USING BIOLOGICAL AND LAND USE INFORMATION TO DEVELOP INDICATORS OF HABITAT AVAILABILITY ON FARMLAND

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-- Plenary Session 2 --

Linking Wild Species With Their Use of Different Agricultural Habitats

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Using Biological and Land Use Information to Develop Indicators of Habitat Availability on Farmland

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Abstract: Agricultural policy issues and questions surrounding genetic, species and ecosystem biodiversity have risen in importance in OECD Member countries. The scientific community is being challenged to develop environmental indicators to inform and support the agricultural policy discourse concerned with biodiversity conservation issues. Recent work in Agriculture and Agri-Food Canada has lead to the construction of an agricultural indicator of the ***Availability of Wildlife Habitat on Farmland***. This approach includes a new tool – the habitat-species matrix – which allows agricultural land use data to be interpreted more directly from a natural biodiversity perspective. Canada's indicator of Wildlife Habitat on Farmland incorporates the concept of land use or cover as habitat, and recognizes that all farm land has some value as wildlife habitat. The indicator is expressed as the proportion (percentage) of habitat uses supported by an increasing, constant or decreasing land base. The approach used in Canada may be of interest to other countries. It allows changes in area of habitat to be identified and mapped, and identifies wildlife species most likely to benefit from or be adversely affected by the changes observed. There are, however, important limitations to the indicator, some of which can be overcome through further biological inventory work and refined spatial analysis of land cover changes. (Paper originally prepared for the May 1999 OECD Expert Meeting on Agricultural Landscape, Wildlife Habitat and Biodiversity Indicators, with September 2001 edits, by Agriculture and Agri-Food Canada.)

Introduction

Under the auspices of the OECD Joint Working Party on Agriculture and Environment (JWP), the OECD Secretariat and many Member countries are developing environmental indicators for agriculture (AEIs) to both inform and support the agri-environmental policy process. At a workshop held in September 1998 in York (UK), OECD countries discussed how certain AEIs might be defined and measured (OECD, 1999). Work continues through the JWP to advance the development of AEIs.

One issue for which indicators are required is agriculture's impact on wildlife habitat. This paper describes the approach used by Agriculture and Agri-Food Canada to develop an indicator of ***wildlife habitat on farmland***, as a contribution to the OECD Expert Meeting on Agro-Biodiversity Indicators (Zurich, 5-8 November 2001). The paper draws on the work of Neave Resource Management (1998a, 1998b, 1998c) supported by Agriculture and Agri-Food Canada.

1.0 Agriculture and Agri-Food Canada's Agri-Environmental Indicator Project

Agriculture and Agri-Food Canada initiated work to develop AEIs in 1993. Through a process of scientific and public consultation (see McRae and Lombardi, 1994; McRae, 1995; and Environmental Indicator Working Group, 1994), six clusters of AEIs were identified and have since been developed, as follows:

X Farm management of land, nutrients (fertilizers, manure) and pests
X Risk of water contamination from nutrients (nitrogen and phosphorous)
X Net emissions of agricultural greenhouse gases
X Availability of wildlife habitat on farmland
X Risk of soil degradation from erosion, salinization, compaction and loss of soil carbon
X Production efficiency (for nitrogen and energy).

These indicators and their sub-components share a number of features but also differ in several respects.

X They are concerned with environmental conditions and risks ***within*** the Canadian agricultural land base, and not (at this stage) with how agricultural conditions interact with non-agricultural conditions.
X For most, 1981 was chosen as the base year from which change is measured at five-year intervals: 1986, 1991 and 1996 (the most recent year for which national data are available).
X They are spatially disaggregated, from the national level to ecozones, ecoregions, ecodistricts and, at the most detailed level, soil landscape polygons. Spatial disaggregation increases the regional sensitivity of the indicators and allows areas at risk to be identified and mapped. However, some indicators are only available at the national and provincial levels of spatial detail.
X They are sensitive to farm management practices. Many were developed using regionally validated models which use data on management practices and other relevant variables (e.g. soil type, weather) as inputs.
X They are expressed in physical units appropriate to the processes of interest (e.g. tonnes of greenhouse gas equivalents emitted). No attempt has been made to aggregate the indicators into an index or to express them in equivalent units (such as monetary units).

A report on the findings and results of the Canadian work: *Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project* was released in March, 2000 (McRae et al., 2000).

2.0 Indicators of Habitat Availability Result of the York Workshop

Building on a paper prepared by Switzerland, participants at the 1998 York workshop identified three indicators related to wildlife habitat:

a) Intensively farmed agricultural habitats, defined as the share of each crop in the agricultural area;
b) Semi-natural agricultural habitats, broadly defined as farmland areas not subject to intensive farming methods;
c) Uncultivated natural habitats, defined as habitat areas (wetlands, aquatic ecosystems and natural forests) converted (lost) to agriculture.

The habitat matrix, defined as a tool to identify and relate the way in which wild species use different agricultural habitat types was later added to this list, and is now included in the OECD set of wildlife habitat indicators (see OECD, 2001, chapter on Wildlife Habitat).

Several areas requiring further work to operationalize these indicators were identified:

> "A key prerequisite before measuring these indicators may be the establishment across OECD countries of common definitions of the major habitat types defined here [...] In some cases wildlife habitat indicators overlap and/or could draw on the agricultural land cover and land use indicators [...]" (OECD, 1999).

3.0 Indicators of Habitat Availability: Agriculture and Agri-Food Canada's Approach
The Indicator of Wildlife Habitat on Farmland builds on the York workshop approach by:

a) incorporating the concept of land use or cover as habitat, and
b) recognizing that all farm land has some value as wildlife habitat.

The AAFC approach differs from the York approach in that:

a) it explicitly incorporates information on how various vertebrate species use farmland to meet their habitat needs,
b) the indicator is expressed as the proportion (percentage) of habitat uses supported by an increasing, constant or decreasing land base (and not as areal change in agricultural land use),
c) the analysis is restricted to habitat change occurring within the agricultural land base only (and not with changes between agriculture and other land uses).

The concepts and methods used to develop this indicator are explained in detail in Neave Resource Management (1998a; 1998b; 1998c). What follows is a brief summary.

3.1 Linking agricultural habitat to species uses of habitats
To construct the indicator, it was necessary to identify how different species use various agricultural habitats. To accomplish this, *habitat suitability matrices* were developed individually for the seven main Ecozones in which agriculture is practised in Canada. These matrices identify wildlife species (birds, mammals, amphibians, and reptiles, with invertebrates excluded at this stage) and the specific uses each makes of agricultural land and adjacent habitats. Each "habitat use" was ranked according to how dependent a species is on a certain habitat for this use. *Primary* use means that a species is dependent on, or strongly prefers, a certain type of habitat (equivalent to the concept of *critical habitat*). *Secondary* use means that a species uses a habitat type (e.g., to obtain food) but is not totally dependent on that type. Matrices for the seven Ecozones were constructed using information from written sources and from wildlife and agricultural experts. An example matrix is included in Annex 1 for Canada's Prairie Ecozone.

3.2 Calculating the Habitat Availability on Farmland Indicator Once the matrices were completed, primary and secondary habitat-use entries were separately summed for five main use categories:

Xbreeding, nesting, and reproduction
Xfeeding and foraging
Xcover, resting, roosting, basking, and loafing
Xwintering
Xstaging (for birds only).

Each separate use of a habitat type by a species was recorded as one *habitat-use unit* (i.e., not the number of species using a habitat type, but the number of individual ways in which a habitat is used, for example, Mallard feeding, Mallard nesting, and Mallard loafing equals three habitat use units).

Habitat-use units were then summed by habitat type for each ecozone. The habitat types correspond to the five main land-use categories defined in the 1996 *Census of Agriculture*, which are:

XCropland (land on which field crops are grown (e.g. grains, oilseeds, fruits, nuts, vegetables, tame hay.
XSummerfallow (cultivated land not cropped for one growing season but part of the crop rotation)
XTame or Seeded Pasture (land that has been cultivated and seeded, usually to introduced forage species / may be fertilized, irrigated, drained.
XNatural Land for Pasture (native pasture land, native hay, grazeable bush
XAll Other Land (land under farm buildings, greenhouses, windbreaks, wetlands, woodlots, and idle land.

As an example, Table 1 below provides a summary of combined primary and secondary habitat use of agricultural habitat types by wildlife species in the Prairie Ecozone, and changes in the area of each habitat type between 1981 and 1996.

The habitat use unit data in Table 1 are derived from the habitat suitability matrix developed for the Prairie ecozone and land use data obtained from the Census of Agriculture. The Table clearly shows that the "All Other Agricultural Land" and "Natural Land for Pasture" habitat types support the greatest number of habitat uses and are the most valuable forms of agricultural habitat in this ecozone (which is also the case in other ecozones).

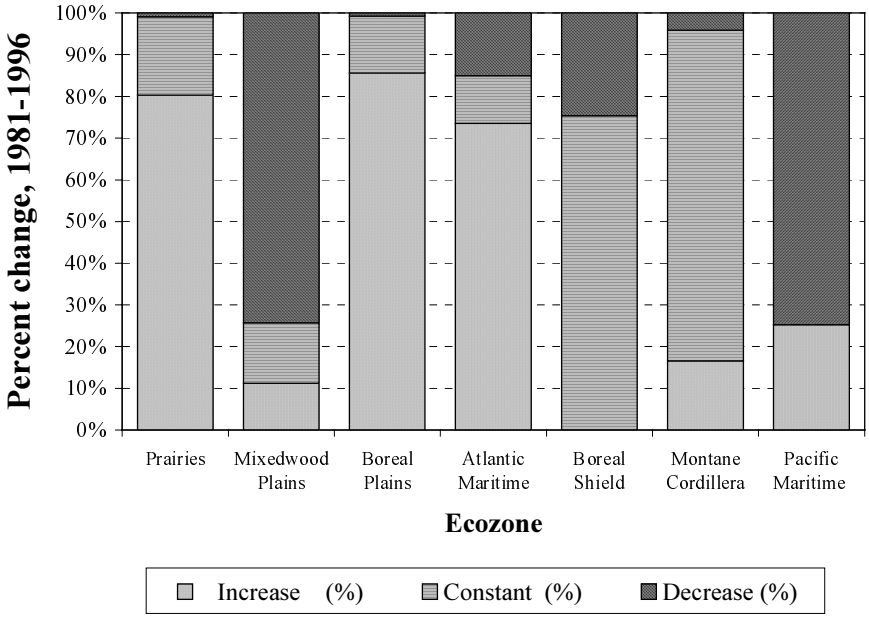
From Table 1, the Availability of Wildlife Habitat on Farmland Indicator can easily be calculated for the Prairie ecozone showing that, between 1981 and 1996, 80% of the habitat uses were supported by an increasing agricultural land base whereas the land base declined or remained constant for 20% of the habitat uses. Overall, the data are interpreted as a positive trend for wildlife habitat in this Ecozone.

Table 1. Summary of combined primary and secondary use of agricultural habitat types in the Prairie ecozone, and change in area of habitat type, 1981-1996.

Habitat type	*Total habitat use units*	*Habitat type area (million ha)*			*% change from 1981*	*Trend*
		1981	*1991*	*1996*		
Cropland	664	18.76	20.86	21.95	16.9	Increase
Summerfallow	34	8.22	6.99	5.51	- 33.0	Decrease
Tame or seeded pasture	161	1.99	1.98	2.25	13.2	Increase
Natural land for pasture	727	10.79	10.57	10.16	- 3.9	Constant
All other agricultural land	2279	0.81	1.71	1.99	16.1	Increase

Matrices and tables were constructed for each of seven ecozones in which agriculture is practised. The results of the indicator are displayed nationally in Figure 1, which shows trends in the indicator between 1981 and 1996 land use conditions.

Figure 1. Share of habitat use units for which habitat area increased, decreased, or remained constant between 1981 and 1996



4.0 Analysis of the Habitat Availability on Farmland Indicator

4.1 Relationship to OECD criteria

The OECD has suggested that to be useful, indicators must be policy relevant, analytically sound, and measurable (OECD, 1997). This section of the paper reviews the AAFC habitat indicator against these criteria.

Policy Relevance

To be relevant to policy, a habitat indicator should (among other things) be able to identify trends in whether habitat is increasing or decreasing over time, identify areas where critical habitats are threatened, and provide a link to the species making use of agricultural habitats. We believe the proposed indicator meets these criteria.

As demonstrated in Figure 1, trends over time are readily calculated using land-use change data. Areas of different habitat types, and changes in those areas, can be mapped thereby allowing policy efforts to target both valuable and/or vulnerable areas. Policy relevance is further enhanced because, through the habitat-species

matrices, changes in habitat over time can be directly linked to the species making use of these habitats. In this way, species that may be affected by changes in land use and habitat can be identified, including species at risk.

Analytical Soundness
The robustness of the indicator is a function of the accuracy of the agricultural land use data used in its calculation, and an understanding of how species use agricultural land. The land use data are obtained through Statistics Canada's national Census of Agriculture. This census covers all farms every five years, is spatially detailed, undergoes extensive testing with respondents prior to its distribution to farmers, and is validated prior to publication. The matrices are based on the biological and ecological literature and on interviews and consultations with field biologists and agrologists across Canada.

Because of the link to land use, the indicator can readily be linked to models which forecast agricultural land use trends. Economic valuation of habitat is also possible, at least for those species and habitat types around which economic activity is organized (such as hunting, birdwatching, wildlife viewing etc).

Measurability
The indicator is readily measurable in countries which collect agricultural land use data and for which information exists on how various species use agricultural land to meet their habitat requirements. The habitat-ecozone matrices represented the bulk of the work required to develop this indicator. No new field research was carried out but a considerable effort to obtain and collate this information was required. However, this largely represents a one-time effort (with potential for fine-tuning by experts over time). Mechanisms to collect national agricultural land use statistics every five years are already in place.

4.2 Limitations
Notwithstanding the above points, there are several key limitations to this approach:

a) Because the indicator records only information about the absence or presence of certain habitat uses, it does not reveal much about habitat quality. An effort was made to factor in habitat quality by dividing habitat types (e.g., Cropland, Natural Land for Pasture, and All Other Land) into finer categories that may have different value for different species. However, the great variation in quality across the five main habitat types shows the difficulty in using census data for habitat studies. In particular, accuracy and quality would improve if a way of disaggregating the "All Other Land" category, which is very coarse, can be found. For e.g. the present analysis may overestimate the value of the All Other Land type because of the inclusion of wetlands and woodlands whereas actual areal extent of wetlands and woodlands cannot presently be obtained from the Census of Agriculture data..

b) Related to this, the indicator does not consider how successful a habitat use is. Success of use is sometimes reflected in the ranking system (e.g., for mallard nesting, a primary ranking was used for habitats where nesting success is considered higher and a secondary ranking for habitats with lower nesting success). This information was often available for waterfowl, but rarely for other species. Thus, even if the area of a certain type of wildlife habitat in agricultural settings grows, that habitat may not be of sufficient quality to support wildlife populations that can replace themselves by successful reproduction. In addition the present analysis is constrained because it gives equal weight to a Primary habitat use unit and a Secondary habitat use unit.

c) The indicator does not examine the effects of various agricultural land-management practices. The effects

on habitat use of practices such as tillage and weed-control have, however, been studied. Using the broad land-use categories also does not account for biological factors that may limit a species' use of a particular habitat type. For example, a species may not be able to use a habitat type where one need may be met (e.g., food) while other needs are not (e.g., water, cover); also the habitat may be too fragmented, there may be behavioural barriers to use, or the species may be too widely dispersed.

e) The habitat-species matrices would be enhanced with inclusion of Invertebrate, fish and endemic plant species.

Conclusions

Agricultural policy issues and questions surrounding genetic, species and ecosystem biodiversity have risen in importance in OECD Member countries, many of which have now signed the United Nations Convention on Biological Diversity. The scientific community is being challenged to develop environmental indicators to inform and support the agricultural policy discourse concerned with biodiversity conservation issues.

The development of biodiversity indicators for agriculture poses a particular challenge. Unlike other resource issues for which considerable research has been conducted (such as soil and water quality), the development of biodiversity indicators is hampered by several factors, including the lack of rigorous analytical frameworks and models, incomplete understanding of biological processes in agroecosystems and often sparse biological inventory data. Habitat is one aspect of biodiversity being considered by the JWP, and conceptual work undertaken to date has identified changes in agricultural land use as a proxy indicator of habitat change. However, this approach is limited in that there is no specific linkage made to how various species use agricultural lands to meet their habitat needs.

Recent work in AAFC in concert with Canadian biologists has lead to the construction of an agricultural indicator of habitat, the ***Availability of Wildlife Habitat on Farmland*** indicator. This approach builds on the JWP proposal but includes a new tool – the habitat-species matrix – which allows agricultural land use data to be interpreted more directly from a natural biodiversity perspective.

The approach used for this indicator may be of interest to other OECD countries. It allows changes in area of habitat to be identified and mapped, and identifies wildlife species most likely to benefit from or be adversely affected by the changes observed. The proposed indicator is readily developed from standard agricultural land use data likely available in most Member countries. It is expected that the development of habitat-species matrices will represent the bulk of additional work required to operationalize this indicator elsewhere. There are, however, important limitations to the indicator, some of which can be overcome through further biological inventory work and refined spatial analysis of land cover changes.

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Annex 1: Agricultural Habitat-Species Matrix for the Prairie Ecozone

Matrix Development

Habitat types:

The Census of Agriculture database from Statistics Canada is the key national source of information for documenting areas of different land cover. Habitat types have been assembled around this database. The Census provides information for 5 main land cover types:

a) Cropland: subdivided into crop types
b) Summerfallow
c) Tame or Seeded Pasture
d) Natural Land for Pasture
e) All other land

These 5 main types are too general for the needs of this project, so we have subdivided some categories into habitat types, distinguished both by species on the ground and by wildlife managers in the field as follows:

1. Cropland
   - any crop whose area is greater than 1 % of total farm area for the ecozone will be considered as a separate habitat type
   - crops that are less than 1 % of total farm area will be grouped into other categories such as:
     - other grains
     - other oilseeds
     - other crops
     - fruits and vegetables
2. Summerfallow:
3. Tame or Seeded Pasture:
4. Natural Land for Pasture:
   - natural land for pasture will be broken into 2 categories:
     A. Natural grassland
     B. Pasture with shrubs/ woodland. In the Prairie and the Montane Cordillera Ecozones, this category will be sagebrush/ shrubs.

5. All other Land: All other land is defined as a variety of potential habitat types including farm buildings, barnyards, lands, gardens, greenhouses, mushroom houses, idle land, woodlots, sugar bushes, tree windbreaks, bogs, marshes, sloughs, etc. This category will be broken into a number of habitat types in the matrix:

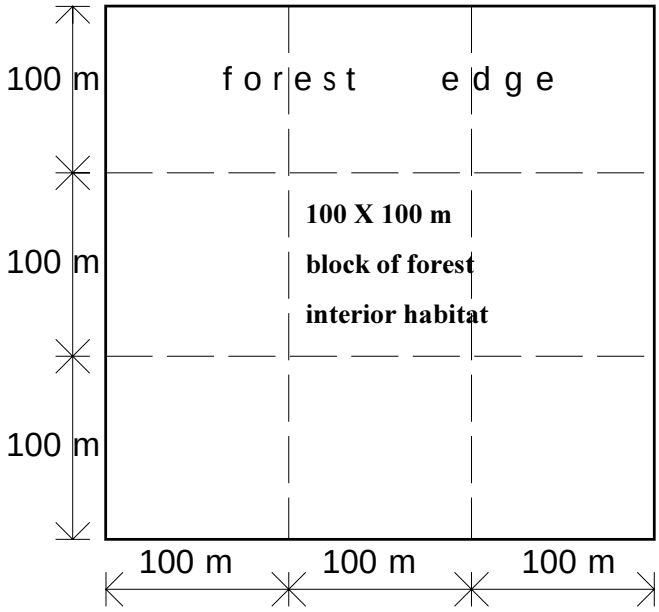
   A. Farm houses and outbuildings: this category represents on average 2 % of total farmland (farm buildings, barnyards, lanes, gardens, greenhouses, mushroom houses, feedlots)
   B. Shelterbelts/ fencerows/ ditches: with distinction between shelterbelts/ fencerows/ ditches with and without trees
   C. Wetlands: with distinction between:

a) riparian areas
b) shallow seasonal ponds with extensive margins
c) shallow seasonal ponds without extensive margins
d) deep permanent ponds with extensive margins
e) deep permanent ponds without extensive margins

D. Woodland: with distinction between:
a) plantations
b) woodlot with interior habitat
c) woodlot without interior habitat

Woodland interior habitat is that habitat which falls at least 100 m from the edge of a woodlot. This definition was frequently used by the Ontario Ministry of Natural Resources when discussing forest fragmentation and planning reform. For a forest to have interior habitat, it must be a minimum size (see Figure A1). Based on the 100 m edge definition this translates to approximately 300 m X 300 m (9 ha or 22 acres).

Figure A1. Diagram of interior habitat with a 100 m edge.



Species

When developing species lists for the matrices for each of the 7 ecozones, the focus was on species that used agricultural land and adjacent habitats to meet one or more specific habitat requirement. For example, the Common Loon was not included in any species list although it is found in every ecozone (except the southern prairies) as its habitat needs did not overlap with the agricultural land base. Similarly

the American Pika was not included in the Montane Cordillera Ecozone, as it is only associated with talus slopes and rock debris, not with agricultural land.

Birds: Preliminary species lists were developed for each ecozone using □The Birds of Canada□ (Godfrey 1966) range maps. These lists were updated with more current reference material such as the Birds of North America journal series and expert opinion.

Mammals: Preliminary species lists were developed from the National Audubon Society□s Field Guide to North American Mammals (Whitaker 1996) and updated with additional reference material such as the American Society of Mammologist□s Mammalian Species series.

Amphibians and Reptiles: Preliminary species lists were developed from the National Audubon Society□s Field Guide to North American Reptiles and Amphibians (Behler and King 1996) and updated with additional reference material.

Defining Habitat Uses

Habitat types are used by species for a variety of purposes. The following habitat uses were distinguished for each habitat type:

For birds:
R= use of habitat for breeding/ nesting/ reproduction
F= use of habitat for feeding/ foraging
L= use of habitat for roosting/ loafing/ resting
C= use of habitat for escape/ cover
W= winter use of habitat
S= use of habitat for staging

For mammals:
R= reproductive needs
F=use of habitat for feeding/ foraging
C= use of habitat escape/ cover
W= winter use of habitat

For amphibians
R= reproductive needs
F= use of habitat for feeding/ foraging
C= use of habitat for escape/ cover
W= winter use of habitat

For reptiles:
R= reproductive needs
F= use of habitat for feeding/ foraging
L= basking/loafing
C= use of habitat for escape/ cover
W= winter use of habitat

Ranking of Habitat Use

In addition to identifying habitat types and uses, it is also important to distinguish the level of use of a habitat by individual species. We used a 5 level ranking system in the matrices defined as follows:

Primary (1): Equivalent to critical habitat, without this habitat the species cannot use the area. Examples of this level of habitat use by species includes: nesting habitat (heron rookeries), deer yards for overwintering and staging areas. Strongly preferred habitats are also identified by this category.

Secondary (2): Often species can use several habitat types for the same purpose. For example, deer can feed in alfalfa, corn, soybeans and pasture and are frequently observed in these habitat types. Deer require some feeding habitat, but not all of these types, the individual type is not critical. Heavily favoured habitat types will still retain the primary rating.

Tertiary (3): This is a level of habitat use where the habitat type is not needed by the species, but it is occasionally observed in the habitat. That is, the habitat type might still be used, but its presence/ absence has no influence on the species being present in an area. For example, the grasshopper sparrow and bobolink occasionally use shelterbelts for nesting. Grasshopper sparrows usually nest in native grassland or pasture, and the presence of shelterbelts in an area has little/ no impact on their populations.

Blank: species is typically not found in this habitat

X: the species actively avoids this habitat

Table A1. Summary of Primary Use of selected agricultural habitat types by species for the Prairie Ecozone

Habitat type	Number of habitat use units per habitat type						Area in habitat type			% change Increase*	
	B	F	L	W	S	Total	1981	1991	1996	From 1981	Decrease Constant
							Millions of ha				
Cropland											
General Use	3	23	10	7	2	45	**18.8**	**20.9**	**21.9**	**+16.9%**	**Increase**
Spring Wheat	3	13	3	2	5	26					
Durum Wheat	2	14	3	2	5	26					
Oats	2	11	3	2	7	25					
Barley	2	12	3	2	5	24					
Winter Clover / Corn	4	14	4	2	8	32					
Canola	0	3	0	0	0	3					
Other Oilseeds	0	10	1	1	2	14					
Alfalfa	7	20	13	1	2	43					
Tame Hay	10	24	18	2	2	56					
Other Crops	0	4	0	0	0	4					
Fruits and Vegetables	9	12	6	1	0	28					
						(326)					
Summerfallow	0	4	1	1	0	6	**8.22**	**6.99**	**5.51**	**-33%**	**Decrease**
Tame or Seeded Pasture	21	38	26	12	3	100	**1.99**	**1.98**	**2.25**	**+13.2%**	**Increase**
Natural Land for Pasture							**10.79**	**10.57**	**10.16**	**-3.9%****	**Constant**
Natural Grassland	65	86	69	38	3	261					
Shrubs / woodland	71	90	78	39	3	281					
						(542)					
All other land							**.81**	**1.71**	**1.99**	**+16.1%****	**Increase**
Houses / Outbuildings	10	13	12	9	0	44					
Woodland											
Plantation	9	8	8	4	0	29					
Woodlot with interior	98	97	103	46	1	345					
Woodlot without interior	100	101	104	47	1	353					
Shelterberts/Fencerpws											
Treed	45	51	48	12	1	157					
Grass	12	24	22	9	0	67					
Wetlands											
Riparian	75	98	87	33	0	293					
Shallow with margins	61	80	59	16	4	220					
Shallow without margins	15	43	27	4	2	91					
Deep with margins	41	64	46	9	6	156					
Deep without margins	6	28	19	1	5	59					
						(1814)					
Total						**(2788)**	**40.57**	**42.11**	**41.86**		

* Greater than +5% change constitutes an increase, and less than –5% a decrease; from –5 to 5% is defined as constant

** Percent change is based on 1991 for *Natural Land for Pasture* and *All Other Land* due to the change in Census definitions associated with these land cover types from 1986-1991

Habitat type	Arctic Shrew				Masked Shrew				Pygmy Shrew				Northern Shorttailed Shrew				<...>
	r	f	c	w	r	f	c	w	r	f	c	w	r	f	c	w	
Cropland																	
General Use																	
Spring Wheat																	
Durum Wheat																	
Oats																	
Barley																	
Winter Clover / Corn																	
Canola																	
Other Oilseeds																	
Alfalfa																	
Tame Hay	1	1	1	1	1	2	2						2	2	2		
Other Crops																	
Fruits and Vegetables																	
Summerfallow																	
Tame or Seeded Pasture	**1**	**1**	**1**	**1**	**1**	**2**	**2**						**2**	**2**	**2**	**2**	
Natural Land for Pasture																	
Natural Grassland	1	1	1	1	1	1	1	2	1	1	1	1	2	2	2	2	
Shrubs / woodland					1	1	1	2	1	1	1	1	2	2	2	2	
All other land																	
Houses / Outbuildings																	
Woodland																	
Plantation																	
Woodlot with interior					1	1	1	1	1	1	1	1	1	1	1	1	
Woodlot without interior					1	1	1	1	1	1	1	1	1	1	1	1	
Shelterberts/Fencerpws																	
Treed					1	1	1	1									
Grass					1	1	1	1	1	1	1						
Wetlands																	
Riparian					1	1	1	1	1	1	1	1	1	1	1	1	
Shallow with margins	1	1	1	1	1	1	1		1	1	1	1					
Shallow without margins																	
Deep with margins	1	1	1	1	1	1	1		1	1	1	1					
Deep without margins																	
NOTES	Christian et al. 1997 Whitaker 1996 VanZyll and DeJong 1983 Banfield 1974				Kirkland 1997 Peterson 1991 Christian et al. 1997 Whitaker 1996 Yahner 1983 VanZyll and DeJong 1983 Banfield 1974				Churchfield 1997 Whitaker 1996 Long 1974 –bog margins and uplands –habitat varies seasonally				Christian et al. 1997 Kaufman et al 1990 Yahner 1983 George and Choate 1986				

Only a small sample is presented here. The same type of information was generated for the whole matrix, which contains all mammals (53sp), birds (189sp) and reptilians (25sp) that are present in the Ecozone.

<...>