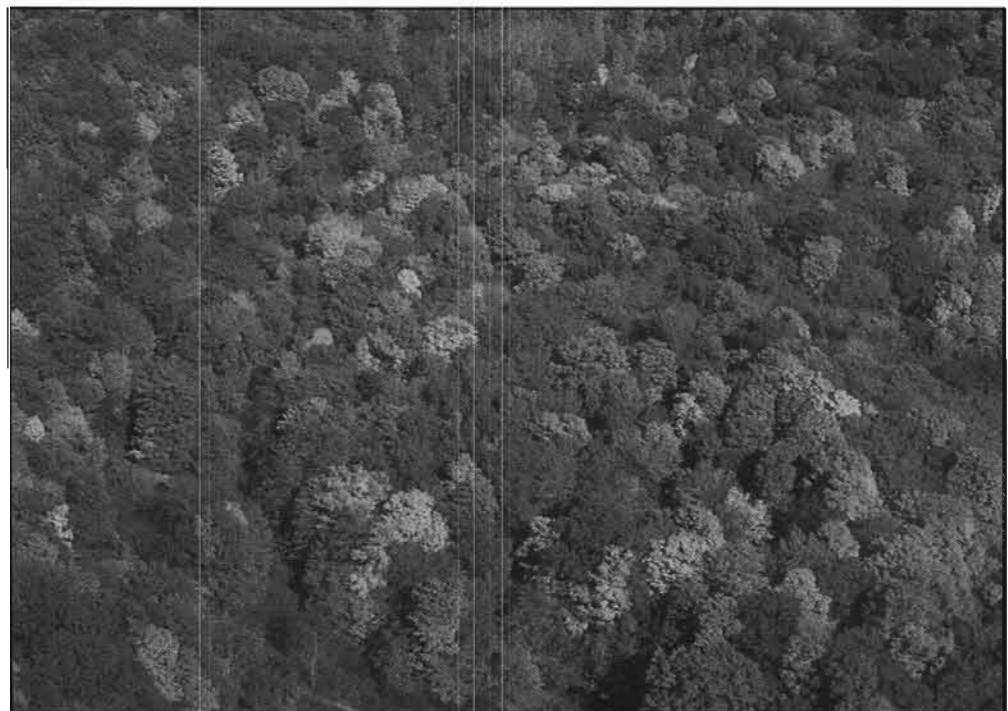


Figure 20 - Forests of Backus Woods at Long Point Biosphere Reserve

The identification of significant threats at the area level guides the selection of sites for more intensive monitoring at a smaller scale - the site level. Site level investigations target specific threats identified at the regional and area levels of analysis. In the Halton area, forest fragmentation was identified as an area of concern. A site level investigation was designed to address the following question: what are the effects of forest fragmentation on forest bird productivity? To address the impact of development on vegetation community status, a forest biodiversity monitoring "control" plot was established in the Hilton Falls Conservation Area. Based on area level analysis results, this area was identified as one that has not been significantly impacted by development which was confirmed by field data. The plot contained a high proportion of native species, some of which were habitat specific and sensitive to disturbance. Analysis of field data revealed that increased rates of predation and parasitism in small woodlots negatively impacted the reproduction of Wood Thrush. Therefore, increased forest fragmentation will likely have serious impacts on the nesting and breeding success of this species of conservation concern as well as other neotropical migrant birds.

What are the next steps?

The three levels of analysis identified in this study are not meant to be considered individual methods of analysis, but rather as interrelated ways to examine landscape change at Biosphere Reserves. Starting at an extensive, larger scale and moving towards an intensive, smaller scale is an effective tool for identifying landscape patterns, pressure areas, and answering specific monitoring questions based on a greater understanding of the distribution of land-use/cover and species-habitat relationships. The techniques used at the three scales of analysis could form the basis for integrated analysis of landscape change for other Biosphere Reserves and environmentally significant areas in Canada.

Recommendations for further study

Based on the integration of landscape change information at the three scales of analysis, the following recommendations are made:

1. Analysis at the region, area, and site levels should be continued as part of the Ontario Niagara Escarpment Monitoring Program as it provides useful information for examining landscape change on the Escarpment.
2. Regional and area level analysis information should be used to select a site in the Halton Region for monitoring land-use pressure and human-induced stress with the same habitat type as the existing control plot.
3. Regional level analysis has been completed for the northern Niagara Escarpment. Based on this macro-scale information, the need exists to monitor the cumulative effects of land-use and landscape change at the area level.
4. Analysis methods should be developed and tested in other Canadian Biosphere Reserves.
5. Forest bird productivity monitoring should be continued and also applied in other Escarpment forests outside of the Halton Region.

To obtain the complete and original study titled Niagara Escarpment Biosphere Reserve Landscape Change Project: Integrated Analysis of Regional, Area and Site Level Land-Use Change Information, write to the Niagara Escarpment Commission, 232 Guelph Street, Georgetown, ON, CANADA L7G 4B1.

Long Point Biosphere Reserve

What are the results and implications of the study? And lessons learned for Long Point Biosphere Reserve and other decision-makers?

The historical (1790) forest cover (see Figure 22) and the present (1990) forest cover (see Figure 23) reveal no surprises with the most striking difference being the decrease in regional forest cover. The agricultural and resource-based economies of the local area in the 19th century required extensive forest clearing. It is well documented that by the end of the 19th century, the amount of forest cover had dropped to levels that were as low or lower than what is present today. For example, the forest cover in South Walsingham Township dropped from almost 90 percent in 1851 to about 22 percent in 1911. In the early 1900s, forest lands in the entire Long Point region had been reduced to 11 percent of the landscape. Farms were turned into blow-sand deserts as a result of the loss of forest cover and were being sold or abandoned. Some lands began to revert back to forest and vast areas were reforested.

Composite Patterns of Pre-settlement Vegetation in the Long Point World Biosphere Reserve (~1790) (adapted from Chanasyk, 1972)

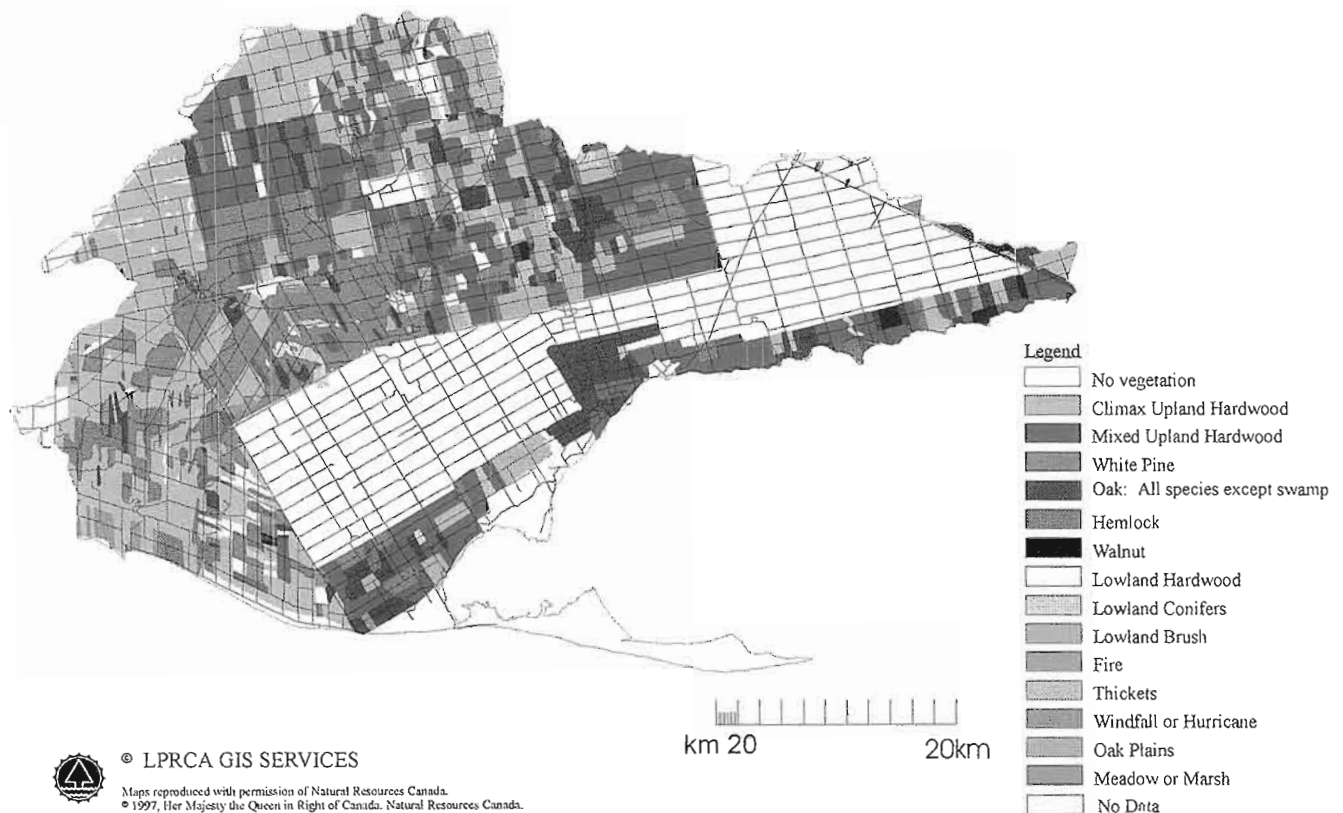


Figure 22 - Vegetation at the Long Point Biosphere Reserve ~1790

What is the study area?

The Long Point World Biosphere Reserve is located on the north shore of Lake Erie in the Regional Municipality of Haldimand-Norfolk. It contains the largest sand spit on the Great Lakes (see Figure 21), and one of the most extensive wild areas remaining in southwestern Ontario. Long Point was officially designated as a World Biosphere Reserve in 1986. The reserve consists of a core protected area (the Long Point National Wildlife Area), a buffer area (defined by the 10 metre depth contour offshore, and the "regulatory" 1:100 year flood line onshore), and an undefined "zone of co-operation". Although defined in numerous ways, the biosphere's "zone of cooperation" is defined most extensively as the watersheds under the jurisdiction of the Long Point Region Conservation Authority, and is done so for the purposes of this study.

The Long Point Region Conservation Authority watershed is predominately a rural agricultural landscape with agricultural land comprising 73 percent of the total land area. Much of the terrestrial vegetation remains in deeply incised river valleys and forested wetlands. Some of the largest tracts of mature deciduous forest in southern Ontario (much of it with an "old-growth structure") are found in this watershed area.

What are the methods used in the landscape change study?

The focus of the Long Point Biosphere Reserve Landscape Change Study is on forest cover change in both quantity and quality. Three time periods were selected to complete this analysis: pre-settlement, 1985 and 1990. Pre-settlement vegetation was mapped to help gain an understanding the aerial extent of the forests and the location of forest community types. As such, historic forest cover maps also provide insight for future restoration and management efforts.

Forested areas in 1985 and 1990 were mapped in order to examine recent changes in quantity (area) - that is, changes through restoration efforts as well as clearing, and changes in quality such as edge length. It is well recognized that forest cover has decreased since pre-settlement times - at Long Point it has been documented to be about 18 percent of the pre-settlement forest cover. However, it is not well recognized what changes have occurred recently. There has been a shift away from rural farms to more residential houses. So, in addition to looking at changes in forest area and edge length, an examination of the number of houses within and adjacent to woodlots was also made. This may have an impact on the forests that is not well known.

Using a geographic information system, the present day road network was overlain on the historical forest cover map. This made it possible to identify the location of present day blocks of forest on the historical forest cover map. In terms of forest species composition, four known forested sites - Turkey Point Forests, Backus Forests, and the South Walsingham Sandridge Forests - were compared to see whether obvious changes were apparent.

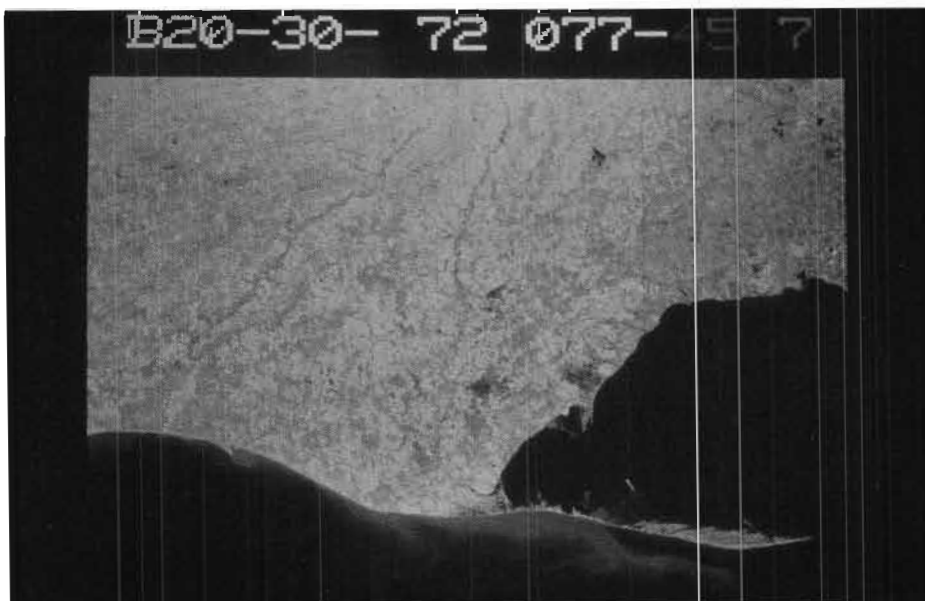


Figure 21 - Satellite Image of the Long Point Biosphere Reserve

Long Point Biosphere Reserve

Historical Versus Present Tree Species Composition

Table 5 - Historical Versus Present Tree Species Composition at Long Point Biosphere Reserve		
Site	1790 Species Composition	1990 Species Composition
Courtland Swamp	Lowland Forest and Marsh: Black Ash, Silver Maple, Hemlock, Willow, Alder	Composed of a variety of mesic to wet forested communities and a few open wetlands including: 1. Mesic Red Maple-Sugare Maple-Red Oak 2. Silver Maple Swamp 3. Dry White Oak-White Pine 4. Open Buttonbush thickets 5. Swamp Birch-Black Willow-Meadowsweet-Alder carr 6. Open, semi-permanent ponds
Turkey Point	Oak Savanna	Oak Parkland. A dry Black Oak barrens community dominates.
South Walsingham	Dry Mesic: Oak, Walnut,	1. Eastern Hemlock Woodland on steep ravine slopes Sand Ridges Forest Chestnut, Ash, Cherry with Red Maple and Yellow Birch 2. Dry-mesic Red Oak American Beech and Red Maple woodland with Black Cherry, Yellow Birch and Large Toothed Aspen 3. Dry ridge tops dominated by Black Oak, Red Oak and White Oak woodland.
Backus Woods	Dry Mesic: Oak, Walnut, Chestnut, Ash, Cherry	As many as 37 vegetation units were identified. The wet areas are characterized by Red and Silver Maple swamps. The dry areas are characterized by Red and White Oak.

In comparisons of recent changes in forest cover from 1985 to 1990 (see Figure 24), the 1985 forest cover was determined to be 18.6 percent of the watershed while the 1990 forest cover was determined to be 20.9 percent of the watershed. Although this initial result suggests that the area of forest cover within the Long Point Biosphere Reserve is increasing, this statistic needs to be interpreted with caution. Additional work needs to be completed to remove additional biases from the data set.

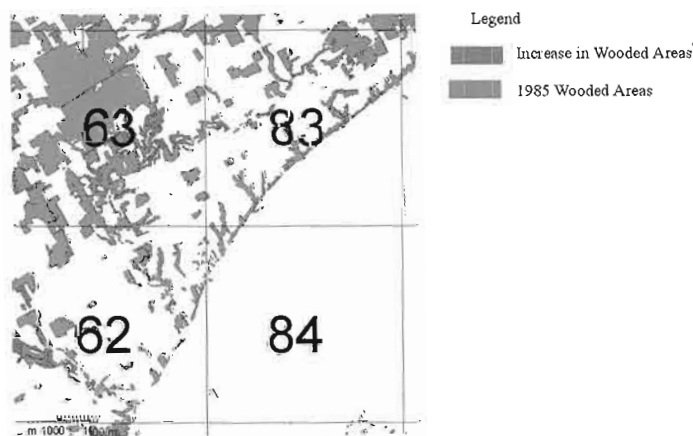


Figure 24 - 1990 versus 1985 Forest Cover: Areas of Perceived Changes

Landscape Change Study

Those areas where increases in forest cover occurred were largely a result of early reforestation efforts, such as those through the St. Williams Forestry Station, and the natural succession of marginal farmland back to forest. Even to this day, most of the remaining forest cover is concentrated in ravines or areas of rugged topography, wet areas such as swamps, and other areas that were unsuitable for cultivation. For example, the Courtland swamp forest appears to be virtually unchanged in terms of its size and location.

As is apparent from the forest species table (see Table 5), the tree species composition in these areas is basically the same as it was 200 years ago. This should not be surprising, since these areas have been identified as "Significant Natural Areas" on the basis of vegetation communities that are largely undisturbed.

1990 Forest Cover in the Long Point World Biosphere Reserve (source: National Topographic Data Base)



Figure 23 - Forest Cover at the Long Point Biosphere Reserve 1990

Charlevoix Biosphere Reserve Landscape Change Study

What are the study objectives?

The Charlevoix Biosphere Reserve Land-Use Change Study was undertaken to determine:

- how road and housing developments have affected the natural and agricultural landscapes;
- whether the decrease in farming has had an impact on the natural landscape; and
- what circumstances and opportunities exist for the natural landscape to be restored in the study area



Figure 25 - Parcs Grands Jardins at Charlevoix Biosphere Reserve

What is the study area?

The Charlevoix Biosphere Reserve covers a core area of 4,600 square kilometres, with the zone of influence extending the range to 11,000 square kilometres. Located 100 kilometres east of Quebec City, the Charlevoix Biosphere Reserve is bounded by the Cap Tourmente on the west side and the mouth of the Saguenay River to the east. Human population of the biosphere reserve is estimated at 30,000 people, most of whom are employed in tourism, forestry and agriculture. There are three core areas: the Grands-Jardins Provincial Park (see Figure 25), the soon-to-be-created Hautes-Gorges-de-la-Rivière-Malbaie Provincial Park, and the Port-au-Saumon Ecological Center.

The Charlevoix Biosphere Reserve is representative of the Appalachians, the St-Lawrence Lowlands and the Canadian Shield. The landscape at the centre of the Reserve was shaped by the impact of a meteorite 350 million years ago. The crater has a diameter of 56 kilometres and created two circular valleys where agricultural activities are possible. The altitude of the highlands of the Canadian Shield is between 600 metres and 1160 metres, an area characterized by a subarctic climate and boreal forest. The Reserve is the southernmost lichen woodland found in Quebec, which probably explains the presence of a woodland caribou population at Charlevoix. Arctic-Alpine tundra is found on several mountains and deciduous forest are found in the valleys. The St-Lawrence River is home to rich and remarkable marine flora and fauna including six species of whales such as the St-Lawrence beluga, and two species of seals (Harbour and Gray).

All of these exceptional characteristics make Charlevoix un pays où il fait bon d'y vivre that was designated by UNESCO as a Biosphere Reserve in 1989.

The area examined in this study is located south of the Laurentian Foothills and around the village of Notre-Dame-des-Monts. The area is right in the middle of the Charlevoix Biosphere Reserve located in the circular valley of the Charlevoix crater and covers an area of 148.52 square kilometres. The study area is characterized by mostly forested land and extensive agricultural use. Human development in the area is low, and the economy is dominated by forestry, tourism and agriculture.

At selected sites examined for their perceived forest change - Turkey Point Forests, Backus Forests, and the South Walsingham Sandridge Forests - the areas of fairly large forest cover change can, in most cases, be explained by either reforestation efforts, or the natural succession of marginal farmland back to forests.

However, areas where perceived forest cover change cannot be explained as easily seem to occur along the watercourses and other riparian zones - an observation that appears to extend over the entire watershed. Areas of perceived forest increases are especially apparent in the eastern portion of the watershed where there is less forest cover. One possibility is that changing land-use practices are resulting in some re-forestation of the riparian areas, i.e., wider stream buffer strips are being maintained in areas with cultivation, less cattle pasturing is occurring in stream valleys, etc.. There is no doubt that these changes are occurring within the Biosphere Reserve, but it is very unlikely that they have occurred to the extent portrayed here.

What are the next steps?

The creation of landscape change maps for the Long Point region directly supports the primary goal of the Long Point Biosphere Reserve Foundation - specifically, to integrate research, monitoring, and education in support of the goals of conservation and sustainable development. Maps such as those prepared in this report are effective tools that can quickly convey a considerable amount of information to the local community in an understandable and user-friendly format. And an increased understanding of the local landscape is often the first step toward conservation and sustainable use of that environment.

Recommendations for further study

1. Digitize 1978 Forest Resource Inventory data and compare to pre-settlement forest cover. General trends in forest composition can be identified through an analysis of this type. The information could be important in defining future management strategies.
2. Join the 1985 Ontario Base Maps forest polygons so that they are not divided by roads to make them comparable to National Topographic Database information - then complete an analysis of edge length and forest interior.

To obtain the complete and original study titled A Land-use Change Study for Long Point World Biosphere Reserve: Initial Analysis and Prospectus for Further Study, write to the Long Point World Biosphere Reserve at General Delivery, Port Rowan, Ontario, N0E 1M0.

Charlevoix Biosphere Reserve Landscape Change Study

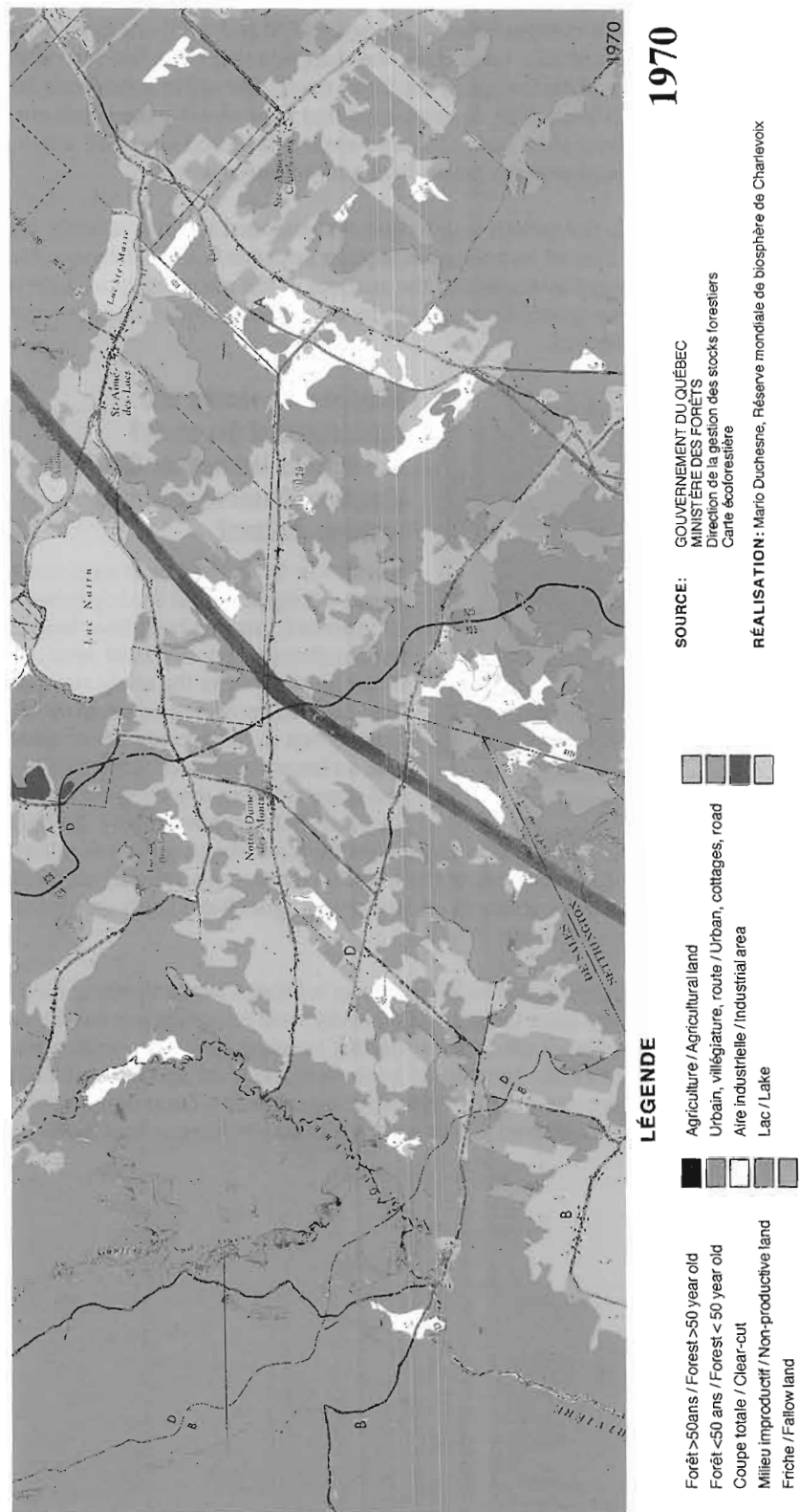


Figure 27 -Land Cover South of the Laurentian Foothills
at Charlevoix Biosphere Reserve 1970

What are the methods used in the landscape change study?

The study compared landscape changes between the years 1970 and 1990 using ecological forestry maps (see Figures 27 and 28). Land cover was mapped using the following categories: the forests (two categories based on the age of the forest stand), the active agricultural lands, the abandoned farm lands (fallow lands), forested areas that have recently been clear cut, non-productive lands (bogs and fens, alder stands, flooded areas), gravel and sand pits, urban areas, cottage development areas, road systems, power lines and industrial areas.

Specific attention was paid to the growth and decline of abandoned agriculture lands, forests and wildlife habitats. Given the limited technological support available at the Charlevoix Biosphere Reserve, the maps were coloured by hand, and the analyses of the maps was qualitative using human judgement rather than quantitative techniques using geographic information systems to calculate the extent of the changes.



Figure 26 -Landscape South of the Laurentian Foothills at Charlevoix Biosphere Reserve

What are the results and implications of the study? And lessons learned for Charlevoix Biosphere Reserve and other decision-makers?

Forests - In 1970, the forests were mainly young stands (all stands in the study area were under 50 years old) growing back from human and natural disturbances. By 1990, over one-third of the forest cover in the study area was older than 50 years providing an excellent wildlife habitat, rich in biodiversity. These stands provide an improvement for forest species of birds and mammals that rely on older forest habitat.

The open habitats have greatly disappeared since 1970 as by 1990, the old forest stands and the young forest stands are the dominant features of the landscape. While the recovery of the forest is creating new habitats for wildlife that prefer forested habitats, the growth of forests on abandoned agricultural lands are resulting in a loss for wildlife that prefer open habitats.

Agricultural Lands - In 1970, the agricultural land cover is located primarily along rural roads, and there is evidence that these same lands are still heavily used for agriculture (see Figures 29 and 30). By 1990, agricultural lands are in severe decline in many areas, representing not more than one-third of the lands in 1970. Agricultural lands were abundant in 1970 and during the 1970s and 1980s the decrease in land-use for agriculture was dramatic corresponding to the regional decrease of agriculture observed in western Charlevoix - a decrease that is still observed today in the study area.

Charlevoix Biosphere Reserve

Abandoned Agricultural Lands - In 1970, abandoned agricultural land cover (fallow lands) makes up a significant portion of the study area and the number of abandoned properties in fallow lands was relatively high. Even though agriculture remains very important in the area, there has since been a severe decline in agriculture because the fallow lands are very numerous, and are relatively well-distributed throughout the whole study area. By 1990, the size of the fallow lands was smaller and the number of fallow lands is less. The area of the St-Antoine rural road of Notre-Dame-des-Monts municipality and south of this village together contain almost half of the fallow lands of the territory

Comparison of the St. Antoine Road abandoned agricultural lands with the two main valleys in the study area would be interesting and should be considered for further study. The lands used for agriculture in the valley areas are of much better soil quality whereas the growth in fallow lands in the study area has been in areas of poorer soil quality, and this probably explains why the agricultural activity in the study area is decreasing. This raises the question as to whether these areas with poorer soil quality should be used for agriculture, or whether these areas should be adapted for another kind of land-use. Alternative land-use possibilities/opportunities should be explored and models developed that are in harmony with the character and cultural heritage of the region. This might mean practicing integrated management of the land for alternative agricultural production, productive forestry, wildlife and tourism with a focus on caring for both the natural and rural landscapes. Integrated management is seen as the only viable path available to enhance the value of these marginal lands.



Figure 29 - Pumpkin Fields South of the Laurentian Foothills in Charlevoix Biosphere Reserve

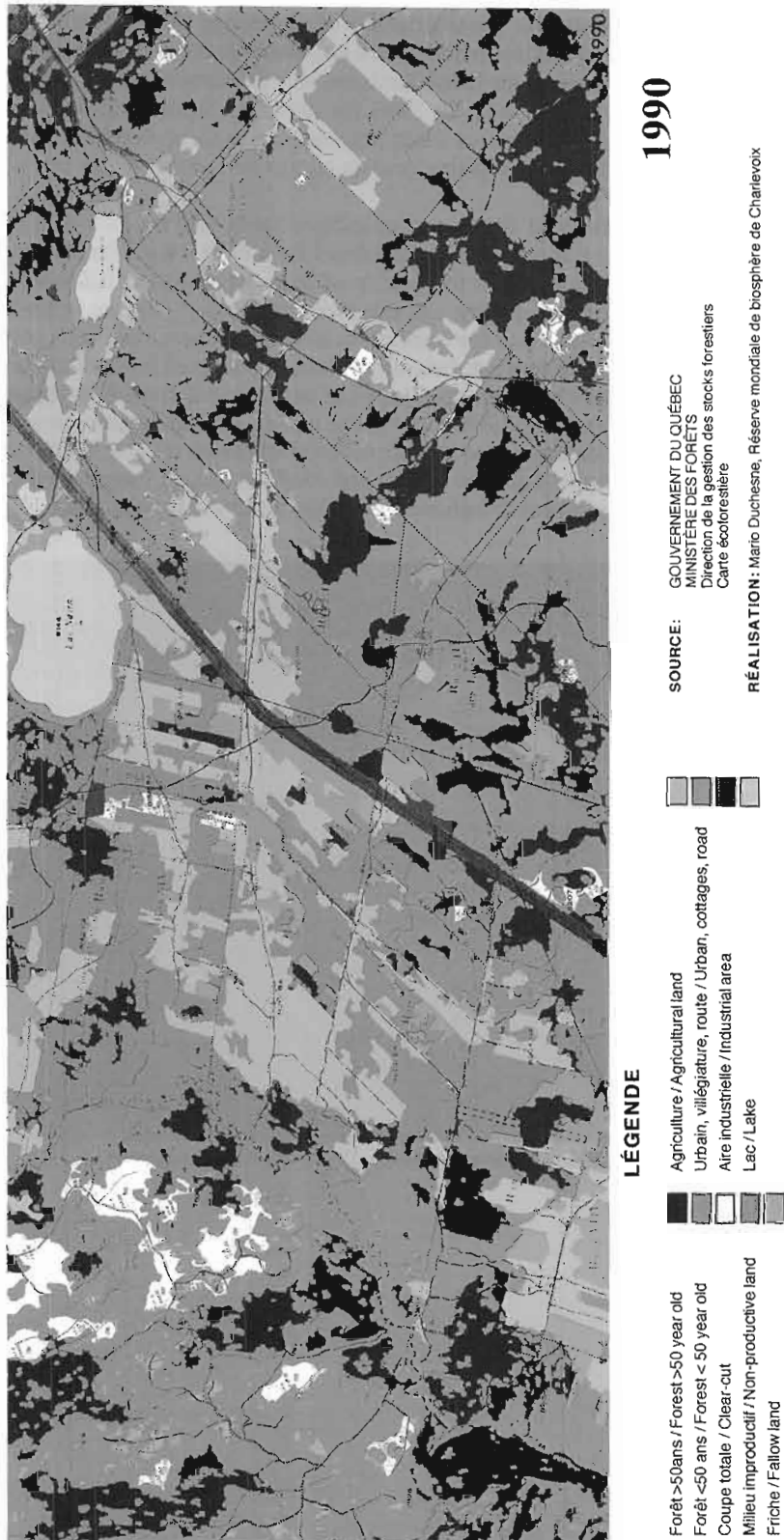


Figure 28 -Land Cover South of the Laurentian Foothills
at Charlevoix Biosphere Reserve 1990

Riding Mountain Biosphere Reserve Landscape Change Study

What are the study objectives?

The purpose of the Riding Mountain Biosphere Reserve Landscape Change Project was to document and describe the human alteration of the natural landscape around the perimeter of the Riding Mountain National Park as a result of over 100 years of agricultural development. The description is the first step toward understanding current ecological processes and their effects. It can assist in the interpretation of other long-term data sets, further local decision-making by providing historical perspective, and provide a local landscape history which can be incorporated into school curricula.

The overall intent of this work is to prepare a series of pictures of the Riding Mountain Biosphere Reserve, showing gross landscape features, representing different periods in time, and to incorporate these pictures into a geographical information system (GIS). The GIS and imagery will then be made available to municipal governments and schools within the Riding Mountain Biosphere Reserve.



Figure 31 - Landscape at Riding Mountain Biosphere Reserve

What is the study area?

The current Western Canadian prairie landscape has been drastically changed over the past 140 years. Agricultural development began around 1860 with the near-extirpation of bison and the restriction of Native Peoples to reserves, and has continued to the present as grassland was ploughed, forest cleared, and water drained. The ecosystems of 1860 currently exist only as incomplete remnants.

Riding Mountain National Park is one of these remnants, and forms the core area of the Riding Mountain Biosphere Reserve. The Riding Mountain Biosphere Reserve is a 10,000 square kilometre area in western Manitoba consisting of the National Park and the 18 Rural Municipalities whose boundaries are contiguous with it. Recent Landsat satellite imagery show the Park as an island of natural landscape entirely surrounded by agricultural development. The pattern and timing of landscape alteration around Riding Mountain National Park had, and still has, important effects on both the Park mandate and on the pursuit of agriculture around it. The interaction of the Park with the surrounding Rural Municipalities, which form the area of co-operation of the Biosphere Reserve, is thus important with respect to co-operative environmental management.

Housing- In 1970, there were no urban developments with housing distributed along the main roads. A higher concentration of housing was found at the centre of the villages near the church, the school, the General store, the bank and the City Hall. By 1990, villages have developed such as Notre-Dame-des-Monts, Ste-Agnès and St-Aimé-de-Lacs. Housing developments were found along the main roads crossing the villages, and in the rural roads near the villages. The recent housing developments associated with the villages does not respect the historical pattern of concentration around the church and service buildings. Instead, rural lands and landscapes surrounding the villages are being converted to housing, thereby draining the villages of their human population and extending the areas of human lodging. Future developments should not extend housing sprawl but instead be concentrated perhaps following urban design patterns found in the Alpine villages of France or Italy. This is an important consideration for the community as it moves forward with caring for the natural and rural landscapes of the Charlevoix Biosphere Reserve.

Cottages - In 1970, the shore of the Nairn and Ste-Marie lakes remained relatively undeveloped. About one-third of the shore of Nairn Lake was developed and only several cottages occupied the shore of the Ste-Marie lake. By 1990, the whole shore of Nairn lake was occupied by cottages, and cottages occupy two-thirds of the shore of the Ste-Marie lake. The development of cottages along these two lakes in the study area demonstrate the impact human development can have on the natural landscape of the Charlevoix region.

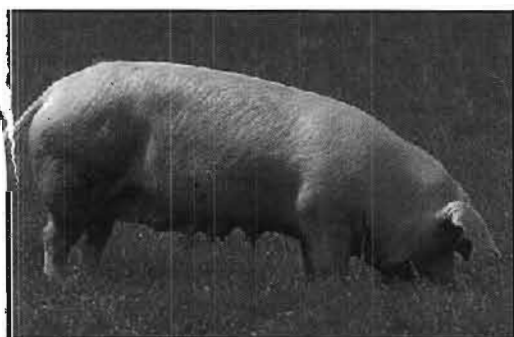


Figure 30 - Domestic Hog

Industrial Activities and Roads - In 1970, industrial activities were very limited in the study area with only an electricity power transportation line as a major industrial feature. By 1990, there were several gravel and sand pits, electricity transformation posts and electrical distribution lines. At least two hog farms (see Figure 32) had emerged in the study area, focused along the St-Joseph rural road near Ste-Agnès and the St-Antoine rural road near Notre-Dame-des-Monts. Many businesses also developed in the study area. In 1970, the main road system

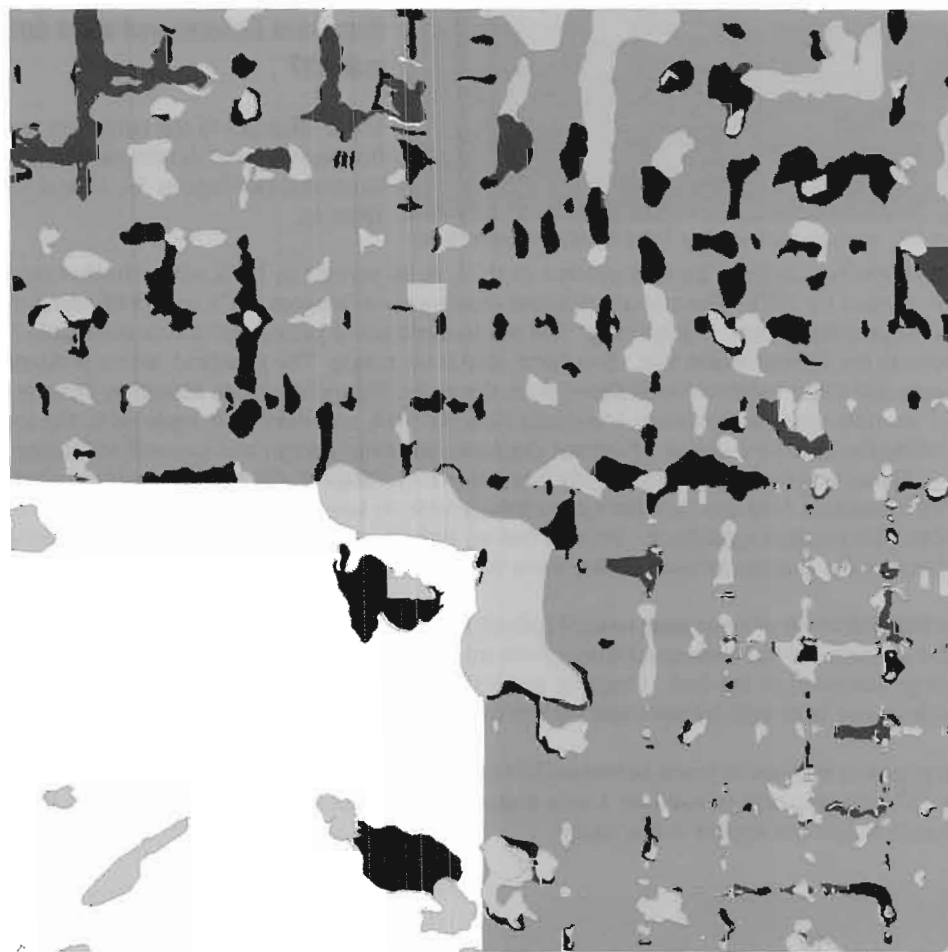
was already in place. Access to the Seminaire Lands was possible by the bridge of the Rebecca area, near the rural road St-Antoine in Notre-Dame-des-Monts. By 1990, the road system was slightly branched and the whole road network had been upgraded. The access to the Seminaire Lands by the bridge of the Rebecca area, near the rural road St-Antoine in Notre-Dame-des-Monts was abandoned. The industrial areas and the road system did not really change in the 20-year time period of the study, and the impact on the landscape was probably minor, although attention should be paid to how industrial and road developments are planned in the future.

What are the Next Steps?

The Charlevoix Biosphere Reserve was designated internationally as an area to balance its economic development with the protection of the natural and rural landscapes. The information presented here provides the rationale for integrated land management for the Charlevoix Biosphere Reserve. This information should be used as a basis for the development of a management plan for the area. This would require numerous stakeholders/partners working together towards the objective of sustainable development in the Charlevoix Biosphere Reserve over the long term.

Riding Mountain Biosphere Reserve

Rural Municipality of Clanwilliam 1873



Total Land Base	39,641 ha
Forest Cover	82% (24,334 ha)
Grassland / Prairie	8% (2241 ha)
Wetland	5% (3689 ha)
Lake / Waterbody	4% (2513 ha)
Agriculture	< 1% (59 ha)

Source : Original Township Survey Plans
Supplied by Natural Resources Land Survey's Unit

Figure 33 - Land Cover of the Rural Municipality of Clanwilliam 1873

What are the methods used in the landscape change study?

The specific intent of the work reported herein involved the choice of the Rural Municipality (RM) of Clanwilliam (144 square miles in area) as a test site, and the collection and evaluation of all available landscape data and imagery for this area. Landscape pictures would then be prepared from the best data sources. Conclusions drawn from this smaller area will then be applied to the larger project.

Data examined and evaluated include the original land survey data from 1873; air photo series from 1928/9, 1948/9, 1970, and 1986; topographic maps; and landsat imagery from 1973 and 1993. Based on this evaluation, landscape pictures were prepared for the following times: 1) 1873 - The original pre-settlement land survey required the cutting of lines through the bush at 1 mile intervals in both north-south and east-west directions, forming a grid. The surveyors recorded gross vegetation descriptions along these lines, and an image was prepared from these descriptions; 2) 1948/9 - The first complete, high resolution set of air photos at a scale of 1:15,840 is from this period, and formed the basis for version 1 topographic maps at a scale of 1:50,000. Photos were scanned and landscape features were classified on the computer screen, using heads-up digitizing techniques; and 3) 1993/4 - In 1995, agricultural Western Canada was classified according to land cover by the Federal Department of Agriculture, through the Prairie Farm Rehabilitation Administration (PFRA) from Landsat satellite images (Thematic Mapper), in order to verify farmers' applications for payouts under the Crow Benefit Program. The Manitoba portion was classified by Manitoba Remote Sensing, and PFRA kindly provided the Riding Mountain Biosphere Reserve with a part of this image.



Figure 32 - Agricultural Landscape at Riding Mountain Biosphere Reserve

What are the results and implications of the study?

And lessons learned for Riding Mountain Biosphere Reserve and other decision-makers?

Major changes to the landscape resulting from agricultural development are clearly illustrated (see Figures 33, 34 and 35; and Table 6).

Forest cover has declined from 82 percent in 1873, to 46 percent in 1948, with a further reduction to 34 percent by 1993. The amount of forest clearing done between 1873 and 1948, using mostly non-mechanized means, is surprising. The mechanized era of prairie agriculture essentially began following the Second World War. Ecosystem effects are major. The grassland, aspen parkland, and mixedwood forest habitats found throughout the entire Riding Mountain Biosphere Reserve prior to 1873 are now restricted to Riding Mountain National Park, and have been replaced in the area surrounding the Park by a mosaic of annual cropland, perennial forage, and exposed soil (summer fallow). Remaining forest habitat is highly fragmented. Ecological effects in the lands surrounding Riding Mountain National Park have been most severe on large animals, whose presence is not compatible with modern agriculture. Wolves, moose, and elk are visitors to this area, and often are killed by hunters and farmers as soon as they leave Riding Mountain National Park.

The fragmentation of remaining natural habitat in the area surrounding Riding Mountain National Park has made animal movement throughout the whole region difficult, and has increasingly restricted large mammals to the Park. Ongoing research is showing genetic isolation, the implications of which do not bode well for the continuation of such populations over the long-term.

The apparent increase in water between 1873 (4 percent) and 1948 (9 percent) is misleading. The 1873 classification is based on 1 mile transects, and water bodies not intersected by these transects would not appear in the image.

Rural Municipality of Clanwilliam

1993

Total Land Base	38,524 ha	
Agriculture	20,574 ha	53%
Forest	13,054 ha	34%
Water	2309 ha	6%
Wetland	1707 ha	5%
Development	880 ha	2%

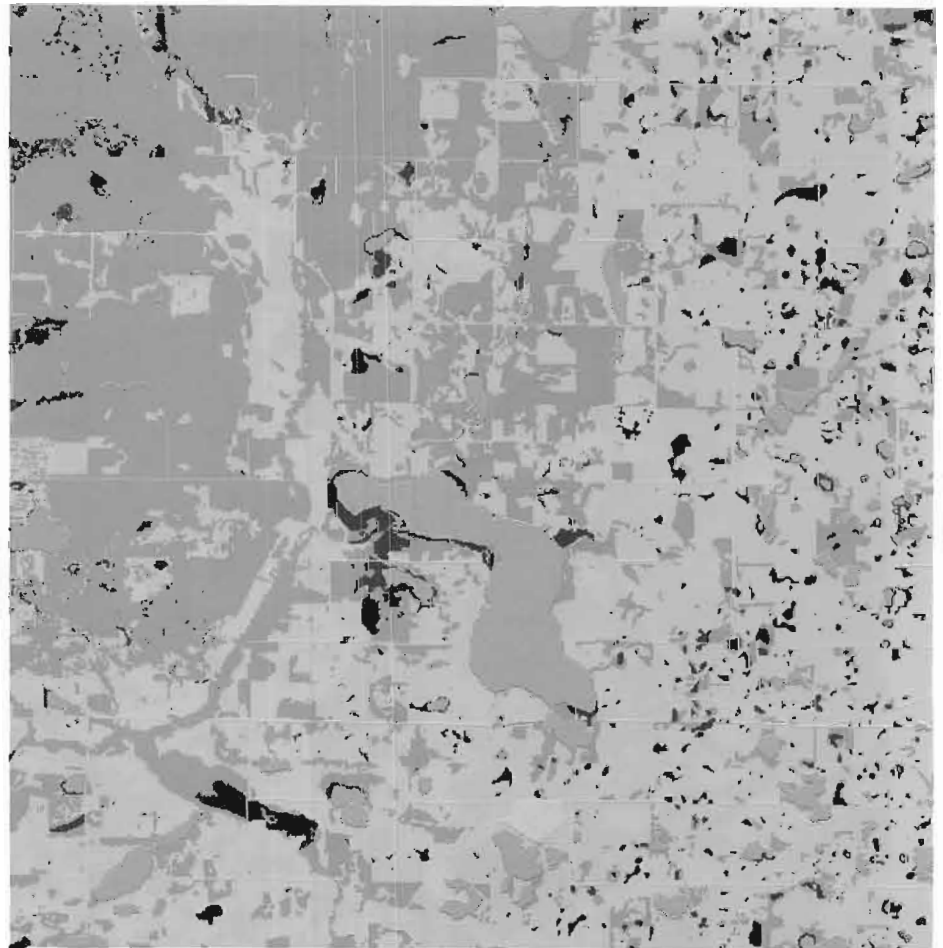


Figure 35 - Land Cover of the Rural Municipality of Clanwilliam 1993

Source: Prairie Farm Rehabilitation Administration and Manitoba Remote Sensing Classified Landsat TM.

Rural Municipality of Clanwilliam 1948

TOTAL LAND BASE	39,634 ha
Forest Cover	15,876 ha (40%)
Agriculture	18,083 ha (46%)
Wetland	1,833 ha (5%)
Water	3,611 ha (9%)
Settlement	

ROAD CLASSIFICATION (linear km's)

All Weather Road	64 KM
Seasonal (dry) weather	121 KM
Cart Track	69 KM
Trail	50 KM

SOURCE: 1948 AIR PHOTOS
SUPPLEMENTARY NTS MAP SHEETS
62J12 & 62J5 (1:50,000)

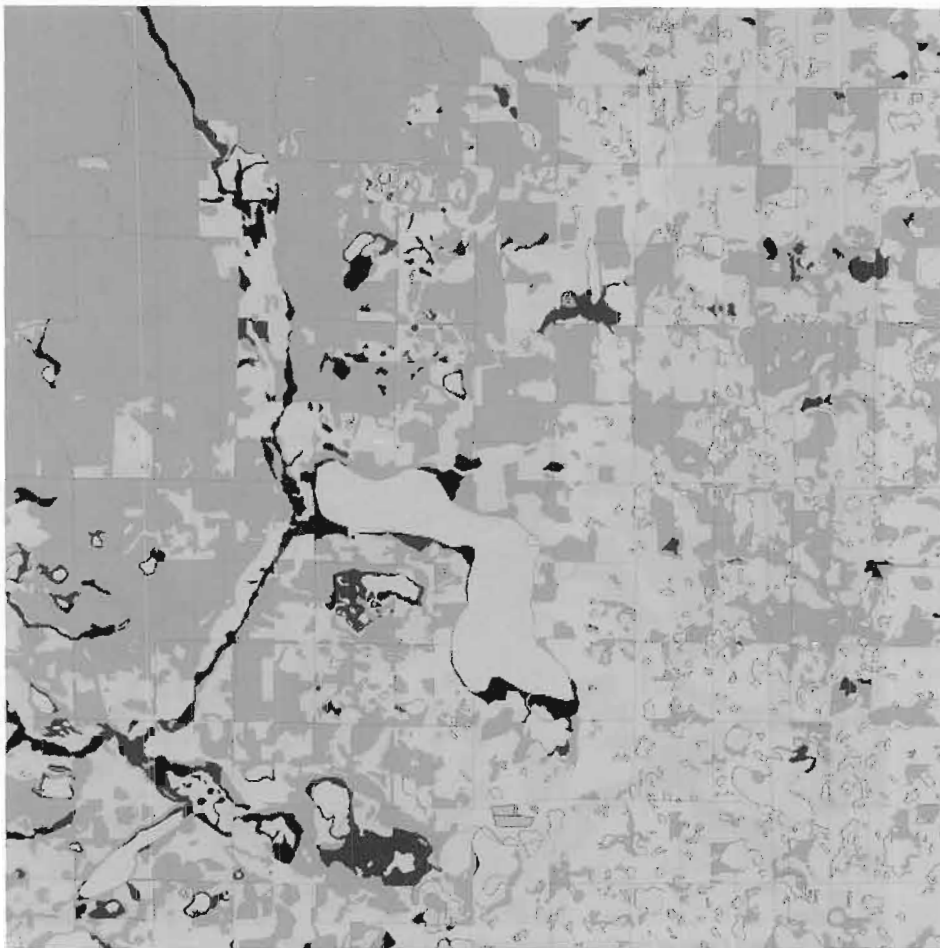


Figure 34 - Land Cover of the Rural Municipality of Clanwilliam 1948

Mont St. Hilaire Biosphere Reserve Landscape Change Study

What are the study objectives?

The goal of the Mont St. Hilaire Landscape Change Study is to examine the patterns of change in the use of land around Mont St. Hilaire from the perspectives of conservation and forest value - the change in the area of old-growth forest, and the closeness of forest to other land uses (roads and housing developments).

The change in the area of forest cover is examined from 1761 to 1993, and patterns of this change are described in terms of the total area of forest from 1761 until now; the area of the forest patches during the same period; and the compactness of the forest patches. Areas of old-growth forest are examined over the whole study period by identifying forested area never cut from 1761 to 1993. In addition, the change in the road and dwelling use of the landscape in

relation to the forest land-use is quantified for the last 70 years.

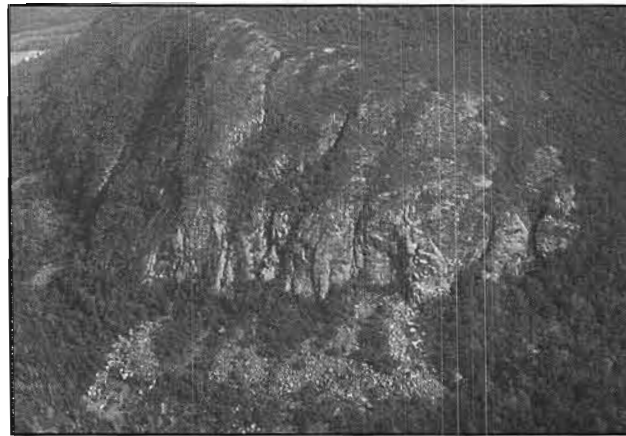


Figure 36 - Mont St. Hilaire Biosphere Reserve

What is the study area?

Mont St. Hilaire in the Richelieu Valley represents a unique case of old-growth forest in south-western Quebec. This low hill (see Figure 36) rising abruptly from the floor of the St. Lawrence River Valley is part of the unusual Monteregian petrographic province, a series of igneous intrusions that occurred about 95 millions years ago. Since agriculture is not practicable on the steep and rocky slopes (aside from apple tree growth on the

lower slopes), a large portion of the forest cover on Mont St. Hilaire never was removed. Since the retreat of the Wisconsin ice sheet, a biologically diverse and interesting forest has established through rare migration events and from the particular adaptability of the floral community to the cyclic occurrence of ice storms and forest fires.

The surrounding region is historically very interesting. The Richelieu Valley is an area where English, French, Americans and Natives have interacted intensively for years. Until 1665, the Richelieu Valley was inhabited solely by the Iroquois. The European settlers in the Valley used only the land bordering the Richelieu River at first. Despite Iroquois attacks and also two American invasions, settlers then broke into the forest with more or less intensity from 1760 on, but most intensively during the peaceful period between 1839 and 1867.

Hence, the forested landscape progressively was fragmented into smaller patches by a road network extending further away from the Richelieu River to reach deeper agricultural lands. The steady clearing of the forest created a pattern of increasingly high edge density and a growing portion of the forested area became affected by closeness to roads and settlements. The floral composition of the forest ecosystem was changed by invasive agricultural plant types and wildlife migration has been disrupted by fragmentation.

The area of study is limited to the South and West by the latitude line 45°30' and the longitude line 73°15' respectively. The gross northern and eastern limits are the latitude line 45°37'30" and the longitude line 73°6' respectively. The Richelieu River and the Huron River are good natural limits to the study area and all forest features west of the Richelieu River or east of the Huron River have been omitted. This basically defines a perimeter around the mountain itself and encompasses the settled areas that most influence contemporary efforts at conservation on the mountain.

**Table 6 - Landscape Changes in the Rural Municipality of Clanwilliam
(in hectares) at Riding Mountain Biosphere Reserve**

	1873	1948	1993
Forest Cover	24,334	15,876	13,054
Grassland/Prairie	2,241		
Agriculture	59	18,083	20,574
Wetland	3,689	1,883	1,707
Water	2,513	3,661	2,309
Settlement			880
Total Land Base	39,641	39,876	38,524

A set of images clearly showing the impact of human-caused change to large landscapes can be prepared from the information described above. However, these 3 images pose more questions than they answer. Further work over a larger geographic area (the entire Riding Mountain Biosphere Reserve) and for additional periods of time (1928, 1973) is ongoing, and will provide information on the timing and pattern of landscape alteration that will be useful to local authorities when dealing with the present day consequences of changes which occurred as much as 125 years ago. In addition, it will lead to the identification of natural wildlife corridors which facilitate movement between larger blocks of natural habitat. Such movement is essential to reverse currently observed genetic isolation.

Mont St. Hilaire Biosphere Reserve

Despite the 1837-38 revolution, when the Richelieu Valley was the centre of the Patriote activity, strong development continued until 1839. The 24 year time span since 1815 saw the road network evolving more tightly around the forest; roads now cut through the large remaining forest around Mont St. Hilaire. Some fifteen farms were installed in the region south of Mont St. Hilaire. Due to the development of the southern area, the important central patch was deforested on its eastern, western and south-eastern edges, thinning the bridge with the southern forested zone; on the other hand, larger length-wise patches of forest had regrown in the Northeast. Previously deforested ground along the tracts of land in the northern area of the study region was abandoned to the regrowth of forest between 1815 and 1839 maybe because the farmers realised that the topography or quality of the soil was unfavourable to agriculture. A neighbouring small forest tract was deforested during the same time interval.

The advent of peace is probably the cause of the intense and active development of the following period. The railway that cuts through the study region was constructed by 1867 and more road segments were constructed (the pattern of roads will remain as it was until 1932). The density of dwellings in the southern portion of the territory increased significantly, particularly immediately south of the mount. The southern slope of Mont St. Hilaire was now covered in cultivated apple trees and a small community south of the mountain also maintained an axe factory, two grist-mills, a cloth mill and a production of maple sugar. These 28 years of fast development caused the limits of the large forest covering Mont St. Hilaire to recede considerably and this forest patch, now distinctly bigger than any other, becomes tightly shaped around the mountain at a contour of about 125 metres. Generally, the forested landscape became much more fragmented by 1867 (see Figure 40): everywhere south of Mont St. Hilaire is patchy; up to then, the north-eastern forest has become more fragmented and the position of the forest has changed.

The second period from 1867 to 1993 defined earlier begins with industrialization. Almost 40 years after 1867, only short segments of road have been added to the road network. The density of dwellings has increased immediately south of Mont St. Hilaire, where the houses have agglomerated, and the town of St. Hilaire has developed on the bank of the Richelieu River, north-west of Mont St. Hilaire. Rural emigration has started in 1861 and deforestation slows down. Forest re-growth seems to have happened by 1914, and mostly south of Mont St. Hilaire. From 1932 on, the forest area continues to shrink.

By 1932, straight lines have appeared in the forested landscape. This period marks the end of the economic crisis, when the steady decline in rural population stops. Where the railway meets the road boarding the Richelieu River, a housing agglomeration has developed. From then on, deforestation does not remove huge tracts of forest like it did between 1839 and 1867, but rather causes the creation of new forest patches and the slow reduction in areas of existing ones. The need for agriculture does not seem to justify the deforestation of the less arable ground that has been spared up to now.

In 1963, the housing development located south-west of Mont St. Hilaire on the east bank of the Richelieu has evolved into a town easily occupying twice as much land as thirty years earlier (see Figure 41). Moreover, in the more rural area everywhere else in the study region, the density of human dwellings has dramatically increased. The density of the road network increased, in addition to Highway 20 that now cuts the map from west to east at a quarter of the top of the territory. The pattern of progressive reduction of forest patch area continues until 1963; the patch of Mont St. Hilaire is then completely detached from the southern forested landscape.

The same pattern of progression in rural housing development and road network expansion continues until 1993 (see Figure 42). Some new core areas of houses have appeared, particularly at the north-east of the map. The present forest cover is quite fragmented, especially by roads in two important forest patches in the north-eastern corner of the study region and in the South; the main patch around Mont St. Hilaire has become increasingly intruded by other land-uses, making it less and less compact; the gap between it and the patchy southern forest has widened.

What are the methods used in the landscape change study?

The analysis presented in this paper is focused on the patterns governing changes in the forested land and how other land-uses affect it. The land-use categories are simplified to the very general uses that follow forest harvesting and influence the conservation of remaining forested land: roads, housing developments, and agricultural land.



Figure 37 - Botany Bay at Mont St. Hilaire Biosphere Reserve

The study period extends from 1761 to 1993. Early maps of the study area used include: a 1761 map, at the close of the French regime, from the Murray Atlas; a 1815 map adapted from a topographical map by Joseph Bouchette, at the time Surveyor General of Lower Canada; a 1839 superimposition of Bouchette's 1831 map over a map produced at the Topographical Department of the British War Office; a 1867 composite map of three topographical maps by army engineers; a 1914 map, composite of topographic sheets ranging from 1907 to 1914. More recent topographic maps were drawn from aerial photos from 1932, 1963 and 1993 and show recent patterns of land-use in detail.

All maps were digitized using the GRASS software and each category of land-use was digitized into an individual layer. The digitized vector layers were then transferred as ArcInfo vector files into the geographic information system (GIS) software IDRISI for analysis. Finally, all layers were rasterized at a resolution of 25 metres, a compromise between a low resolution to favour computer speed and a high resolution to maximise the accuracy of the rasterization process. The GIS software IDRISI was used for creating the final maps presented in this work and for obtaining the different values of forest area.

What are the results and implications of the study?

And lessons learned for Mont St. Hilaire Biosphere Reserve and other decision-makers?

History of Human Development and Its Impact on Total Forested Area 1761 to 1993

The total forested area of the study region changed significantly from 1761 to 1993 (see Figure 38) as a result of human activity causing deforestation - a transformation of the use of land from forested land to agricultural land, road or dwelling construction. On the basis of the economic development in the whole Richelieu Valley, the study period is divided into two periods: one from 1761 to 1867, when the Richelieu Valley lost its original character, and another from 1867 on when the patterns of land settlement proceeded to their modern form.

The situation in 1761 (see Figure 39) serves as the starting point when the territory was almost untouched by European civilization: the approximate 160 square kilometres study zone then contains almost 100 square kilometres of uninterrupted forest. There is no road in the territory bordered by the Richelieu and the Huron rivers, although farmhouses were built in an almost continuous line on the east shore of the Richelieu.

By 1815 the forest cover had decreased by half. Agricultural land occupied most of the northern half of the study region; five road segments were constructed, along the interior bank of the two rivers and on the deforested area in the North; dwellings were regularly spaced on the North-South roads. The early development of the British Regime takes place during this 50 year interval and, in the Richelieu Valley, there were two American invasions, the settlement of Loyalists at the end of the Independence War and advances by French inhabitants. This initial phase of development off the river required major deforestation and a certain amount of drainage of swampy land, causing dramatic changes in the forest cover that left primarily only a big forest patch comprising Mont St. Hilaire and an important area south of it. Otherwise, only long, thin-shaped forest patches are uncut, probably retained as woodlots that were selectively cut for firewood and timber.

Mont St. Hilaire Biosphere Reserve

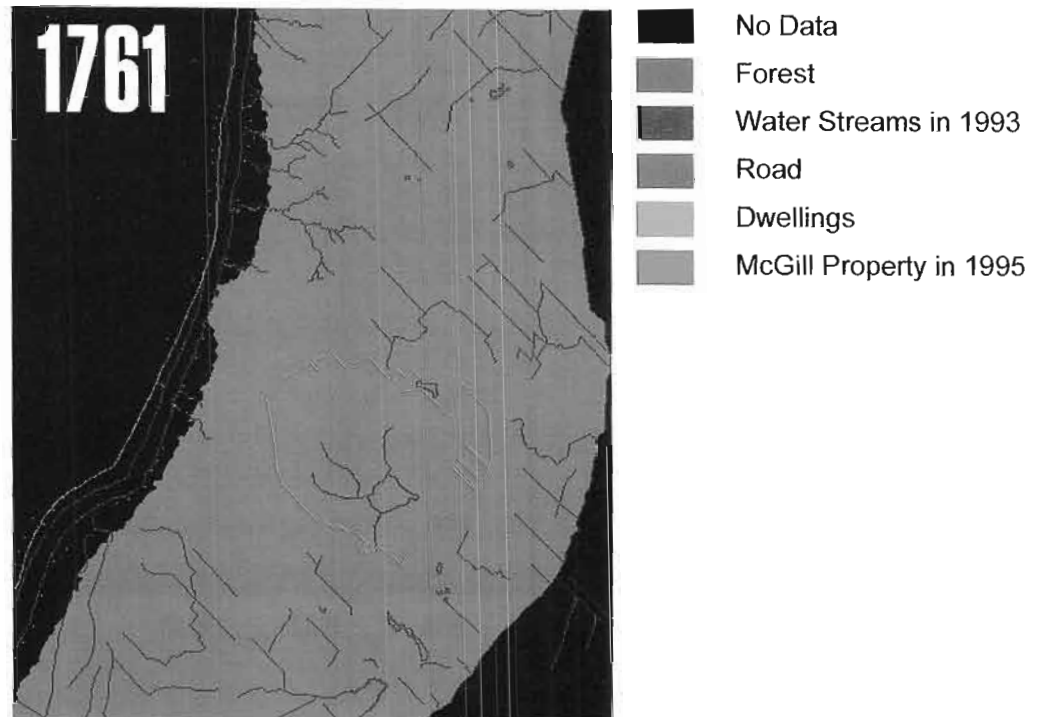


Figure 39- Land Cover at Mont St. Hilaire Biosphere Reserve 1761

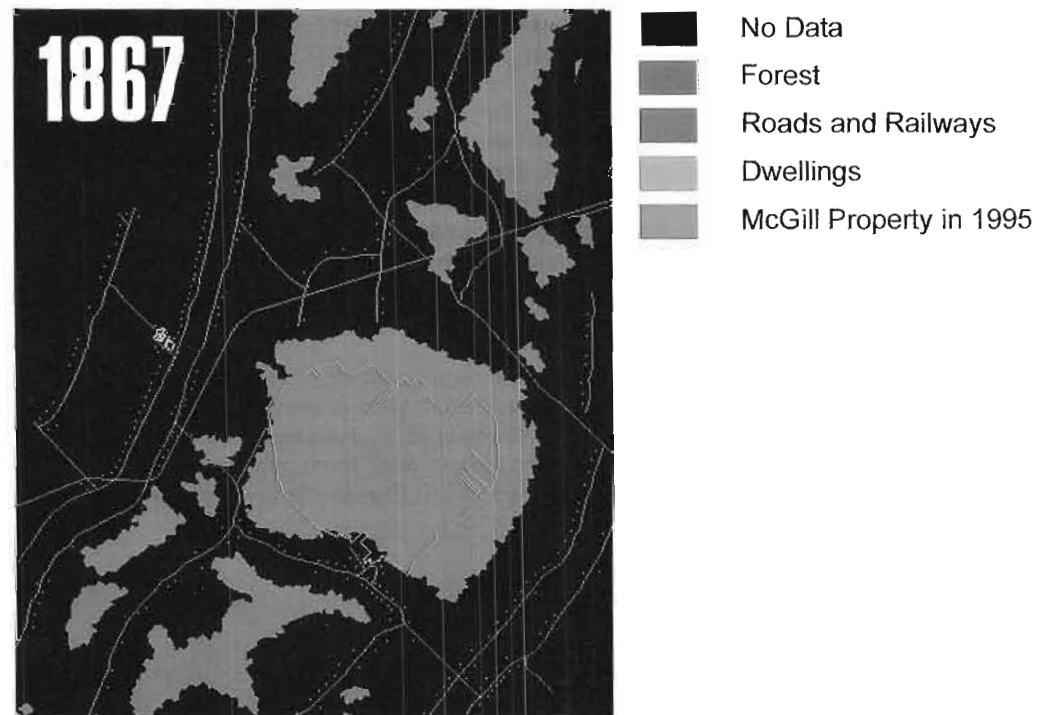


Figure 40- Land Cover at Mont St. Hilaire Biosphere Reserve 1867

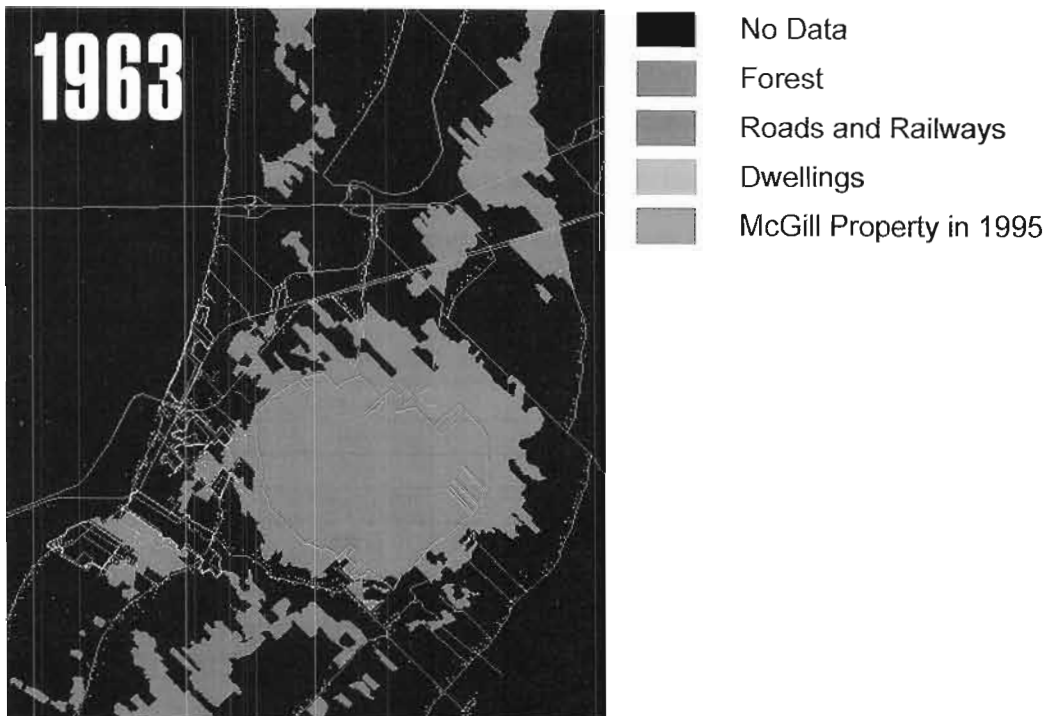


Figure 41 - Land Cover at Mont St. Hilaire Biosphere Reserve 1963

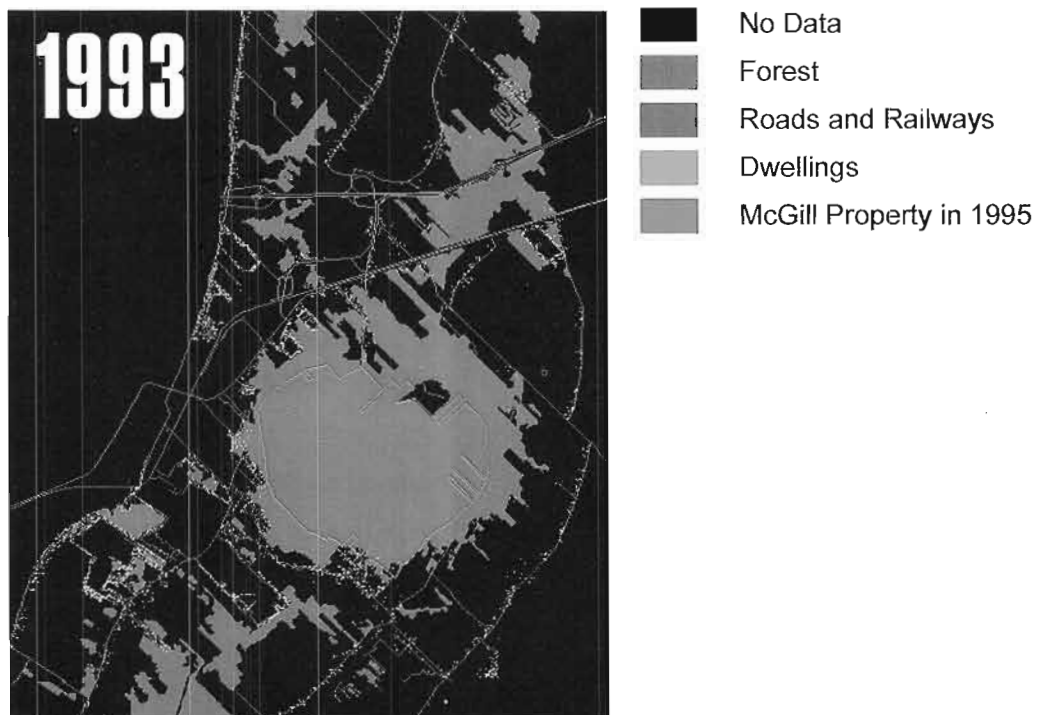


Figure 42 - Land Cover at Mont St. Hilaire Biosphere Reserve 1993

Mont St. Hilaire Biosphere Reserve

The Age of Remaining Forest

As could be predicted from the deforestation pattern around Mont St. Hilaire, the zones at the edge of the forest patches are young and the core zones are older (see Figure 43). It presents an interesting pattern as the edge of a forest patch is often younger than the ones at the core of a forest patch.

This is due to "nibbling", or the incremental removal and intrusion of human development along the edges of forested areas. The pattern also presents the forest zones that never have been cut. Mont St. Hilaire constitutes the most important uncut forest area by far in the study region. Table 7 shows the area of the forest within every age category. After the area of uncut forest, the majority of forest is between 79 and 126 years old. This portion of the forest re-grew between 1867 and 1914. Next in abundance is the younger than 30 years old forest, that re-grew after 1963.

Table 7 - Age and Area of Forests at the Mont St. Hilaire Biosphere Reserve	
Age of Forest (years)	Area (km ²)
More than 232 (uncut forest)	13.960
Less than 232	0.978
Less than 154	2.232
Less than 126	3.388
Less than 79	2.574
Less than 61	1.526
Less than 30	3.865

In a general way, this region of the Richelieu Valley presents a variety of forest successions.

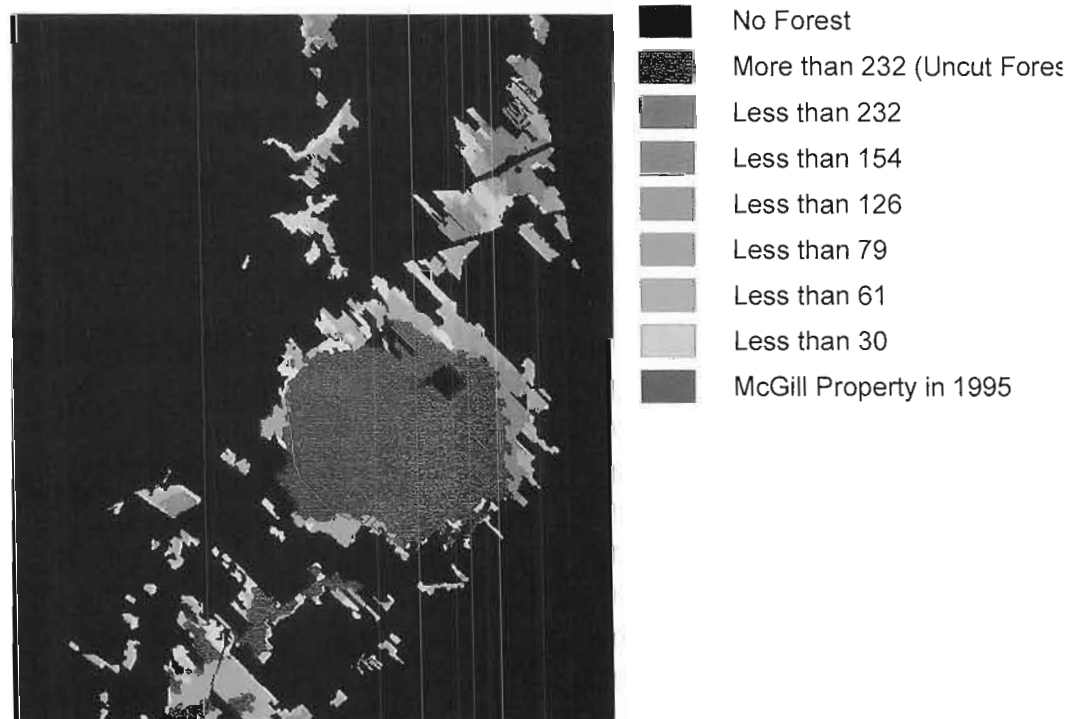


Figure 43 - Age of Forest in 1993 at Mont St. Hilaire Biosphere Reserve

The Roads and Houses Became Closer to Forest from 1932 until 1993

The human development of the study region from 1932 to 1993 can be regarded as a time of reduction in total forested area or fragmentation of the forested landscape. The road network definitely extended, the housing developments occupy many times as much area in 1993 as in 1932 and the rural zones developed significantly as well, as much at the level of secondary roads construction as in terms of dwellings establishment.

Roads and human dwellings are pollution sources as well as physical obstacles for forest ecosystem processes. Thus, the closeness of roads and dwellings to forest is an important element of the interaction between land-uses. The change in interaction (closeness) between forest and respectively roads and dwellings lead to simple conclusions: the road network is increasingly expanding, becoming more complex, and closer to forests from 1932 to 1993; and human dwellings become closer and closer to forests from 1932 to 1993, affecting the ecosystems existing in the remaining forest patches.

What are the next steps?

In some ways the general patterns illustrated above are little different from those typical of post-settlement landscapes anywhere in southeastern Canada. What makes these specific patterns valuable is two things: 1) their vivid depiction of just how much the landscape has changed around Mont St. Hilaire in the past 300 years and 2) the details of local history that can inform contemporary management of green space on and around Mont St. Hilaire. Both strengths of this study are important in ongoing discussions at the Mont St. Hilaire Biosphere Reserve. These discussions involve the town of Mont St. Hilaire, which is now a formal partner in the management of the Biosphere Reserve. In Quebec each town controls zoning within its boundaries, but all zoning decisions are subject to review by a regional level of governance referred to as an MRC. Three MRCs extend out in different directions from the mountain that is at the center of the study area. Much of the land around the mountain is zoned green and dedicated to agriculture, forestry and other rural activities. Development of houses and industry can happen only on land zoned white. The switch of green-zoned land to white zoning is very nearly impossible, and one of the principal roles of the MRCs is to ensure the preservation of green-zoned land-uses. This historical analysis of land-use patterns on and around the mountain will help inform discussions of zoning in both the white and green zones of the Mont St. Hilaire Biosphere Reserve. An increased appreciation of past patterns of forest and historic settlements will help local citizens refine contemporary development plans and ensure that goals for conservation and sustainable development are more likely to be met.

To obtain the complete and original study titled Land-use Change Around Mont St. Hilaire, write the Mont St. Hilaire Biosphere Reserve c/o Martin Lechowicz, Department of Biology, McGill University, 1205 Docteur Penfield Avenue, Montreal, Quebec, CANADA H3A 1B1.

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