Environment Canada Environnement Canada

AN APPROACH TO ASSESSING RISK TO TERRESTRIAL BIODIVERSITY IN CANADA

Prepared for

Indicators and Assessment Office
Environmental Conservation Service
Environment Canada
Ottawa

by

GeoInsight Corporation
Kanata, Ontario

SOE Occasional Paper No. 11

Canada

Note to reader

The Occasional Papers Series is produced by the Indicators and Assessment Office of Environment Canada to enable circulation of a variety of technical and methodological studies, meeting proceedings, and contract or internal reports. The ideas and opinions expressed in this document are those of the authors and do not necessarily represent those of Environment Canada.

A limited number of each report is produced; once distributed, no reprints are planned. Copies of these reports may be obtained through interlibrary loan from Environment Canada Department Library. This report should be cited as follows:

> GeoInsight Corporation[1]. 1999. An approach to assessing risk to terrestrial biodiversity in Canada. Prepared for Indicators and Assessment Office, Environment Canada. State of the Environment Reporting Occasional Paper Series No. 11. Ottawa.

---

[1] GeoInsight Corporation is the former Gregory Geoscience Limited, which provided geomatics services from 1973 to 1998. The corporation's Internet site can be found at URL http://www.cyberus.ca/~hmoore-gg/GeoInsight.htm

CONTENTS

INTRODUCTION 1

What is biodiversity 1

Policies and action plans for biodiversity conservation 1

BACKGROUND 2

OBJECTIVE 2

AN APPROACH TO ASSESSING RISK TO TERRESTRIAL BIODIVERSITY 3

Introduction 3

The 1996 theoretical model of risk to biodiversity 4

GIS modelling 5

MAPS OF THE RISK TO TERRESTRIAL BIODIVERSITY MODEL 6

Stress 7

Road access 7

Population density 8

Population change 9

Land activity 11

Stress index 12

Environmental condition 13

Terrestrial vertebrate species diversity 14

Rare and endemic terrestrial plants 14

Species at risk 16

Land cover diversity 18

Environmental condition index 19

Stress/environmental condition index 20

Societal response 21

Protected areas 21

Risk to terrestrial biodiversity 23

Risk to terrestrial biodiversity with protected areas 24

DISCUSSION 25

CONCLUSIONS 26

REFERENCES 26

LIST OF MAPS

Map 1: Road access 8
Map 2: Population density 9
Map 3: Population change, 1971–91 11
Map 4: Land activity 12
Map 5: Stress index 13
Map 6: Terrestrial species diversity 15
Map 7: Species at risk 17
Map 8: Land cover diversity 19
Map 9: Environmental condition index 20
Map 10: Stress/environmental condition index 21
Map 11: Protected areas 23
Map 12: Risk to terrestrial biodiversity 24
Map 13: Risk to terrestrial biodiversity with protected areas overlay 25

Appendix 1: Range values and GIS values used for maps in the *risk to terrestrial biodiversity model* 29
Appendix 2: Meta data for maps used in the development of the risk to terrestrial biodiversity assessment 32
Appendix 3: Agencies and individuals contacted during the course of the project: Risk to biodiversity (1996) and Risk to terrestrial biodiversity (1997) 43
Appendix 4: Some measures or indicators that might help to approximate an “ideal” model of risk to biodiversity 44
Appendix 5: IUCN categories of protected area: defining characteristics and typical management practices 46

LIST OF TABLES

Table 1: Data sets used in the risk to biodiversity (1996) and the terrestrial risk to biodiversity (1997) models 5

LIST OF APPENDICES

Appendix 1: Range values and GIS values used for maps in the *risk to terrestrial biodiversity model* 29
Appendix 2: Meta data for maps used in the development of the risk to terrestrial biodiversity assessment 32
Appendix 3: Agencies and individuals contacted during the course of the project: Risk to biodiversity (1996) and Risk to terrestrial biodiversity (1997) 43
Appendix 4: Some measures or indicators that might help to approximate an “ideal” model of risk to biodiversity 44
Appendix 5: IUCN categories of protected area: defining characteristics and typical management practices 46

INTRODUCTION

What is biodiversity

Biodiversity (short for biological diversity) refers to the variability among living organisms. It includes three basic components:

1. *Ecosystem diversity* refers to the number, variety, and extent of ecosystems within a given geographic area. A diversity of ecosystems is necessary to provide the food, shelter, and other needs for a full range of species that inhabit the Earth's lands and waters.

2. *Species diversity* involves the variety of species within a given geographic area or ecosystem. It is essential to the production, consumption, decomposition, recycling, and other processes that take place in ecosystems.

3. *Genetic diversity* pertains to the extent of genetic variation among members and populations of species. It allows species to adapt to changes in their environment.

This report focuses on wild, native, terrestrial biodiversity, especially related to ecosystems and species.

Policies and action plans for biodiversity conservation

Biodiversity conservation has fundamental implications for both environmental and socio-economic well-being. It is a sustainable development priority both in Canada and internationally. In 1992, the United Nations Convention on Biological Diversity (UNEP 1992) was a major achievement of the United Nations Conference on Environment and Development. In support of this Convention's ratification, Canada has developed the Canadian Biodiversity Strategy (Federal–Provincial–Territorial Biodiversity Working Group 1995) and is currently developing a national action plan. Progress to this end is reported in recent publications such as Caring for Canada's Biodiversity (Canada 1998), Biodiversity in the Forest (Canadian Forest Service 1997), Conserving Wildlife Diversity (Environment Canada 1998), and Implementing the Canadian Biodiversity Strategy (Government of Canada 1997). In addition, Environment Canada has completed a comprehensive science assessment of biodiversity (Biodiversity Science Assessment Team 1994). However, much remains to be done to measure and report on biodiversity in support of effective management action.

BACKGROUND

Risk to biodiversity can be measured at several levels — from local, to regional, to national, to continental, to global. This report focuses on the national to regional levels, and uses the work of Rubec et al. (1992) as a starting point. In that study, a model of risk to biodiversity was developed sing the terrestrial ecoregion level of the national ecological framework for Canada as the common building block (Ecological Stratification Working Group 1996). The model used available data representing factors believed to influence changes in biodiversity at a regional scale. The data were georeferenced and analyzed spatially using a geographic information system (GIS).

This model of risk to biodiversity was further refined in 1996 under contract for Indicators and Assessment Office and funded by the Biodiversity Convention Office of Environment Canada and the Geomatics Development Program (GDP) of Natural Resources Canada (Turner et al. 1998, Gregory Geoscience Limited and Paul C. Rump and Associates 1996). The model was improved with respect to an increased number of data sets available, the sophistication of the modelling process, and the use of a team of experts to advise on the selection and use of the data.

In 1997, as part of another GDP-funded project called EcoMAP, various refinements were made to the 1996 model based on comments from reviewers of the 1996 work. Primary among the changes was a focusing of the model towards only terrestrial biodiversity, which partly accounted for a reduction in the number of maps used (from 13 to 8). The GIS maps were placed in categories according to the stress–environmental condition–societal response model used in Canada's National Environmental Indicator Series (Indicators and Assessment Office 1998). As well, the contents of many map layers were updated, and the weightings of maps in the modelling process were further refined. This document summarizes this most recent modelling work.

OBJECTIVE

The principal objective was to develop an ecosystem-based, repeatable model to assess the relative risk of terrestrial biodiversity to changes through the spatial and quantitative valuations of 1) stress on biodiversity resulting from human activities, 2) environmental conditions, and 3) societal responses aimed at conserving biodiversity.

The model was to be significant for regional to national scale planning and reporting.

AN APPROACH TO ASSESSING RISK TO TERRESTRIAL BIODIVERSITY

Introduction

The risk to terrestrial biodiversity model required a conceptual framework within which many of the factors that affect changes in biodiversity could be linked together. The conceptual framework chosen evolved from the stress–condition–societal response framework commonly used in the development of environmental indicators (e.g., Environment Canada 1993 to present). As applied to the risk to terrestrial biodiversity, the three elements of the framework are:

1. ***Stress***: includes those factors that are commonly thought to threaten biodiversity directly or indirectly. Most commonly these are various human activities.

2. ***Environmental condition***: includes those non-human aspects of ecosystems that indicate relative vulnerability to change. These include various measures of natural ecosystems and species such as diversity and endemism.

3. ***Societal response***: includes those actions that either reduce the stresses on biodiversity or help improve the condition of ecosystems such that the natural sensitivity aspects are not diminished. Most commonly these are measures of programs and policies that are employed to manage the conservation of ecosystems or species.

Using these three categories of risk together in an ecosystem model relies upon the following logic.

- Measures of stress, such as land conversion, harvesting, and pollution, generally have negative effects on ecosystems, such as those that are mapped as terrestrial ecoregions. Human activities can be ranked according to their presumed impact on biodiversity, and ecoregions can be compared with respect to the occurrence and magnitude of these activities.
- Similarly, ecoregions can be compared with respect to their intrinsic importance in maintaining native biodiversity. When human activities concentrate in relatively unique or highly diverse ecosystems, it is assumed that there is a higher potential risk to biodiversity than there would be in ecoregions that are not unique or are less diverse.
- Societal responses, such as the amount of land in protected areas, are generally believed to lessen the negative impacts of stresses on biodiversity and preserve the natural diversity. Consequently the overall risk to

biodiversity can be reduced in ecoregions which possess more protected area.

The 1996 theoretical model of risk to biodiversity

The 1996 modelling work used GIS technology to apply the above conceptual framework. GIS was employed to analyse and compare diverse ecological data in a spatial context. The theoretical “threat to biodiversity index” was defined as a composite of three separate indices that provide a measures of the pressure or stress on biodiversity caused by human activity (p*ressure index*), the sensitivity of the ecosystem to the pressures (s*ensitivity index*), and the degree to which the pressures have been remediated (societal r*esponse index*). Each of the three indices are themselves composites of several input indicators. For example, a forestry index was created as a subset of the pressure index. Similarly, a protected areas index as a measure of societal response. The input indices are developed from the measurement of a single attribute or a combination of several attributes.

Rounds of consultation with experts identified many measures that would ideally fit into the GIS model with no consideration of their availability, extent, or ability to be analyzed using GIS technology. The numerous measures and the data that might constitute them are presented in Appendix 4. The model can be used as a guide for data collection and analysis during the development of an operational risk to biodiversity model. It can also be used to outline the data sets which maybe needed but are not available at the present time. As these data sets become available in the future, they could be added to the operational model for a more complete and detailed representation of the risk to biodiversity.

With the theoretical model as a guide and after practical aspects were considered, the data sets needed to run the 1996 operational model were defined and acquired. The original model used 13 data sets, which are listed in Table 1. For comparison purposes, the data sets used for the current risk to terrestrial biodiversity model are also shown. The selection of data sets for the current model was based on additional consultations with experts concerned with changing the focus to strictly terrestrial biodiversity and reducing overlap and achieving a better balance of measures.

Table 1: Data sets used in the risk to biodiversity (1996) and the terrestrial risk to biodiversity (1997) models

Data sets	Risk to biodiversity model (1996)	Risk to terrestrial biodiversity model (1997)
Road access	√	√
Population density	√	√
Population change	√	√
Sewage treatment	√	
Land use index	√	√
Mining index	√	
Industrial discharge	√	
Species richness	√	√
Species at risk	√	√
Rare and endemic plants	√	√
Land cover diversity	√	√
Climate zone index	√	
Protected area index	√	√

GIS modelling

The primary tool for compiling and integrating the individual data sets was geographic information system (GIS) technology. GIS combines elements of database management, mapping, image processing, and statistical analysis. By exploiting the spatial nature of data, GIS analysis introduces a new perspective which can greatly enhance decision making and problem solving.

The GIS approach to modelling consists of three components:

1. the collection of data and information sets;

2. the conversion of the data and information to GIS format using the geographic coordinates and projection of the particular study area as a common link, and structured to permit storage, maintenance, and analysis (this component would include converting tabular data to areas or points for GIS input and production of raw data input maps for each data set to be classified and used in the model); and
3. the processing or analysis of data and information using different spatial analysis techniques to provide new information that can be used in decision making and policy setting.

For all the modelling work thus far, Tydac SPANS (SPatial ANalysis System) GIS was used because of its ability to process a large number of maps in the same model. This modelling function, called *multi-criteria modelling*, or *index overlay modelling*, was used to compare different geographic locations based on multiple spatial criteria, each of which is represented as a map layer in the database. Multi-criteria modelling can be used for identifying areas that are sensitive to certain controlling factors, such as urbanization. It can also be used to identify areas that are best suited for certain uses such as biodiversity conservation or the areas with the highest potential for wildlife and habitat protection.

Suitability or sensitivity is determined by assigning a weighting to each data layer (map) in the model, which indicates its overall importance. For the risk to terrestrial biodiversity model, each input map was assigned a weighting based on its relative impact on biodiversity. The map classes (legend items) of each map are then assigned common GIS values ranging from zero to ten based on their impact on biodiversity. Both the map weightings and class weightings are presented in Appendix 1. During the index overlay process, all of the input maps are scanned and weightings tallied for each terrestrial ecoregion in Canada. This produces a composite index map which represents a measure of the overall risk to biodiversity for each ecoregion. With SPANS, up to 20 maps can be used in any one model routine. More maps than this can be used by splitting the model up into stages and combining them at the end. The weighting factors can easily be changed to permit the testing of many different scenarios. Note that for all the input and index maps, where adjacent ecoregions have the same value (as portrayed by a particular color on each map), the boundary between ecoregions is not visible.

MAPS OF THE RISK TO TERRESTRIAL BIODIVERSITY MODEL

The following data sets and maps were used to produce the current risk to biodiversity model.

Stress

Since European settlement, human activity has had significant and increasing impacts on biodiversity. The stress index is a composite of four separate attributes that measure the stresses of human activities on natural biodiversity.

Road access

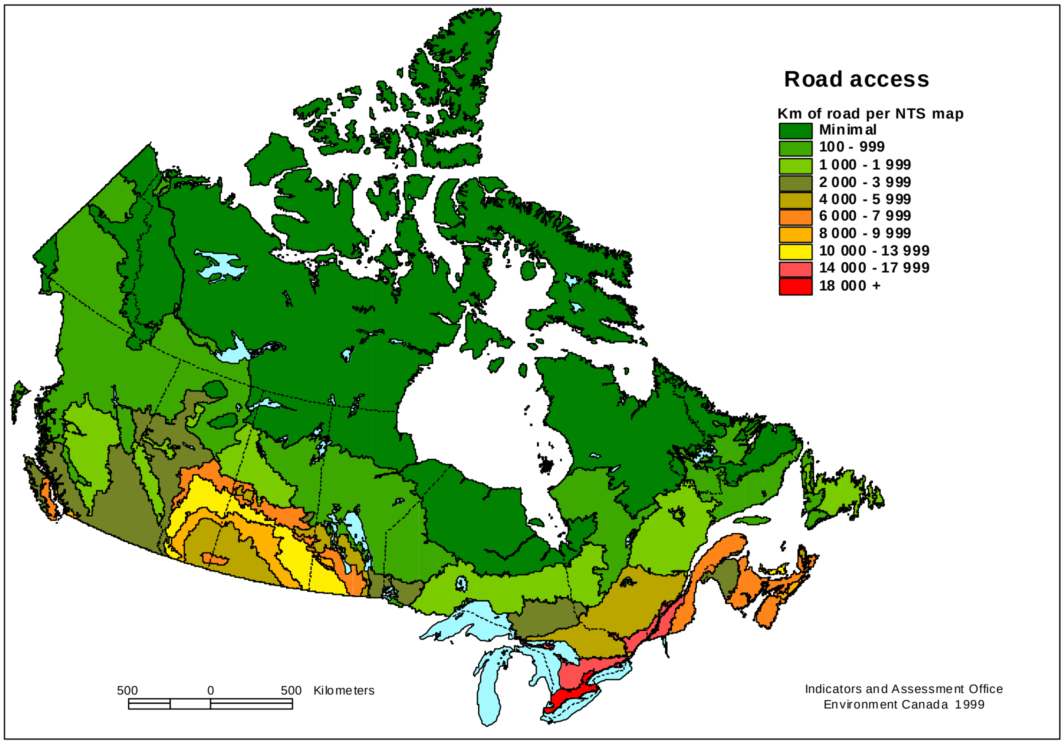
Importance

Human activity in any area is enhanced by ease of access to it. Therefore, a measure of access is an important indicator of stress on biodiversity within a particular ecoregion or other unit of area. Roads are by far the most common form of access in Canada. Roads directly correlate with and are highly concentrated in areas where there is high population and where there is significant resource development. Road access was measured as road density.

Data source and processing

Road density information is a data set of the National Topographic Data Base for Canada (Canada Centre for Geomatics, Geomatics Canada, Natural Resources Canada), Digital Chart of the World, and the National Roads Database, which includes nearly 800 000 km of roads taken from the 1:250 000 and 1:50 000 National Topographic Data Base. The full database is very expensive and therefore was not purchased for this project. As an alternative, the project used a summary database of the number of kilometres of road for each 1:250 000 map sheet. The map-sheet-based road data were aggregated for each ecoregion and both the total road length and road density were measured. Apart from river and stream crossings, roads are typically only found on land. As such, the major area of water (fresh water and marine) was subtracted from the area of each ecoregion in order that it could be fairly compared between ecoregions.

Map 1: Road access



Population density

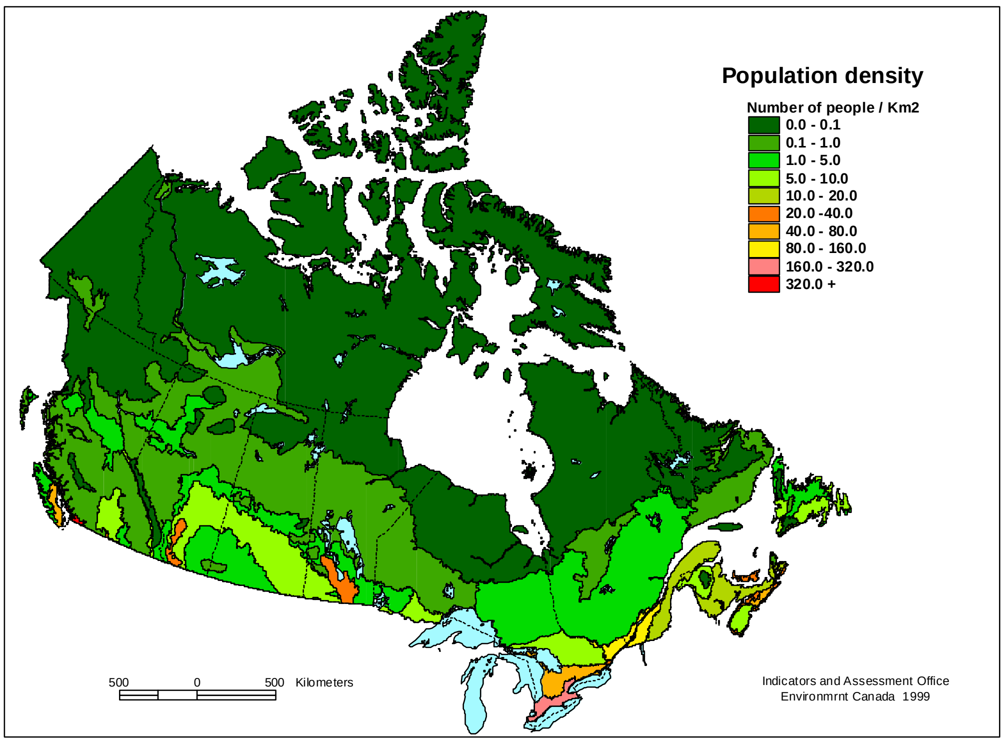
Importance

The concentration of people in any area is a simple surrogate measure of the stresses of many human activities on biodiversity. It is assumed that areas of high population density also contain more urbanization, human infrastructure, and modification of the natural ecosystem. Therefore, all other factors being equal, native biodiversity is more at risk in ecoregions of higher population density than in those with low population density. While total population counts can provide some information about the perceived magnitude of human stresses, ecoregions vary significantly in size, which makes it very difficult to compare population between ecoregions. Therefore, it was decided that population density would be a more accurate indicator.

Data source and processing

Population data originally came form the 1991 Census of Population published by Statistics Canada. The data were aggregated by ecoregion by the Environment and National Accounts Division of Statistics Canada. The data were divided into classes of rural and urban population, a split which helped to identify the intensity of urbanization, where population density is the highest. Southern Ontario, the Montreal region, and the lower Fraser River Basin have the highest population densities.

Map 2: Population density



Population change

Importance

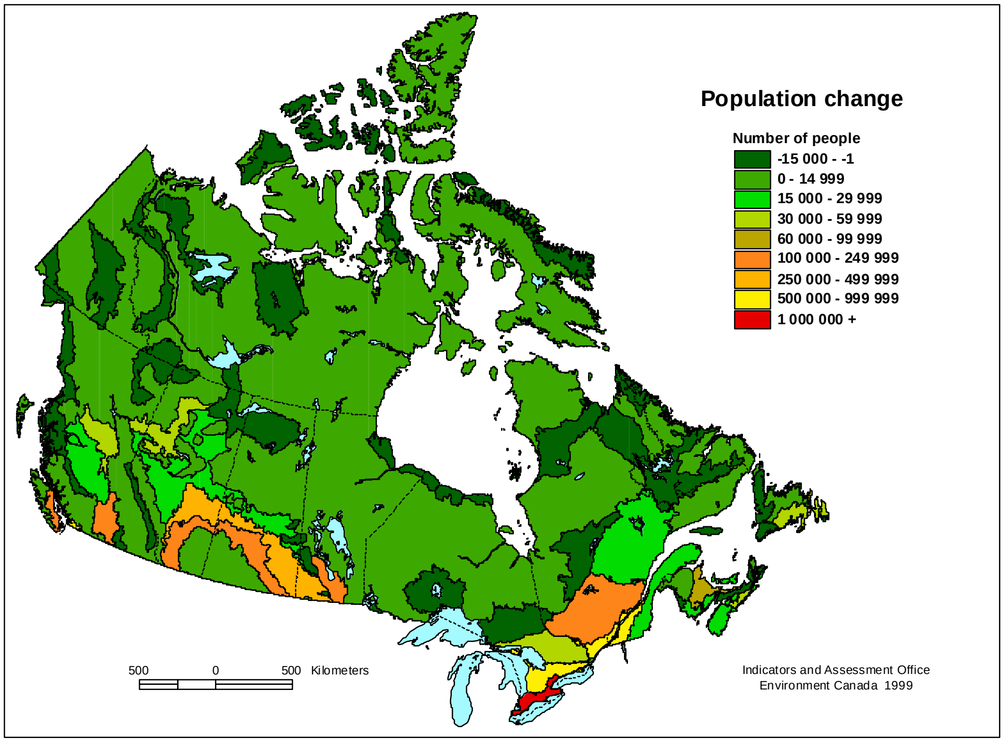
Human activities are not static but rather are in a constant state of change. There is no comprehensive data base that tracks the key changes in the various human activities. Population change was believed to be the best surrogate measure of change available. It is assumed that if population increases rapidly in a particular ecoregion, the supporting infrastructure and land activities which modify the ecosystem and affect native biodiversity will also increase rapidly. On the other hand, if the population in an ecoregion increases slowly, is stable, or declines, the rate of change in stress on native biodiversity will be low to declining. In other words, where population density is an indicator of the current magnitude of stress on biodiversity, population change is a measure of the risk of future changes in stress on biodiversity, assuming that rapid population growth implies continued growth/human activities in the future.

Data source and processing

Population data originally came from the 1971 and 1991 Census of Population published by Statistics Canada. The data were aggregated by ecoregion by the Environment and National Accounts Division of Statistics Canada. Population change was expressed as absolute numbers rather than a percentage increase or decrease. The indicator complements total population (Map2).

Major population declines are found in northern Ontario; major population increases in the Okanagan, an area of known importance for biodiversity in Canada. One prairie ecoregion contains several large cities (Calgary, Edmonton, Saskatoon, and Brandon), but the map distributes the high population growth throughout the ecoregions, giving a somewhat unexpected impression.

Map 3: Population change, 1971–91



Land activity

Importance

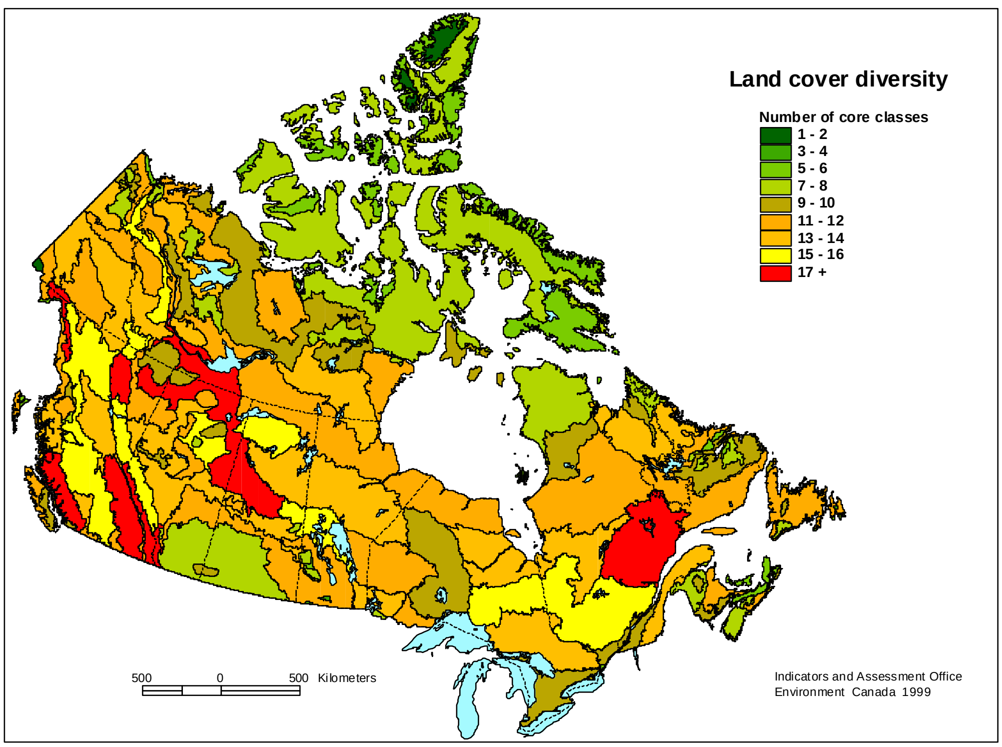
Human activities that modify extensive areas of landscape have long been known to place stress on native biodiversity. For example, the historic wholesale change of a forested or grassland landscape to agricultural uses has ultimately led to the decline and sometimes local extinction of species. This is corroborated by the fact that a large share of Canada's species at risk are found in agricultural regions such as the Prairies and southern Ontario. Other land activities such as urbanization and commercial timber harvesting also modify the landscape and remove habitat for native species to varying degrees and for varying lengths of time.

Since a comprehensive land activity map for Canada does not exist, major land activities can be inferred from land cover information.

Data source and use

The classification of Advanced Very High Resolution Radiometry (AVHRR) satellite imagery from 1995 provided a national coverage of land cover at a spatial resolution of one kilometre (i.e., the size of the smallest feature that could be represented in the coverage). For this analysis, the AVHRR classification used was relatively simple, with 29 original AVHRR classes collapsed into 7 "activity" classes, with each assigned weightings from high (urban, cropland) to low (tundra/barren land). In between are forested areas, which were divided into two broad classes: low-density forest in the north, where commercial forest activity is minimal; and high-density forest in the south, where commercial forestry is prevalent.

Map 4: Land activity

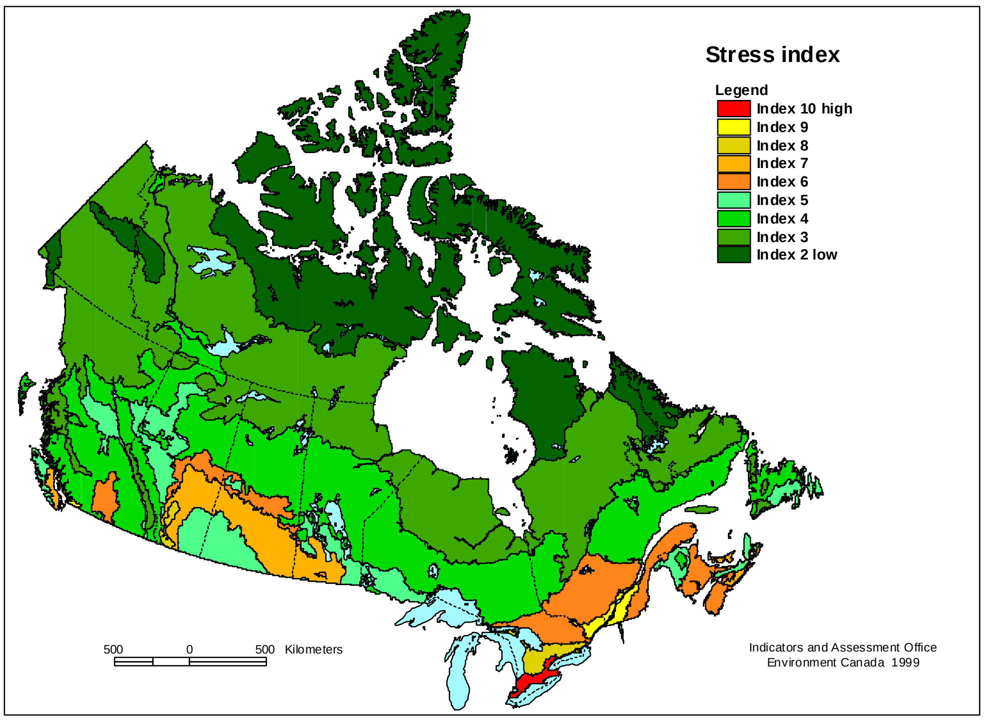


Stress index

The stress index map combines Maps 1 to 4, using equal weightings for each map, to produce a composite stress index with 9 classes. The stress index map shows highest stress on biodiversity where expected — in the settled portions of

Canada, which are dominated by high population and the various stresses on land that accompany high population, such as high road density which fragments the ecosystem, high urbanization, and intensive and extensive cropland, which removes or reduces the available habitat for many species. The biodiversity in forested ecoregions is under moderate stress due to changes from forestry activities. Ecoregions in the northern boreal and Arctic have fewer stressors relative to southern ecoregions, and these are ranked the lowest.

Map 5: Stress index



Environmental condition

Environmental condition indictors are of two types — those that measure the quantity or quality of native biodiversity and those that measure the impact of stresses on native biodiversity. Currently few national data sets provide measures of the environmental conditions in an ecoregion. The environmental condition index is a composite of four currently available data sets which describe the current relative condition of biodiversity on a ecoregion by ecoregion basis.

Terrestrial vertebrate species diversity

Importance

Species diversity, or species richness, was used in the earlier risk to biodiversity model developed by Rubec et al. (1992), although only birds and mammals were included in that work. The logic used for this environmental condition is that, all other factors being equal, the greater the number of native, wild species in an ecoregion, the more species that are potentially vulnerable to and likely to be affected by human activities.

Data source and processing

Species diversity was compiled from the natural range maps for bird, mammal, reptile, and amphibian species. Each range map was cross-correlated with the ecoregion map to determine the ecoregions in which each species is found. The data were then totaled to determine the maximum number of species in each ecoregion, thus giving a species diversity value for each ecoregion. The original species range maps were digitized by staff of the GeoAccess Division, Geomatics Canada, Natural Resources Canada and converted to SPANS format by Environment Canada. In all, the data base includes the ranges of 400 birds, 106 mammals, and 88 reptiles and amphibians. Compared with the 1996 risk to biodiversity model, 79 more mammal ranges were added. Non-terrestrial species, as identified by Haber (1998), were excluded from the analysis.

A linear classification scale was used with counts of 35 species in each class. The resultant map shows the Queen Charlotte Islands is unexpectedly low, perhaps a reflection of errors in the original species range maps, some of which, incorrectly, did not extend the islands. The prairies are high in species diversity, perhaps a reflection of overlapping ranges of western and eastern species as well as high numbers of rodent species found there.

Rare and endemic terrestrial plants

Importance

Another environmental condition that complements species richness is the distribution of rare and endemic plant species. A rare species is one that is found in limited numbers and often limited in its range in Canada.

The word “endemic” describes organisms native to a certain region, with restricted distributions. In other words, endemic plants are found nowhere else on Earth. Where critical habitats are threatened, endemic plants are at a far greater risk of extinction than more widely distributed species. Where endemic plants occur, the biodiversity in a particular ecoregion can be considered as being at higher risk because the very existence of these species depends on maintaining their particular habitats and minimizing the stresses which occur in the ecoregion.

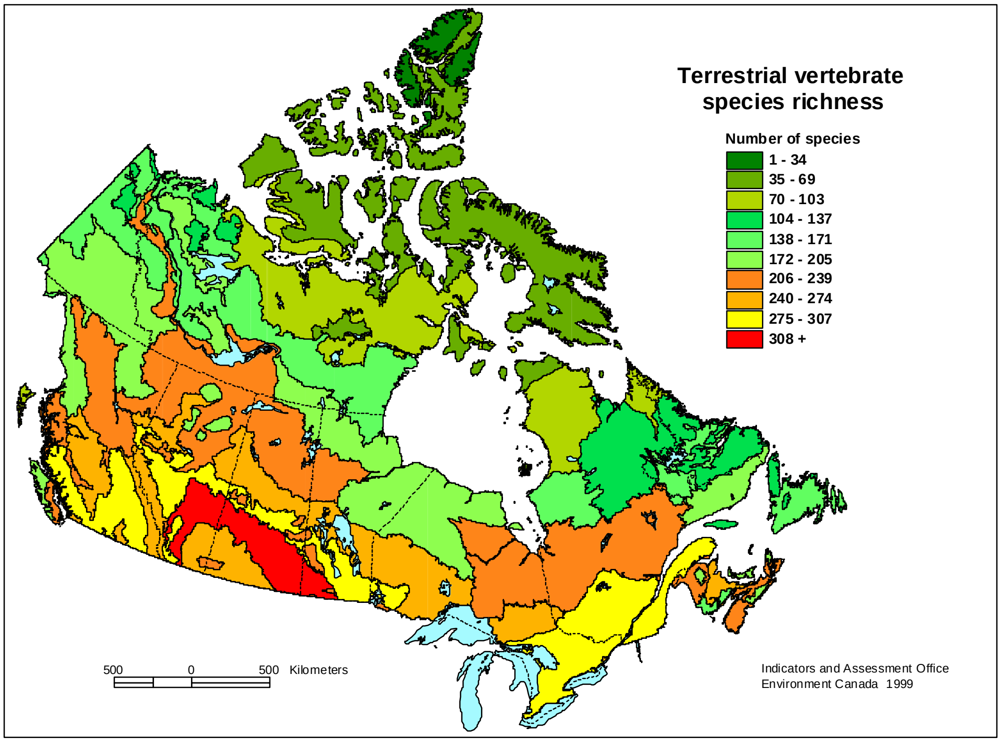
Data source and use

The rare and endemic plant species data base was originally compiled by the Canadian Museum of Nature. It was supplied to the project by the GeoAccess Division of Natural Resources Canada as a point file, which was converted to GIS map format and cross-correlated with the ecoregion framework. Only the terrestrial species in the database, as identified by Haber (1997), were included in the analysis.

The resultant map shows that known pockets of plant endemism emerge, such as the unglaciated portions of the Yukon, the isolated Queen Charlotte Islands, and the unique habitats provided by the Athabasca sand dunes. A very high concentration of rare plants is found in Carolinian southern Ontario. Many of these plants, although rare in Canada, may be quite prolific in the United States. The higher numbers of rare species compared with endemic species tends to weight the map in favour of areas of rare occurrence.

Note: The risk to terrestrial biodiversity model combined the terrestrial vertebrate species diversity with the rare and endemic terrestrial plants to provide an aggregated proxy for a terrestrial species diversity map, Map 6:

Map 6: Terrestrial species diversity



Species at risk

Importance

One environmental condition that has resulted primarily from the stress of human activity is the distribution of species at risk of eventual extinction. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) annually assesses Canada's native wild species and assigns levels of susceptibility. The majority of species assessed are mammals, birds, fish, reptiles, amphibians, and plants, although in recent years a few molluscs, lepidopterans (insects), mosses, and lichens have also been assessed. Most status reports for the species designated as being at risk clearly make a link between specific human activities and the abundance or distribution of the species. Therefore, it seems that species at risk is a reasonable indicator of current environmental conditions.

Data source

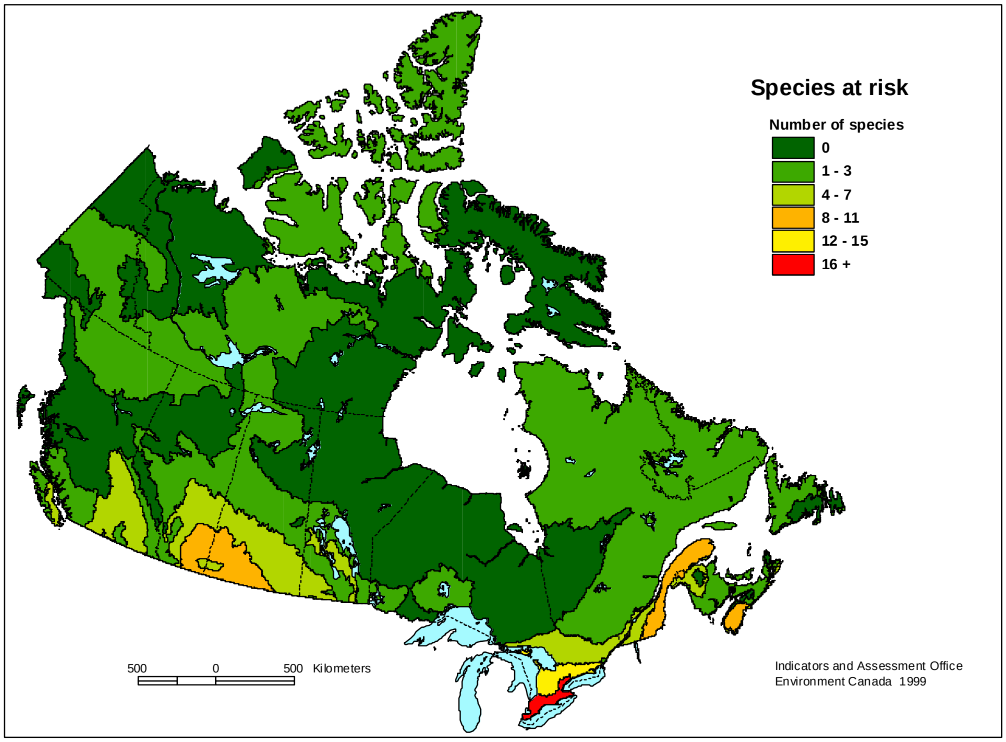
Digital map information on the ranges of endangered[2] and threatened[3] species were acquired from the Canadian Wildlife Service. As of 1997, COSEWIC had assigned status to 265 species, subspecies, or populations of native wild animals and plants listed as endangered, threatened, or vulnerable, another 11 are considered extirpated, and 9 are extinct. A further 87 had been considered and found to require no designation at the time, and 10 more were examined and not designated in any risk category because of insufficient scientific information.

A subset of these range maps representing terrestrial vertebrates as identified by Haber (1997) were correlated with the ecoregion maps to determine the maximum number of species at risk in each ecoregion.

As expected, the highest concentrations of species at risk are found in the Prairies and southern Ontario — areas dominated by extensive landscape modification and fragmentation, which has reduced the quantity and quality of current habitat of many species.

Map 7: Species at risk

[2] The term *endangered*, as used in this report, refers to an official designation assigned by COSEWIC. The designation is assigned to any indigenous species, subspecies, or geographically separate population that is at risk of imminent extinction or extirpation throughout all or a significant portion of its Canadian range.
[3] The term *threatened*, as used in this report, refers to an official designation assigned by COSEWIC. The term describes any indigenous species, subspecies, or geographically separate population that is likely to become *endangered* in Canada if the factors affecting its vulnerability are not reversed.



Land cover diversity

Importance

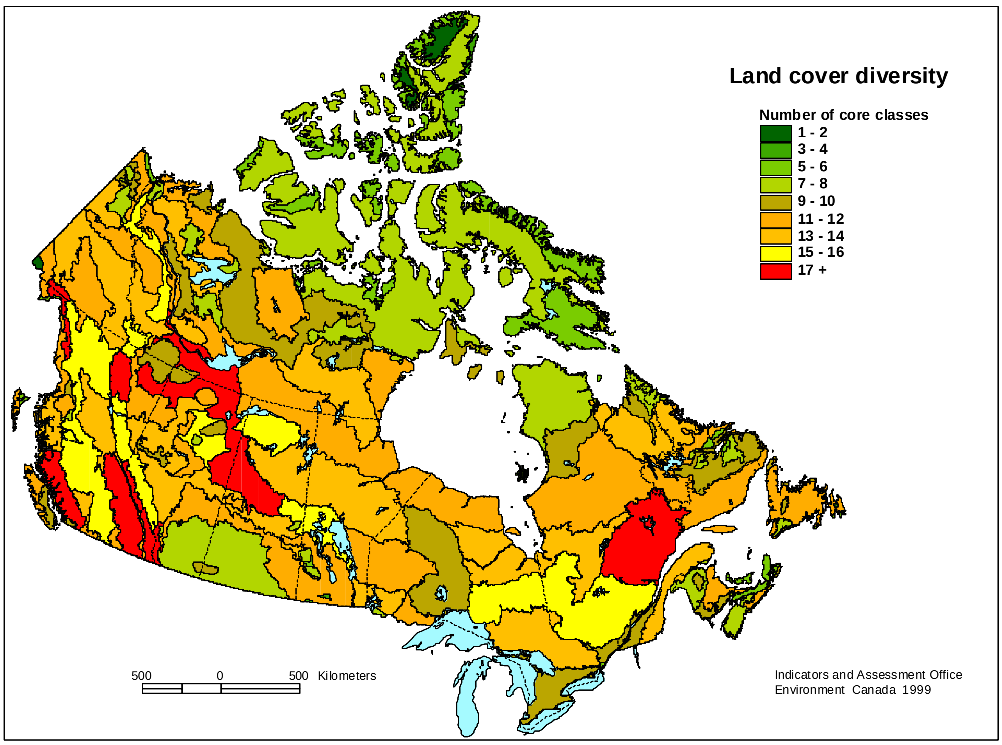
To complement the species diversity information presented in Map 6, a first order measure of ecosystem diversity was also attempted. It was assumed that ecoregions with more diverse landscapes and land cover would support a higher diversity of species. All other factors being equal, ecoregions with higher land cover diversity would likely be at greater risk of impacts to biodiversity from various human activities than ecoregions with lower land cover diversity.

Data source and processing

Although several sources of information can be used to give a measure of land cover diversity (e.g., Canada's Forest Inventory [CanFI] or the Soil Landscapes of Canada), for this study, the AVHRR classification at level 3 (24 classes) was used to derive the number of different land cover types that were present in each ecoregion. Although Map 4 (Land activity) also used AVHRR, the land cover diversity analysis came from a different classification of the data. GIS analysis produced statistics on the total number and average size of land cover class polygons, as well as the number and area size of different types of land cover for each ecoregion.

Scattered individual pixels[4], which can often represent misclassifications, were removed from the classification leaving larger core classes. The map shows the number of core classes found in each ecoregion. Land cover diversity appears greatest in boreal and mountainous areas of Canada — ecoregions which span major ecosystem changes over relatively short vertical or horizontal distances.

Map 8: Land cover diversity



Environmental condition index

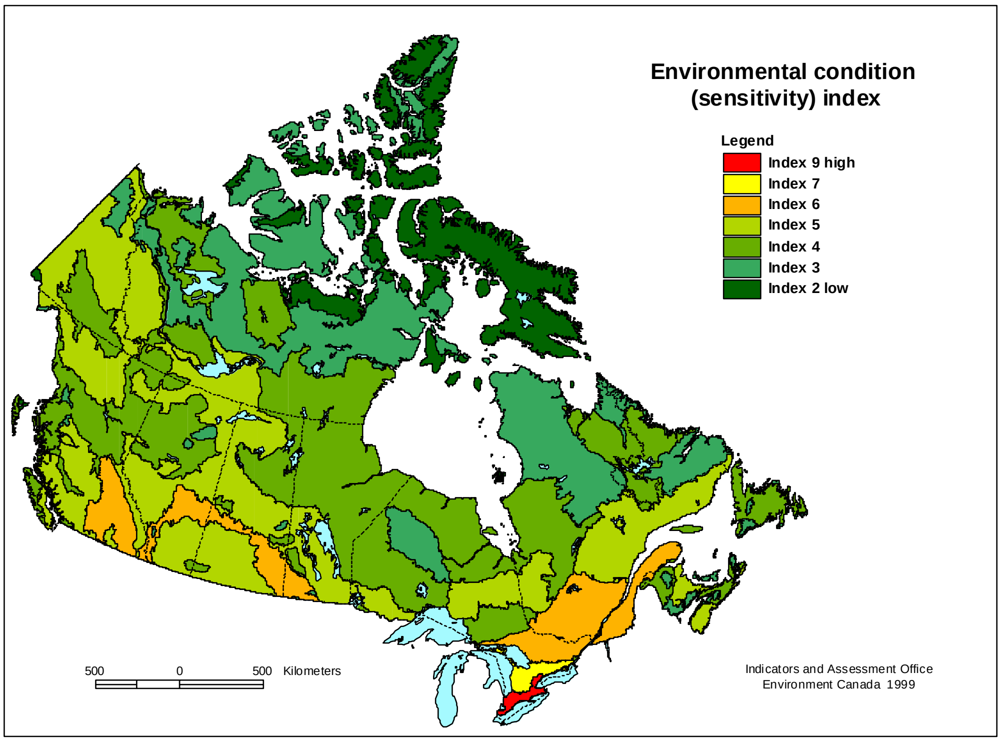
The environmental condition index map combines maps 6–8 into one composite condition index with 7 classes. Each of the three input maps is given equal weighting in the overlay. This map shows, by ecoregion, the aggregated conditions of species diversity, land cover diversity, and species at risk. Therefore, ecoregions that are rich in species and/or land cover types and also

---

[4] A *pixel* is the smallest element of an image that can be individually processed in a video display system.

have a large number of species at risk will have a high environmental condition index value, representing higher potential risk. In a situation of equal stress on ecoregions, the assumption is that these highly rated ecoregions stand to lose more native biodiversity than ecoregions with lower ratings.

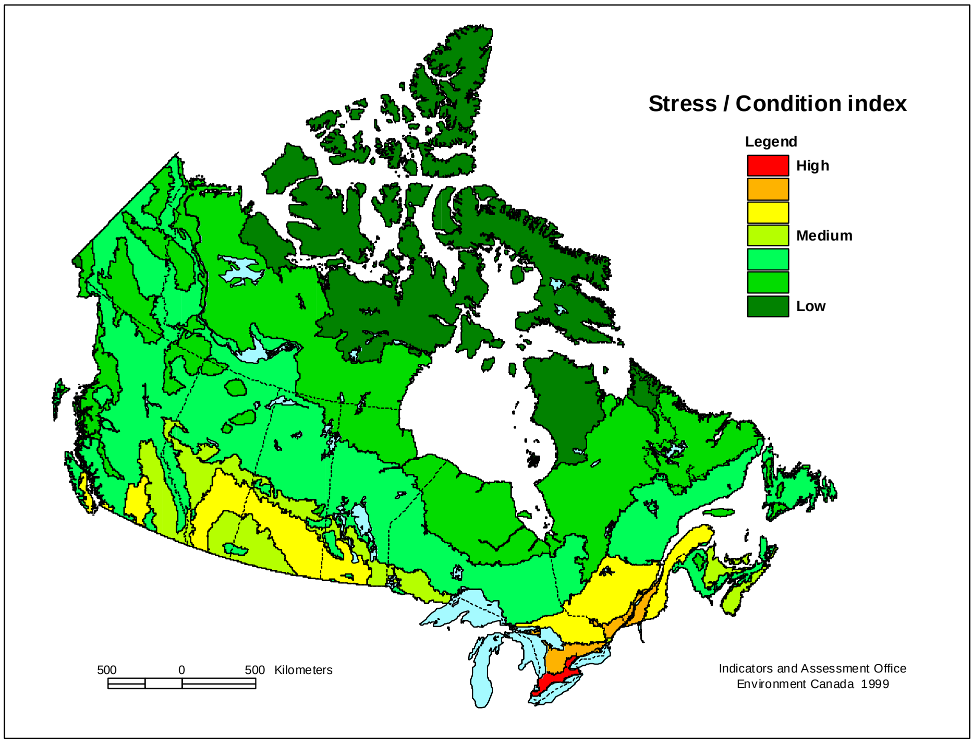
Map 9: Environmental condition index



Stress/environmental condition index

In order to assess the spatial relationship between areas of various levels of stress and the areas represented in the environmental sensitivity index, a composite map was created. This map gives equal weight to maps 5 and 9. Areas of moderate index values may represent variable stress and natural environmental conditions, while low value areas are low in both stress and environmental condition. Overall, it appears that the stress index has more influence in the final map, perhaps because the various stress factors tend to reinforce each other. Southern Ontario shows up as the highest risk because it is influenced by many stressors and also has many native species and species at risk.

Map 10: Stress/environmental condition index



Societal response

There are few national georeferenced data sets that portray a societal response to stresses on biodiversity. Future possibilities include the range of species at risk that are the subject of recovery efforts. For now, the location of protected areas is the best indicator available.

Protected areas

Importance

Protected areas is used as one measure of societal response aimed at conserving biodiversity. Protected areas include nature reserves, designated wilderness areas, national parks or equivalents, habitat/species management areas (e.g., migratory bird sanctuaries), and other conservation areas designated through federal, provincial, and territorial legislation (see Appendix 5).

The general assumption is that protected areas protect biodiversity. Therefore the greater the extent of an ecoregion that is protected and the more comprehensive the protection, the lower the risk to biodiversity for that ecoregion.

Data source and processing

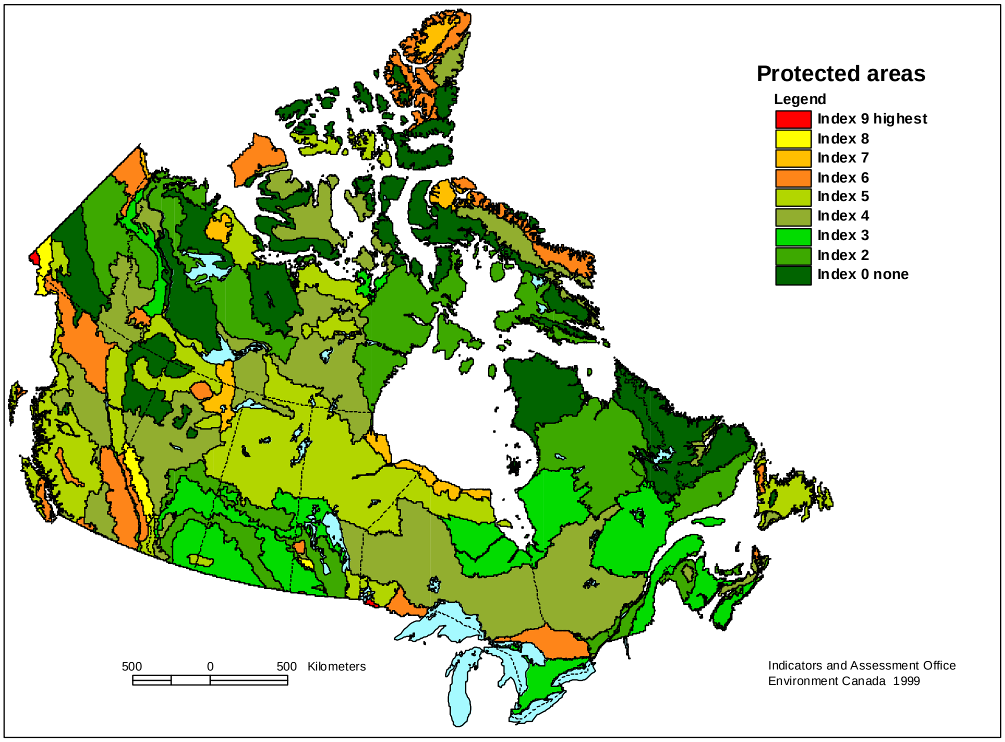
Protected area data was obtained from the Canadian Conservation Areas Database, which is maintained by the Canadian Council on Ecological Areas, with the support of several federal government agencies. The database provides information on all types of areas in Canada that are protected by some form of legislation or legal agreement. CCAD has three components — a main database consisting of all federal, provincial and territorial owned protected areas; a GIS polygonal database for most government owned areas greater than 1 000 hectares; and a database of nongovernment protected areas. This project used the GIS polygonal database which has information current as of about 1995.

Two different protected areas maps were created. One presented the area of each ecoregion that is strictly protected (i.e., IUCN[5] categories I–III) and the second was the area of each ecoregion that is protected under IUCN categories IV–VI. The former measure includes sites that enjoy more complete protection, whereas the latter measure includes other types of protected areas that allow more types of human activities.

The two maps were then combined, with IUCN categories I–III given twice the weight for protecting biodiversity as IUCN categories IV–VI.

[5] IUCN (World Conservation Union) has developed an internationally recognized six-category scheme to classify protected areas according to management objectives (IUCN, 1994; see Appendix 5).

Map 11: Protected areas

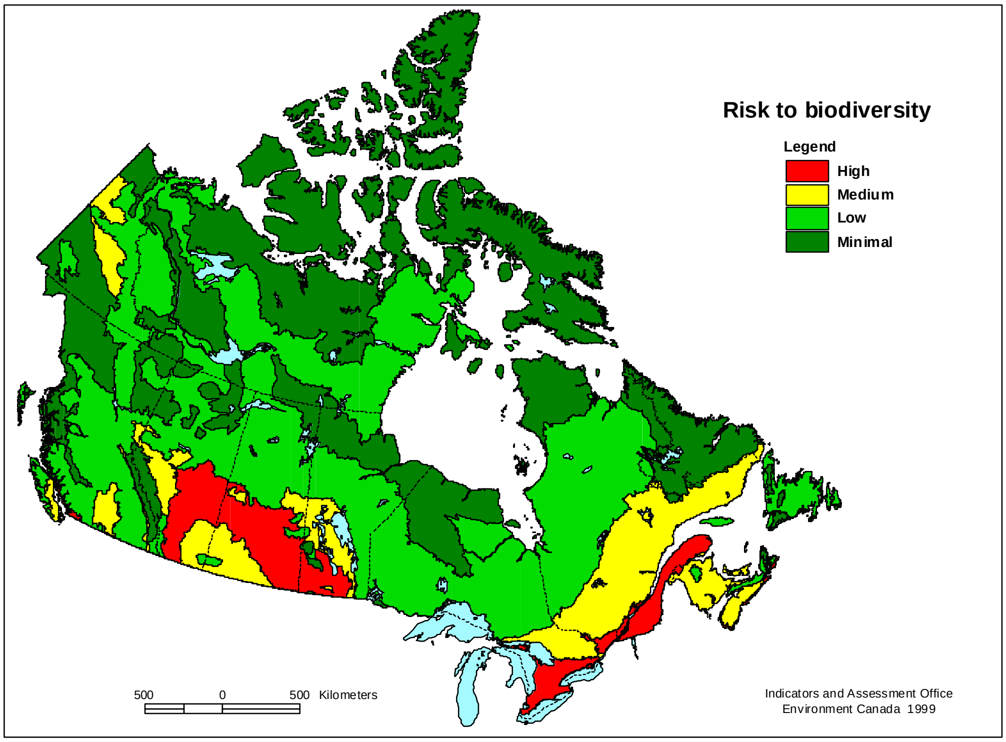


Risk to terrestrial biodiversity

This map combines the stress index, environmental condition index, and societal response (protected areas) in equal weightings. Some unexpected trends emerge, such as the north shore of the St. Lawrence having the same weight as the southern prairies.

The influence of the input maps can be seen in several areas,. For example, most of northern Canada is show as low risk, some of the Yukon Territory is moderate risk, primarily due to the high concentration of rare and endemic plant species (Map 6). This demonstrates that the risk to biodiversity model can be sensitive to regional differences.

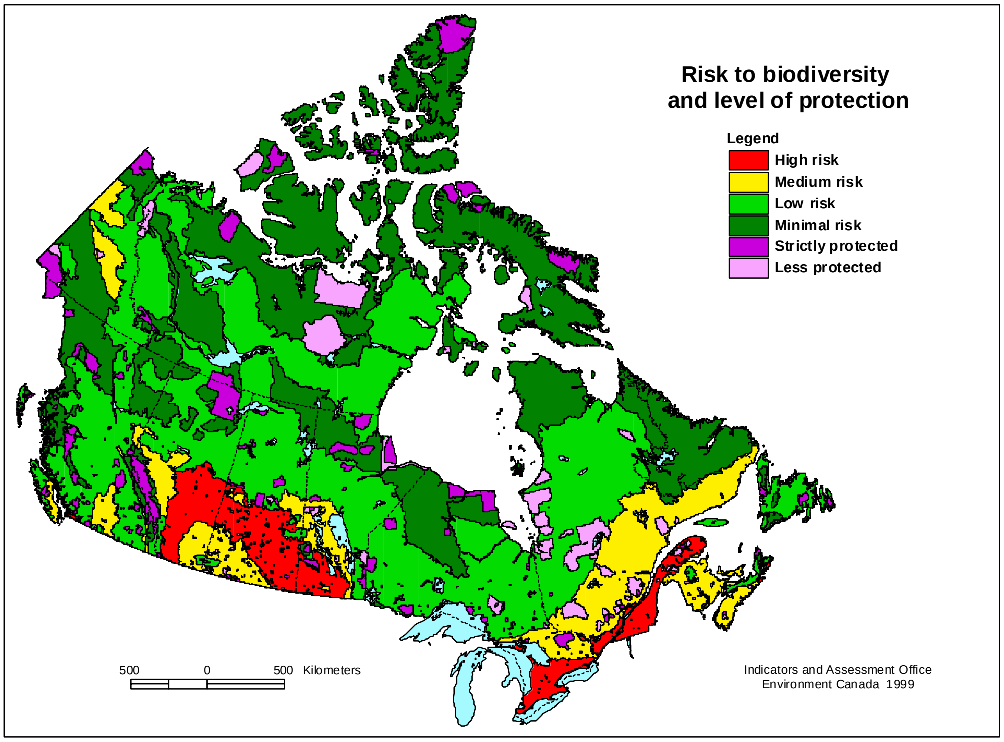
Map 12: Risk to terrestrial biodiversity



Risk to terrestrial biodiversity with protected areas

The final map has taken the results of Map 12 and added the protected area polygons as an overlay. This map gives a graphic comparison of the distribution of risk to terrestrial biodiversity in Canada compared the distribution of efforts designed to protect native biodiversity. The map shows that the greatest areas of stress are located in southern Canada, while the largest protected areas are in the north, where the stresses are least.

Map 13: Risk to terrestrial biodiversity with protected areas overlay



DISCUSSION

The development of a risk to terrestrial biodiversity model has demonstrated that the ecoregion framework is useful for the integration of diverse sets of spatial data to address, at a national scale, a highly complex issue such as biodiversity change. The GIS model is able to balance the stress, environmental condition, and societal response variables in a way that is repeatable by others.

This model of terrestrial risk to terrestrial biodiversity was directed towards the requirements of Environment Canada's National Environmental Indicators Program, which reports on environmental conditions and trends in a number of environmental issue areas at a national level. The choice of maps to include and weightings benefited from the advice of staff of the Indicators and Assessment Office.

The GIS model design is flexible and open-ended. The model is structured to permit quick and easy modification as new or refined data become available and new scenarios developed. As different expertise, data, and model weightings are considered, the risk to terrestrial biodiversity model can be tailored to specific needs of forestry, agriculture, wildlife concerns, ecosystem health, sustainability, or other issues involving human interaction with the natural environment.

The results of this project should not be interpreted at scales below [or greater than?] the ecoregion level. The GIS approach can be translated to other scales, however, as long as there is appropriate data available at that scale.

CONCLUSIONS

This report provides national and regional perspectives on the current susceptibility of terrestrial biodiversity to change. It provides a method for assessing the risk to terrestrial biodiversity, and establishes a foundation for the development of indicators to measure and track over time, changes in the state of biodiversity. It also provides a tool to communicate the complex concepts of biodiversity assessment and protection. It should be kept in mind that this is a first, simplified approximation of the highly complex workings of ecosystems. As more and better data become available, and other expertise is added, the model can be further refined.

REFERENCES

Biodiversity Science Assessment Team. 1994. Biodiversity in Canada: a science assessment for Environment Canada. Ottawa: Environment Canada.

Canada. 1998. Caring for Canada's biodiversity. Canada's first national report to the Parties to the Convention on Biological Diversity. Available from the Biodiversity Convention Office, Environment Canada, Ottawa. Also available, Inventory of initiatives: Annex to Canada's first national report to the Parties to the Convention on Biological Diversity.

Canadian Forest Service. 1997. Biodiversity in the forest: The Canadian Forest Service three-year action plan. Implementing the Canadian Biodiversity Strategy. Ottawa: Natural Resources Canada, Canadian Forest Service.

Ecological Stratification Working Group. 1996. A national ecological framework for Canada. Ottawa: Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research; and Ottawa: Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch. On the Internet at http://www1.ec.gc.ca/~soer/default_e.htm.

Environment Canada. 1993 to present. National Environmental Indicator Series. Ottawa: Environment Canada, Indicators and Assessment Office. On the Internet at http://www1.ec.gc.ca/~soer/default_e.htm.

Environment Canada. 1998. Conserving wildlife diversity: Implementing the Canadian Biodiversity Strategy. Ottawa: available from the Biodiversity Convention Office, Environment Canada.

Federal–Provincial–Territorial Biodiversity Working Group. 1995. Canadian Biodiversity Strategy: Canada's response to the Convention on Biological Diversity. Ottawa: available from the Biodiversity Convention Office, Environment Canada.

Government of Canada. 1996. The State of Canada's environment — 1996. Ottawa: Environment Canada.

Gregory Geoscience Limited and Paul C. Rump and Associates. 1996. Modelling risk to biodiversity in Canada. Report prepared under contract (contract no. K1515-6-0011) for the Indicators and Assessment Office, Environment Canada, Ottawa.

Government of Canada. 1997. Implementing the Canadian Biodiversity Strategy: Protected Areas. Ottawa: Department of Canadian Heritage, Parks Canada; Environment Canada, Canadian Wildlife Service; and Department of Fisheries and Oceans, Habitat Management and Environmental Science.

Haber, E. 1997. Access database and documentation for determining terrestrial-dependent species at risk. Contract submission to Indicators and Assessment Office, Environment Canada, by Eric Haber, National Botanical Services, Ottawa, 17 December 1997.

Indicators and Assessment Office. 1998. National Environmental Indicator Series. Ottawa: Environment Canada, Indicators and Assessment Office. On the Internet at http://www1.ec.gc.ca/~soer/default_e.htm.

IUCN (World Conservation Union). 1994.Guidelines for protected area management categories. Gland, Switzerland: IUCN's Commission on National Parks and Protected Areas (CNPPA), with the assistance of: Cambridge, UK: World Conservation Monitoring Centre (WCMC).

Mineau, P., T. Turner, J. Middleton, and K. Freemark. 1994. Stresses on biodiversity — a brief analysis of principal land use conflicts. Chapter 3, pages 43–49, in Biodiversity in Canada: a science assessment for Environment Canada. Ottawa: Environment Canada, Biodiversity Science Assessment Team.

Rubec, C.D.A., A.M. Turner, and E.B. Wiken. 1992. Integrated modeling for protected areas and biodiversity assessment in Canada. Proceedings of the third national symposium of the Canadian Society for Landscape Ecology and Management, Edmonton. Montreal: Polyscience Publications Ltd.

Turner A.M., E.B. Wiken, and H.D. Moore. 1998. Modelling risk to biodiversity in Canada: an ecosystem approach. Pages 657–667 in Munro, N.W.P. and J.H.M. Willison (eds.), Linking Protected Areas with Working Landscapes Conserving Biodiversity, Proceedings of the Third International Conference on Science and Management of Protected Areas,12–16 May 1997. Wolfville, Nova Scotia: Science and Management of Protected Areas Association (SAMPAA).

UNEP (United Nations Environment Programme). 1992. Convention on Biological Diversity. Printed text and annexes available as publication UNEP/CBD/94/1. Also accessible on the Internet, at URL http://www.biodiv.org/convtext/cbd0000.htm.

Appendix 1: Range values and GIS values used for maps in the *risk to terrestrial biodiversity model*

Stress maps

Map	Range values	GIS values	Map	Range values	GIS values
1: Road access	Length of road per map (km)		3: Population change, 1971–91	Population change	
	≤100	1		-30 000 to -15 001	1
	101–1 000	2		-15 000–0	2
	1 001–2 000	3		1–15 000	3
	2 001–4 000	4		15 001–30 000	4
	4 001–6 000	5		30 001–60 000	5
	6 001–8 000	6		60 001–100 000	6
	8 001–10 000	7		100 001–250 000	7
	10 001–14 000	8		250 001–500 000	8
	14 001–18 000	9		500 001–1 000 000	9
	>18 000	10		>1 000 000	10
2: Population density	People per square kilometre		4: Land activity	Land activity/cover type	
	No data	0		Barren	5
	0–0.1	1		Non-productive forest	6
	0.2–1.0	2			
	1.1–5.0	3		Productive forest	7
	5.1–10.0	4		Range	8
	10.1–20.0	5		Agriculture	9
	20.1–40.0	6		Urban	10
	40.1–80.0	7			
	80.1–160.0	8			
	160.1–320.0	9			
	>320.0	10			

Environmental condition maps

Map	Range values		Map	Range values	
6 : Terrestrial species diversity Part a)	Number of terrestrial vertebrate species	**GIS values**	7: Species at risk	Number of species	**GIS values**
	≤32	1		0	0
	32–64	2		1–3	1
	64–101	3		4–6	2
	102–138	4		7–8	3
	139–176	5		9–12	4
	177–213	6		13–16	5
	214–250	7		16–20	6
	251–287	8		21–24	7
	288–325	9		24–28	8
	326 –362	10		29–32	9
				>32	10
Part b)	b) Number of terrestrial rare and endemic plants		8: Land cover diversity	Number of AVHRR cover types per ecoregion	
	1	2		1–2	2
	2–3	3		3–4	3
	4–5	4		5–6	4
	6–10	5		7–8	5
	11–15	6		9–10	6
	16–20	7		11–12	7
	21–25	8		13–14	8
	26–50	9		15–16	9
	>50	10		>16	10

Societal response map

Map	Break points		GIS values
11: Protected areas: percent ecoregion protected	11a: Percent ecoregion protected IUCN I–III (75% weighting)	11b:Percent ecoregion protected IUCN IV–VI (25% weighting)	
	0	0	1
	10	10	2
	20	20	3
	30	30	4
	40	40	5
	50	50	6
	60	60	7
	70	70	8
	80	80	9
	90	90	10

Notes regarding the protected area map:

The protected areas database was divided into two maps — one showing all areas with IUCN classification 1–3 and the other showing all areas with IUCN classification 4–6. These maps were classified into 10 equal classes, with break points as listed above. Each break point is the bottom value of a 10-unit range of values. So the 0 break point is the start of the 0–<10 range, 10 is the start of the 10–<19 range, and so on. When the two maps 10a and 10b were integrated together with appropriate weightings (75% and 25%) the output map displayed a relative scale of protection value with a maximum value of 10 and a minimum value of 1. In ecoregions where there are no protection areas the this value is a zero; therefore, there is a maximum of 11 protection values. The protection value for each ecoregion is then combined with the percent protected class for each ecoregion to produce a relative measure of protection for each ecoregion. The output from this analysis has a potential maximum of 10 and a minimum of 1 and a 0 value if there are no protected areas found within the ecoregion. The resultant map shows that there are no ecoregions with the values of 10 or 1. This map shows the output of a spatial modelling routine that displays relative measures. In the original risk model, just the percent protected map was used.

The map is presented as a protection index value. As such, the map classes do not have units but are a relative measure computed from the GIS modelling of percent protected with a level of protection value computed from the IUCN classification. In order to have a value of 1 computed, there needs to be ecoregions with a percent protected value but no level of protection value which never happens. Similarly the conditions to produce a score of 10 never happen. If this is still confusing then perhaps we should use the percent protected map which does have map class units and ranges. However it does not reflect the level of protection provided.

Appendix 2: Meta data for maps used in the development of the risk to terrestrial biodiversity assessment

Map 1: Road access	
Based on	Road length, by ecoregion
Originator Sector Branch Author	GeoInsight Corporation
Date of publication or Time period start date Time period end date	199803
Language of resource Language of record	English English
Abstract	Data set depicts the length of roads in each of the 217 terrestrial ecoregions of Canada as a percentage of the total area of the ecoregion. The definition of road is that used for 1:250 000 National Topographic Mapping for rural areas and 1:50 000 mapping in urban areas.
Subject terms	roads, road density
Subject thesaurus	none
Type of resource Bounding coordinates West East North South	Spatial -175 -7 89 38
Location key word	Canada
Availability	
Medium	paper, disk, electronic mail system
Distributor Organization	Harold Moore GeoInsight Corporation
Linkage type	
Access constraints	tbd
Use constraints	tbd
Access to resource	tbd
Order information	tbd
Contact: Name Organization Mailing address City Province Country Email Telephone Fax Hours of service	 Harold Moore GeoInsight Corporation P.O. Box 24196 Hazeldean R.P.O. Kanata ON Canada hmoore-gg@cyberus.ca (613) 831-6434 (613) 831-6435 9am–5pm Mon.–Fri.

Data sources

National Roads Database:
Digital Distribution Services
615 Booth St., Room 174

National Ecological Framework for Canada for Canada:
Ian Marshall, Indicators and Assessment Office

Ottawa, ON K1A 0E9
Tel: (613) 995-0314 Fax: (613) 947-2189

Environment Canada, 351 St. Joseph Blvd.
Hull QC K1A 0H3
Tel: (819) 994-8463 Fax: (819) 994-5738
email: ian.marshall@ec.gc.ca

Map 2: Population density	
Based on	Time period 1991), by ecoregion
Originator Sector Branch Author	Environment Canada Indicators and Assessment Office
Date of publication or Time period start date Time period end date	199803
Language of resource Language of record	English English
Abstract	Data set depicts the number of people residing in each of the 217 terrestrial ecoregions of Canada, as a percentage of the area of each ecoregion, for census year 1991.
Subject terms	population density, population
Subject thesaurus	none
Type of resource Bounding coordinates West East North South	Spatial -175 -7 89 38
Location key word	Canada
Availability	
Medium	paper, disk, electronic mail system
Distributor Organization	
Linkage type	
Access constraints	tbd
Use constraints	tbd
Access to resource	tbd
Order information	tbd
Contact Organization Mailing Address City Province Country Email Telephone Fax Hours of Service	Harold Moore GeoInsight Corporation P.O. Box 24196 Hazeldean R.P.O. Kanata ON Canada hmoore-gg@cyberus.ca (613) 831-6434 (613) 592-9135 9am–5pm Mon.–Fri.

Data sources

Census of population, by ecoregion:
Michael Bordt
Environment and National Accounts Division
Statistics Canada
RH Coates Building, 7th Floor
Tunney's Pasture, Ottawa ON Canada
Tel: (613) 951-8585 Fax: (613) 951-3618
email: mbordt@statcan.ca

National Ecological Framework for Canada for Canada:
Ian Marshall, Indicators and Assessment Office
Environment Canada, 351 St. Joseph Blvd.
Hull QC K1A 0H3
Tel: (819) 994-8463 Fax: (819) 994-5738
email: ian.marshall@ec.gc.ca

Map 3: Population change, 1971–91	
Based on	Four time periods (1971–76, 1976–81, 1981–86, and 1986–91), by ecoregion
Originator Sector Branch Author	Environment Canada Indicators and Assessment Office
Date of publication or Time period start date Time period end date	199803
Language of resource Language of record	English English
Abstract	Data set depicts the number of people residing in each of the 217 terrestrial ecoregions of Canada, as a percentage of the area of each ecoregion for each of the census years 1971, 1976, 1981, 1986, and 1991.
Subject terms	population change, population
Subject thesaurus	none
Type of resource Bounding coordinates West East North South	Spatial -175 -7 89 38
Location key word	Canada
Availability	
Medium	paper, disk, electronic mail system
Distributor Organization	
Linkage type	
Access constraints	tbd
Use constraints	tbd
Access to resource	tbd
Order information	tbd
Contact Organization Mailing Address City Province Country Email Telephone Fax Hours of Service	Harold Moore GeoInsight Corporation P.O. Box 24196 Hazeldean R.P.O. Kanata ON Canada hmoore-gg@cyberus.ca (613) 831-6434 (613) 592-9135 9am–5pm Mon.–Fri.

Data sources

Census of population, by ecoregion:
Michael Bordt
Environment and National Accounts Division
Statistics Canada
RH Coates Building, 7th Floor
Tunney's Pasture, Ottawa ON Canada
Tel: (613) 951-8585 Fax: (613) 951-3618
email: mbordt@statcan.ca

National Ecological Framework for Canada:
Ian Marshall, Indicators and Assessment Office
Environment Canada, 351 St. Joseph Blvd.
Hull QC K1A 0H3
Tel: (819) 994-8463 Fax: (819) 994-5738
email: ian.marshall@ec.gc.ca

Map 4: Land activity	
Based on	AVHRR land cover of Canada — 1995
Originator Sector Branch Author	Natural Resources Canada Geomatics Canada — Canada Centre for Remote Sensing
Date of publication *or* Time period start date Time period end date	01
Language of resource Language of record	English English
Abstract	Data set derived from images of Advanced Very High Resolution Radiometer (AVHRR) sensor of NOAA satellite with a resolution of 1 km. The data set was classified into 29 classes of land cover.
Subject terms	Earth science > Land surface > Land use/Land cover > Land cover > Land cover
Subject Thesaurus	GCMD
Type of resource Bounding coordinates West East North South	Spatial -175 -7 89 38
Location key word	Canada
Availability	
Medium	tbd
Distributor Organization	Josef Cihlar Natural Resources Canada
Linkage type	
Access constraints	tbd
Use constraints	none
Access to resource	
Order information	
Contact Organization Mailing address City Province Postal code Country Email Telephone Fax Hours of service	Josef Cihlar Geomatics Canada — Canada Centre for Remote Sensing Natural Resources Canada 588 Booth Street Ottawa ON K1A 0Y7 Canada Josef.Cihlar@geocan.nrcan.gc.ca (613) 947-1265 (613) 947-1385

Data sources

Land cover of Canada — 1995
Josef Cihlar
Geomatics Canada — Canada Centre for Remote Sensing
Natural Resources Canada
588 Booth Street, Ottawa ON K1A 0Y7 Canada
Tel: (613) 947-1265 Fax: (613) 947-1406
email: josef.cihlar@geocan.nrcan.gc.ca

National Ecological Framework for Canada
Ian Marshall
Indicators and Assessment Office
Environment Canada
351 St. Joseph Blvd
Hull QC Canada K1A 0H3
Tel: (819) 994-8463 Fax: (819) 994-5738
email: ian.marshall@ec.gc.ca

Map 6: Terrestrial species diversity	
Based on (in part)	Number of vertebrate species, by ecoregion
Originator Sector Branch Author	GeoInsight Corporation
Date of publication or Time period start date Time period end date	199803
Language of resource Language of record	English English
Abstract	Data set classifies 660 species of vertebrates (386 birds, 186 mammals, 88 reptiles and amphibians) according to the occurrence of their range within each of the terrestrial ecoregions of Canada.
Subject terms	species diversity, species richness, biodiversity
Subject thesaurus	none
Type of resource Bounding coordinates West East North South	Spatial -167 -8 89 38
Location key word	Canada
Availability	
Medium	paper, disk, electronic mail system
Distributor Organization	Harold Moore GeoInsight Corporation
Linkage type	
Access constraints	tbd
Use constraints	tbd
Access to resource	tbd
Order information	tbd
Contact Organization Mailing address City Province Country E-mail Telephone Fax	Harold Moore GeoInsight Corporation P.O. Box 24196 Hazeldean R.P.O. Kanata ON Canada hmoore-gg@cyberus.ca (613) 831-6434 (613) 592-9135

Data sources

Vertebrate species range maps
Claire Gosson
Geoaccess Division, Geomatics Canada — CCRS
Natural Resources Canada
Tel: (613) 992-4134 Fax: (613) 943-8282
email: claire.gosson@geocan.nrcan.gc.ca

National Ecological Framework for Canada
Ian Marshall, Indicators and Assessment Office
Environment Canada
351 St. Joseph Blvd.
Hull QC Canada K1A 0H3
Tel: (819) 994-8463 Fax: (819) 994-5738
email: ian.marshall@ec.gc.ca

Map 6: Terrestrial species diversity (continued**)**	
Based on (in part)	Number of known endemic vascular plants, by ecoregion
Originator Sector Branch Author	GeoInsight Corporation
Date of publication or Time period start date Time period end date	199803
Language of resource Language of record	English English
Abstract	Data set classifies 93 known nationally endemic (i.e., found only in Canada) vascular plants according to their known presence within each of the terrestrial ecoregions of Canada.
Subject terms	rare and endemic plants, endemic species, endemism, species at risk, biodiversity
Subject thesaurus	none
Type of resource Bounding coordinates West East North South	Spatial -167 -8 89 38
Location key word	Canada
Availability	
Medium	paper, disk, electronic mail system
Distributor Organization	Harold Moore GeoInsight Corporation
Linkage Type	
Access Constraints	tbd
Use Constraints	tbd
Access to Resource	tbd
Order Information	tbd
Contact Organization Mailing Address City Province Country Email Telephone Fax Hours of Service	Harold Moore GeoInsight Corporation P.O. Box 24196 Hazeldean R.P.O. Kanata ON Canada hmoore-gg@cyberus.ca (613) 831-6434 (613) 592-9135 9am–5pm Mon.–Fri.

Data sources

Endemic and Rare plants of Canada:
Erich Haber
National Botanical Services
604 Wavell Ave., Ottawa ON K2A 3A8
Tel: (613) 722-5523 Fax: (613) 722-6291
email: ehaber@magi.com

National Ecological Framework for Canada:
Ian Marshall, Indicators and Assessment Office
Environment Canada, 351 St. Joseph Blvd.
Hull QC K1A 0H3
Tel: (819) 994-8463 Fax: (819) 994-5738
email: ian.marshall@ec.gc.ca

Map 7: Species at risk	
Based on	Number of species at risk — 1997, by ecoregion
Originator Sector Branch Author	GeoInsight Corporation
Date of publication or Time period start date Time period end date	199803
Language of resource Language of record	English English
Abstract	Data set classifies over 200 nationally endangered, threatened, and vulnerable species of birds, mammals, reptiles, amphibians, molluscs, vascular plants and lichens according to their presence within each of the terrestrial ecoregions of Canada.
Subject terms	endangered species, threatened species, species at risk
Subject thesaurus	none
Type of resource Bounding coordinates West East North South	Spatial -167 -8 89 38
Location key word	Canada
Availability	
Medium	paper, disk, electronic mail system
Distributor Organization	Harold Moore GeoInsight Corporation
Linkage type	
Access constraints	tbd
Use constraints	tbd
Access to resource	tbd
Order information	tbd
Contact Organization Mailing address City Province Country Email Telephone Fax Hours of service	Harold Moore GeoInsight Corporation P.O. Box 24196 Hazeldean R.P.O. Kanata ON Canada hmoore-gg@cyberus.ca (613) 831-6434 (613) 592-9135 9am–5pm Mon.–Fri.

Data sources

Species at risk:
Richard Post
Canadian Wildlife Service
Environment Canada, Ottawa ON KIA 0H3
Tel: (819) 997-3681 Fax: (819) 997-3822
email: richard.post@ec.gc.ca

National Ecological Framework for Canada
Ian Marshall
Indicators and Assessment Office
Environment Canada, 351 St. Joseph Blvd.
Hull QC Canada K1A 0H3
Tel: (819) 994-8463 Fax: (819) 994-5738
email: ian.marshall@ec.gc.ca

Map 8: Land cover diversity	
Based on	Land cover diversity 1995, by ecoregion
Originator Sector Branch Author	GeoInsight Corporation
Date of publication *or* Time period start date Time period end date	199803
Language of resource Language of record	English English
Abstract	Data set classifies the number of 29 land cover types, for each of the 217 Terrestrial ecoregions of Canada.
Subject terms	land cover, diversity, ecosystem diversity
Subject thesaurus	none
Type of resource Bounding coordinates West East North South	Spatial -175 -7 89 38
Location key word	Canada
Availability	
Medium	paper, disk, electronic mail system
Distributor Organization	Harold Moore GeoInsight Corporation
Linkage type	
Access constraints	tbd
Use constraints	tbd
Access to resource	tbd
Order information	tbd
Contact Organization Mailing address City Province Country E-mail Telephone Fax Hours of service	Harold Moore GeoInsight Corporation P.O. Box 24196 Hazeldean R.P.O. Kanata ON Canada hmoore-gg@cyberus.ca (613) 831-6434 (613) 592-9135 9am–5pm Mon.–Fri.

Data sources

Land cover of Canada — 1995
Josef Cihlar, Geomatics Canada — Canada
Centre for Remote Sensing
Natural Resources Canada
588 Booth Street
Ottawa ON Canada K1A 0Y7
Tel: (613) 947-1265 Fax: (613) 947-1406
email: Josef.Cihlar@geocan.nrcan.gc.ca

National Ecological Framework for Canada
Ian Marshall
Indicators and Assessment Office
Environment Canada
351 St. Joseph Blvd
Hull QC Canada K1A 0H3
Tel: (819) 994-8463 Fax: (819) 994-5738
email: ian.marshall@ec.gc.ca

Map 11: Protected areas	
Based on	Percent protected area (IUCN I–III and IV–VI), by ecoregion
Originator Sector Branch Author	GeoInsight Corporation
Date of publication or Time period start date Time period end date	199803
Language of resource Language of record	English English
Abstract	Data set depicts the amount of protected area located in each of the 217 terrestrial ecoregions of Canada as a percentage of the total area of the ecoregion. For IUCN categories, see Appendix 5.
Subject terms	protected areas, conservation areas, ecosystem protection, gap analysis
Subject thesaurus	none
Type of resource Bounding coordinates West East North South	Spatial -175 -7 89 38
Location key word	Canada
Availability	
Medium	paper, disk, electronic mail system
Distributor Organization	Harold Moore GeoInsight Corporation
Linkage type	
Access constraints	tbd
Use constraints	tbd
Access to resource	tbd
Order information	tbd
Contact Organization Mailing address City Province Country Email Telephone Fax Hours of service	Harold Moore GeoInsight Corporation P.O. Box 24196 Hazeldean R.P.O. Kanata ON Canada hmoore-gg@cyberus.ca (613) 831-6434 (613) 592-9135 9am–5pm Mon.–Fri.

Data sources

Canadian Conservation Areas Database:
Ed Wiken
Canadian Council on Ecological Areas (CCEA)
c/o CCEA Secretariat
Canadian Wildlife Service
Environment Canada Ottawa ON KIA 0H3
Tel: (819) 994-9533 Fax: (613) 994-4445
email: ecologic@istar.ca

National Ecological Framework for Canada:
Ian Marshall
Indicators and Assessment Office
Environment Canada
Hull QC K1A 0H3
Tel: (819) 994-8463 Fax: (819) 994-5738
email: ian.marshall@ec.gc.ca

Reference

IUCN (World Conservation Union). 1994. Guidelines for protected area management categories. IUCN Commission on National Parks and Protected Areas with the assistance of the World Conservation Monitoring Centre. Gland, Switzerland, and Cambridge UK.

Appendix 3: Agencies and individuals contacted during the course of the project: Risk to biodiversity (1996) and Risk to terrestrial biodiversity (1997)[6]

Agriculture and Agri-Food Canada
Peter Schut, Land Evaluation

Environment Canada
Kathy Dickson, Canadian Wildlife Service
Colleen Hyslop, Canadian Wildlife Service
Gary Ironside, Indicators and Assessment Office, formerly State of the Environment Directorate
Anne Kerr, Indicators and Assessment Office
Hélène Lévesque, Canadian Wildlife Service
Ian Marshall, Indicators and Assessment Office, formerly State of the Environment Directorate
Paul Quinn, Indicators and Assessment Office, formerly State of the Environment Directorate
Peter Rodgers, retired, formerly State of the Environment Directorate
Tony Turner, Turner and Associates, formerly State of the Environment Directorate
Ed Wiken, Canadian Wildlife Service, formerly State of the Environment Directorate

Natural Resources Canada
Josef Cihlar, Canada Centre for Remote Sensing
Claire Gosson, GeoAccess Division, formerly National Atlas of Canada
Brian Haddon, National Forestry Database Program (Statistics), Canadian Forest Service
Harry Hirvonen, Canadian Forest Service, formerly State of the Environment Directorate
Bruce McCuaig, formerly Geomatics Canada
Katja Power, Canadian Forest Service

Statistics Canada
Michael Bordt, Information System for Science and Technology
Bruce Mitchell, Geography Business Units, formerly National Accounts and Environment Division

United States Geological Survey
Tom Loveland
Brad Reed

---

[6] For individuals who have changed affiliation since they were contacted, their current affiliation is indicated first, followed by the former one.

Appendix 4: Some measures or indicators that might help to approximate an "ideal" model of risk to biodiversity

Stress • **Measures**	**Forestry** • harvest • silviculture • pesticide • fire by humans • change 1986, 1991, 1996 • forest land cover 1986,1993 (AVHRR) • # of mills • mill area of influence	**Agriculture** • % cropland • % pasture • pesticide use • % irrigation • conservation tillage • change 1986, 1991, 1996 • agricultural land cover 1986, 1993 (AVHRR) • farm area/size	**Urban** • population density • population change • population distribution • road density • manufacturing
	Access • length of road • road density • road buffer • length of rail • # of airports	**Utility** • length hydro line • length pipeline • corridor density • # of generator stations • type of generation • amount of generation	**Harvest** • mammals • birds • fish
	Exotic species • # of exotic animals • # of exotic plants	**Pollution** • acidic deposition • # of discharge sites • water quality • UV index • air quality	**Extraction** • # of mines • density of mines • oil/gas potential
Environmental condition • **Measures**	**Species diversity** • # of vertebrate species • # of breeding birds	**Species at risk** • # of species listed by COSEWIC	**Fragmentation** • # of fragments by road • # of fragments (AVHRR) • average fragment size (AVHRR)
	Ecosystem diversity • # of AVHRR land cover classes • # of forest types • # of soil landscape units	**Climatic zone** • ecoclimatic zones	
Societal response • **Measures**	**Protected area** • area of government-protected areas	**Pollution reduction** (% of target reached) • land • water • air	**Ecosystem protection** • wetlands • shoreline • riparian • escarpments • floodplain

Source: adapted from Gregory Geoscience Limited and Paul C. Rump and Associates, 1996.

Appendix 5: IUCN categories of protected area: defining characteristics and typical management practices

IUCN category	Defining characteristics	Management goals or practices	Canadian example
I. Nature reserve or wilderness area			
a. Nature reserve	Possesses some outstanding or representative ecosystems, geological or physiographic features, or species	Primarily for scientific research or ecological monitoring	Oak Mountain Ecological Reserve (New Brunswick)
..b. Wilderness area	Large areas, unmodified or slightly modified, retaining their natural character and influence, without permanent or significant habitation	Preservation of natural conditions	Bay du Nord Wilderness Area (Newfoundland)
II. National park (or equivalent)	Designated to sustain the integrity of one or more ecosystems, exclude exploitation or intensive occupation, and provide a foundation for scientific, educational, recreational, and visitor opportunities, all of which must be ecologically and culturally compatible	Ecosystem protection and recreation	Pukaskwa National Park (Ontario)
III. Natural monument	Contains one or more specific natural or cultural features of outstanding or unique value because of inherent rarity, representative or aesthetic qualities, or cultural significance	Protection of specific outstanding natural features, provision of opportunities for research and education, and prevention of exploitation or occupation	Parrsboro Fossil Cliffs (Nova Scotia)
IV. Habitat/ species management areas	Areas important for ensuring the maintenance of habitats or for meeting the requirements of certain species	Securement and maintenance of habitat conditions necessary to protect species and ecosystem features where these require human manipulation for optimum management	Watshishou Migratory Bird Sanctuary (Quebec)
V. Protected landscape or seascape	Areas where interactions of people and nature have produced a distinct character with significant cultural or ecological value and often with high biodiversity	Conservation, education, recreation, and provision of natural products aimed at safeguarding the integrity of harmonious interactions of nature and culture	Kinbrook Island Provincial Park (Alberta)
VI. Managed resource protected areas	Predominantly natural areas that are large enough to absorb sustainable resource uses without harming long-term maintenance of biodiversity	Long-term protection and maintenance of biodiversity and other natural values and the promotion of sound management practices for sustainable production purposes	Battle Creek Community Pasture (Saskatchewan)

Source: After IUCN (1994); extracted from Government of Canada 1996.