AGRI-ENVIRONMENTAL INDICATOR PROJECT

Agriculture and Agri-Food Canada

REPORT NO. 26

AGROECOSYSTEM BIODIVERSITY INDICATOR: HABITAT COMPONENT

Review and Assessment of Concepts and Indicators of Wildlife Habitat and Habitat Availability in the Agricultural Landscape: Concept Paper

Prepared for the Prairie Farm Rehabilitation Administration
and the Agri-Environmental Indicator Project
Agriculture and Agri-Food Canada

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PREFACE

The Agri-Environmental Indicator Project of Agriculture and Agri-Food Canada was initiated in 1993 in response to recommendations made by several agencies, organizations and special studies. The overall objective of the project is to develop and provide information to help integrate environmental considerations into decision-making processes of the agri-food sector.

A core set of regionally-sensitive national indicators is being developed that builds on and will enhance the information base currently available on environmental conditions and trends related to primary agriculture in Canada. The habitat availability component of the Agroecosystem Biodiversity indicator is an important part of the set of agri-environmental indicators. Indicators are also being developed in relation to issues of farm resource management, soil and water quality, greenhouse gas emissions and agricultural production efficiency.

Research results in the form of discussion papers, scientific articles and progress reports are released periodically. A comprehensive report to be prepared in 1999 will provide an overall assessment of agri-environmental sustainability as revealed by the indicators.

This paper investigates possible approaches to developing indicators of habitat availability in agroecosystems in Canada. Comments and questions should be addressed to:

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Executive Summary

The habitat component of the proposed "Agroecosystem Biodiversity Change" indicator is being developed under the Agri-Environmental Indicator (AEI) Project of Agriculture and Agri-Food Canada. Six environmental indicators are being developed to: assess the degree to which agri-environmental issues are being addressed and objectives met; identify areas and resources at risk; support the design and targeting of strategies and actions and facilitate communications among and between stakeholders and policy makers. The wildlife habitat concept paper reviews concepts, definitions, assumptions, frameworks and methodologies; and it recommends potential approaches for developing habitat indicators.

Two potential approaches are outlined, a landscape approach and a species approach:

- The landscape approach involves identifying broad land cover classes such as cropland, windbreaks, wetlands, woodland and grassland which are proxies for habitat types. However the question arises, what species are these cover types providing habitat for? A process is outlined for identifying the species inhabiting certain cover type classes.

- The species approach involves carefully selecting species whose numbers closely reflect changes in the quality and/or quantity of their habitat. Species numbers could be tracked as a potential indicator of this change.

Fourteen types of indicators developed by other organizations are assessed for potential use by the AEI Project. Based on the criteria used, two of the fourteen, "trends in habitat degradation" and "trends in the abundance or occurrence of a species"are rated as having "high" suitability for the AEI Project.

Four habitat assessment and modelling tools are assessed for their potential for developing indicators including: The Gap Analysis Program (GAP), Habitat Mapping, the Cowardin (Mallard) Model and Habitat Suitability Index (HSI) Models. Analysis of these tools for potential indicators shows that Gap analysis could provide information on percentage of community types protected, species rich areas and habitat fragmentation. Habitat Mapping could provide maps of potential habitat which could be used as proxies for the former habitat of many species. The Mallard Model has limited application because it is presently targetted to waterfowl applications. HSI models offer direct linkage between habitat and various wildlife species, however, there have been very few species assessed in Canada.

Four frameworks are considered to develop a series of indicators of agro-ecosystem habitat availability. These were the Framework for Evaluating Sustainable Land Management (FESLM), the Pressure - State - Response Framework, the Lake Superior Ecosystem Health Indicator Framework, and the Sensitive Species Habitat Framework. The Framework for Evaluating Sustainable Land Management is recommended for use because it:

- provides for a statement of objectives and purpose;
- provides for the development of cause-effect relationships;
- identifies potential indicators for all five pillars of sustainable land management, all of which are equally important in a system's sustainability.

Twenty-five personal interviews were conducted with wildlife and agriculture experts from across Canada. These interviews examined opinion on the definition of habitat, critical issues affecting habitat availability in agricultural landscapes, available databases and various approaches to develop habitat indicators.

An annotated bibliography was produced which documents literature available on: the concept of environmental indicators, definitions of habitat and habitat availability, habitat indicator options and databases for potential use.

The next steps in developing habitat indicator(s) are to pursue a habitat approach (not a species approach) to:

1. Develop a habitat-species suitability matrix for the Prairies, and for other Canadian ecozones containing agricultural land. These matrices will address which habitat types (land cover/land use) are suitable for selected wildlife species or species groups. This will help validate the monitoring of land cover (habitat types) as an indicator.

2. Develop selected recommended Habitat Indicators using the Framework for Evaluating Sustainable Land Management.

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I. Introduction:

Sustainable agriculture is a long term vision and its aims are:

- to produce an economically viable crop while conserving the long and short term integrity of the local, regional and global environment (Paul and Robertson 1989).

Conserving the environment includes protecting water, soil, wildlife habitat and biodiversity and genetic resources. It also includes limiting waste and pollution, adapting to climate change and enhancing energy efficiency and diversity.

The Agri-Environmental Indicator Project of Agriculture and Agri-Food Canada was initiated to monitor the impact of Canadian agriculture on the environment. One area where indicators will be developed is for wildlife habitat and habitat availability in the agricultural landscape. Other organizations have also identified the need for habitat indicators including: Wildlife Habitat Canada (Lynch *et al.* 1997), Wildlife Management Institute (McKenzie *et al.* 1995) and the United States Department of Agriculture (1996). Indicators will provide direction for policy and decision makers, and will also highlight areas of concern which can be addressed by new initiatives.

The Habitat Indicator: Where does it fit in?

Agricultural development has modified natural ecosystems in Canada. Many of the extensive areas of prime agricultural land are also prime habitat for wildlife species presenting conflicting needs for the land base (D. Neave, Wildlife Habitat Canada, interview). Although we cannot ignore agricultural land needs, we also cannot afford to ignore the needs of the diverse flora and fauna native to these regions. Wildlife plays a critical role in the sustainability of these systems as they are critical links to overall ecosystem function including processes such as nutrient cycling, decomposition and the maintenance of water quality (Crossley *et al.* 1989).

Wildlife populations and their habitat are directly impacted by agricultural practices, are often the first to illustrate subtle changes in land use patterns, and can serve as an early warning signal that an ecosystem is under stress. For example, some arctic species concentrate pollutants which have originated in the south, and have served as an early warning of long range transport of pollutants (High *et al.* 1991). Wildlife diversity is very dependent on the quality of habitat. As a result, species that have very specific habitat needs may be sensitive indicators of change.

Habitat and environment are somewhat synonymous, they are both the place where organisms live. Because of this similarity, other indicators developed for the Agri-Environmental Indicator (AEI) Project may also reflect habitat quality. Related indicators should be integrated into the habitat component where appropriate, providing an opportunity to link components of the AEI project as a whole.

The complexity of habitat, ecosystems and biodiversity has slowed the development of potential indicators in the habitat/biodiversity areas. This paper reviews many of the concepts, definitions, assumptions, frameworks and methodological approaches to the development of habitat indicators. An annotated bibliography relating to these topics is also available. Options and recommendations on how to approach the development of habitat indicators are identified.

II. Habitat

A. What is wildlife?

Wildlife for the purpose of this report is defined as all wild organisms ranging from single celled organisms, to plants and vertebrates (Wildlife Minister's Council of Canada 1990).

B. What is wildlife habitat?

Wildlife habitat is defined as the food, water, cover and home range (space) requirements for an individual species. Sufficient amounts of these resources must be available across space and over time. Habitat must also provide for special needs such as reproduction and dispersal (Morrison *et al.* 1992).

This definition is accurate yet very simplistic. There are some problems with its application in an operational context for individual species including:

- the lack of defined measurable habitat goals or objectives for most species
- habitat for different contexts e.g. definitions: geographical (species range), functional (critical habitat components), ecosystems (land classification or land cover types) (C. Caza, Wildlife Habitat Canada, interview).

Even in historical times, fire, succession and other agents of change created a patchy habitat mosaic. As a result of human settlement and cultivation of land for agriculture, this patchiness of the landscape has increased. In the Prairies, grasslands have been converted to croplands, hay and pasture, and in Eastern Canada meadow and forest have been similarly converted. On the Prairies, native habitat conversion has been substantial. It is estimated that less than 13% of shortgrass prairie, 19% of mixed grass prairie, 1% of tallgrass prairie and 16% of the aspen parkland remain in their native state in the prairie provinces (Biodiversity Science Assessment Team 1994). In southwestern Ontario, forest cover has decreased to 4% in Essex county (S. Weaver, interview).

Some species are able to thrive where native habitat has been replaced by agricultural habitat. But for many species, cropland and intensively grazed pasture is lower quality habitat, and these species have become dependent on the remnants of natural or semi-natural habitats.

C. What is wildlife habitat availability?

Species may use different portions of the landscape to acquire their range of resource needs. Their ability to access all needs is the concept of habitat availability. Availability of habitat to a specific species is determined by:

- Patchiness of the landscape: Natural landscapes are patchy by nature, and most species use different patches to meet different resource needs over time. These patches will change through time in their ability to provide resource needs. Differences in quality of habitat patches and their landscape position determine species survival and distribution (Kozakiewicz 1995). Agroecosystems are often very patchy, and this often limits species viability.

Access/Connectance: Certain landscape features may act as physical or behavioural barriers or may make the species vulnerable to predation. All resource needs must be accessible to a species for it to survive in an area (Kozakiewicz 1995).

Seasonal needs: Some species require specific breeding areas or wintering habitat. If these habitats are absent, populations will decline (Kozakiewicz 1995).

Occurrence of competitors, predators and disease. Competition can be a major factor affecting the use of habitat by some bird species. For example, the red-shouldered hawk being a much smaller bird than the red-tailed hawk is unable to compete for nesting habitat. Hence, it is only able to nest in the interior of large woodlots, away from the red-tailed hawk which typically nests at the forest edge. With increased fragmentation and cropping intensity in southwestern Ontario, few large woodlots with interior habitats remain. As a result, few red-shouldered hawks nest in the area.

Increased patchiness and decreased connectance are symptoms of habitat fragmentation. Fragmentation decreases habitat quality and availability for many species by isolating their habitat needs. Fragmentation can also isolate populations, possibly leading to local extinctions (Merriam *et al.*1993). Habitat fragmentation can also benefit some species, particularly those that depend on edge. These species are often numerous in agricultural landscapes, often benefiting at the expense of other species. For example, forest interior nesting species may not reproduce successfully if forest patches are too small, resulting in competition, nest predation, brood parasitism (Biodiversity Science Assessment Team 1994).

There are two factors of concern for wildlife habitat conservation in the agricultural landscape: quality of habitat and quantity of habitat. These two factors underlie all wildlife habitat conservation issues. Because all land is habitat for something (bacteria, fungi, etc.) the quantity issue is not as important as quality for many species. For example, food is rarely limiting in agroecosystems, whereas cover and nesting habitat are. These features are often critical habitat components, and the quality of the agricultural landscape as habitat is often determined the abundance of these features.

The breeding summer range of the Northern Pintail (*Anus acuta*) on the prairies is an example illustrating many of these issues. The pintail prefers to nest in the mixed grassland and shortgrass prairie, in areas typical to Southern Saskatchewan and southeast Alberta. In some years however, there is not enough moisture to create the wetland areas it requires for brood survival. Although all other habitat resources are available, the pintail moves on to the boreal forest zone of northern Canada in these years. This is still waterfowl habitat, however food availability is lower in these areas for pintails and their productivity is often reduced (D. Chekay, Ducks Unlimited interview).

D. Habitat for what?

It is relatively easy to apply the habitat definition to one species and to identify habitat needs, acknowledging the previously mentioned limitations. However there are too many species to consider the habitat requirements of each individually. It is also very difficult to summarize habitat for a range of species because of the tremendous variation in scale. Habitat can range in scale from a film of water around a soil particle for soil bacteria and protozoa, to intercontinental migration ranges. Habitat needs also vary seasonally for many species, increasing this complexity.

To complicate the issue, when all known species are considered, everything becomes habitat. Bacteria and fungi live everywhere. **It is safe to say that every component of the agro-ecosystem is habitat for some organism**. In the consideration of agro-ecosystems, the question is therefore not one of what is habitat, but rather habitat for what?

Because of the large number of species using the agricultural landscape, it would be impractical to measure and manage for habitat requirements for all species. However there are at least **two other options to assess habitat quality and quantity**:

1. Landscape level:

In a landscape approach, the first step is to break up the landscape into land cover types. The agricultural landscape can be broken into recognizable land cover types such as: cropland, woodland, wetland, etc. **These land cover types are proxies for habitat types**. It is much easier to monitor/ assess long term trends in the availability of these land cover types than to consider a large number of specific habitat requirements. It is also easier to assess the impact of agricultural management practices on these land cover types than it is to habitats of individual species. There is also much more data available for this approach.

There can be tremendous variation in the habitat quality of these broad types: cropland, pasture, unimproved land, shelterbelts, woodlands, and wetlands. For example, a shelterbelt with only one tree species, such as Norway spruce, is not as high quality a habitat as a shelterbelt with a variety of tree species, shrubs and undergrowth. Another example is wetland depth. Deep water is a feature that duck species such as redheads and canvasbacks require, so shallow wetlands are not good quality habitat for these species. Width of field margins around a wetland can also determine the quality of otherwise similar wetlands for some nesting birds. It therefore becomes difficult to have just one category. Different classes (or qualities) must be considered (Table 1).

Table 1. Land cover/habitat types and potential classes based on variation in quality.
(See also Table 2: Habitat Suitability Matrix)

Land cover/ habitat type	**Variation in quality**
Cropland/ Summerfallow	- conventional tillage - conservation tillage - permanent cover (winter wheat, legume crop rotations)
Summerfallow	- conventional tillage - conservation tillage
Grassland/ Rangeland	- improved or seeded pasture/ forage/ hay - unimproved or native pasture/ forage/ hay - unimproved land (abandoned fields, field margins, steep slopes)
Shelterbelts/ Fencerows	- single species and single row - diverse/ native multi-row or block plantings
Woodland	- plantation - woodlot/ native bluffs
Wetlands	- shallow temporary ponds with extensive margins (a) - shallow temporary ponds without extensive margins (b) - deep permanent ponds with extensive margins © - deep permanent ponds without extensive margins (d)
Riparian System	- streams and banks, shorelines, ponds, lakes, rivers

The next question is how do these land cover types relate to habitat quality? What types of species rely on/ utilize these land cover types/ habitat types? An extensive literature review has not been conducted relating species to land cover types but **it is recommended that a Habitat Suitability Matrix be constructed for: a) the prairies and b) southern Ontario and Quebec as a minimum (example in Appendix I)**. Species using multiple habitats (e.g. white-tailed deer) can also be identified in a habitat suitability matrix. A potential format is outlined in Table 2.

The habitat suitability matrix could be extremely valuable in developing habitat indicators. Changes in land use could be more easily linked to species. For example increases in the proportion of cropland in conservation tillage could be an indicator of increased habitat for certain species. A lot of the information required to construct a matrix of this type is available in the literature, particularly for bird species. A literature review could be done, and then the matrix could be submitted for expert review and input. This type of matrix could be of use to both agriculture and wildlife managers.

Table 2. Habitat suitability matrix for agricultural landscapes (potentially by Ecozone).

Habitat type→	Cropland			Summer-fallow		Grassland/ Rangeland			Shelterbelts		Woodland		Riparian	Wetland				**
Species* ↘	Con v till	Cons till	Perm cover	Con v till	Cons till	improved or seeded	unimproved or native	rangeland	1 spp	diverse multi-row	woodlot	plantation		a	b	c	d	
Mammal species - - - -																		
Bird species - - - -																		
Amphibians / Reptiles																		
Selected invertebrate s (earthworms carabid beetles?)																		

* animals deemed to be agro-ecosystem dependent at some time in their life cycle and present in the Ecozone
** final column would be for specific habitat considerations not included in the land cover types listed

The landscape/land cover type approach is a coarse filter strategy wherein it is assumed that if a representative group of habitats is maintained, then all or most species will be maintained (Biodiversity Science Assessment Team 1994). This may hold true for common or abundant species, however **species which are threatened or endangered should not be covered by this approach**. In many cases, monitoring and management plans already exist for those species.

2. Select species as indicators of habitat change

Some species have specific habitat needs that are impacted by agriculture. The populations of these species may be suitable as indicators of change in habitat quality or quantity. **To be a suitable indicator species, there must be a strong link between population numbers and agricultural practices**. If other influences are too strong, change in populations will not accurately reflect management practices.

Some criteria for the choice of indicator species are:

- response to change in management practice must be rapid (Debinski and Broussard 1990)
- group must be present in both diversity and abundance in the geographical area of interest (Kremen *et al.* 1993; Debinski and Broussard 1990)
- politically salable (Debinski and Broussard 1990)
- amenable to sampling and identification by non-specialists (Debinski and Broussard 1990)
- group should contain some taxa with short generation times (Debinski and Broussard 1990)
- group should contain species in different trophic or habitat guilds (Debinski and Broussard 1990)
- group should be well known in terms of ecology and life history (Debinski and Broussard 1990)
- species with special habitat needs, low densities, large homeranges, poor dispersal abilities, susceptible to local extinction, with a critical position in the food chain, and socio-economic implications may also be of interest as indicators (Duinker 1993).
- assemblage should also have varying sensitivity to environmental disturbances and a diversity of life history and ecological preferences (Kremen *et al.* 1993)
- change in species populations must be linked to agricultural practices

III. Indicators

1. Common objectives for biodiversity indicators

Why do we need habitat and habitat availability indicators?

- To show the status/ trends of habitat availability on the agricultural landscape:
  - it is difficult to identify all causes of habitat loss, however agricultural practices are a major component
  - others causes include: natural environmental fluctuations, forestry, urban expansion, climate change
- To show the impact of agricultural practices on habitat:
  - these could be positive impacts from practices such as conservation tillage and planting shelterbelts or negative impacts from practices such as draining quality wetlands and converting native grasslands to cropland.

For the Agri-Environmental Indicator Project of Agriculture and Agri-Food Canada the wildlife habitat vision is:

"Canada's agri-food sector and wildlife resources to be managed for sustainability and long-term mutual benefits" (Agriculture and Agri-Food Canada 1993a)"

Indicator objectives for the AEI project are:
- to evaluate performance of the agricultural sector
- to integrate environmental factors into policy and decision making
- to inform decision makers about environmental conditions and trends.

For the Agri-Environmental Indicator Project there are two possible policy questions which the indicator component should address:

- Is the quantity and quality of wildlife habitat in agricultural regions of Canada increasing or decreasing?
- Are wildlife populations residing in agricultural regions of Canada being sustained?

These policy questions suggest a need to identify indicators to track changes in these variables.

In addition an indicator needs to be an early warning system to show that something is out of balance. This will then trigger some kind of action because of the need to move it back into balance. There is a need for targets and thresholds which trigger and define the direction of mitigative actions (B. MacGregor, AAFC, interview).

Furthermore, there is a need to identify critical goals to which the indicators will relate (Indicators Task Force 1991; Elliot 1995).

Habitat indicators are being developed by other organizations to address goals such as:

- sensitivity of habitat loss (*) relates to vulnerability of the habitat and sensitivity of certain species)
- to identify habitat conservation objectives
- to facilitate communication
- to assess impacts of policies/ programs/ practices
- to track progress (Elliot 1995).

2. *Limitations of indicators in general*

Indicators are not the answer to every question. They need to be interpreted and used judiciously. For example, there is difficulty in separating out change due to natural variation and change due to human activities. In addition some indicators are a "proxy for direct measurement", and where direct measurement is possible and feasible, it is often the preferred choice (Weins and Elliot 1995; C. Caza, Wildlife Habitat Canada, interview). Statistics and summaries of direct measurements, however can make excellent indicators. Furthermore, there is a danger in using indicators that may not be accurate or directly linked to the subject in question. Poor indicators may lead to inappropriate management and mitigative actions.

3. *Criteria for selecting a suitable environmental indicator(s)*

(Note bolded criteria chosen for analysis of select indicators)

Indicators must have certain qualities or criteria to be useful to policy makers, resource managers and the public. These criteria include:

- **data** should be **available**, **reliable** and **updateable** (Caza and Neave 1993)
- **quantifiable**, representative and **sensitive to change** (Caza and Neave 1993; Duinker 1993; Indicators Task Force 1991)
- **ease of interpretation** and ease of use at varying levels of decision making (Caza and Neave 1993)
- **able to measure cumulative impacts** (Caza and Neave 1993)
- effectiveness at various scales (Caza and Neave 1993)
- capability to provide assessment over a wide range of stresses (Duinker 1993)
- **responsive to a wide variety of pressures** rather than to specific circumstances (Neave *et al.* 1995)
- independent of sample size (Duinker 1993)
- ability to differentiate between stresses due to natural causes versus human causes (Duinker 1993)
- ecologically relevant, scientifically valid (State of the Environment Directorate 1995; Caza and Neave 1993; Duinker 1993; Indicators Task Force 1991)
- **relevant to stated goals and objectives** (Gameda and Dumanski 1995; Indicators Task Force 1991)

- **have a target/ threshold level to compare it to** (Gameda and Dumanski 1995; State of the Environment Directorate 1995; Stribling 1994; Indicators Task Force 1991)
- national in scope or applicable to regional issues (Indicators Task Force 1991)

IV. What other groups have done in terms of habitat or biodiversity indicators

1. Indicator Analysis

Fourteen indicators related to species and/or habitat were found in the literature. Each is presented, assessed and rated using common criteria:

Indicator #1. Trends in abundance or occurrence of a species which is a possible indicator of habitat quality (Criteria and Indicators Technical Committee 1996)

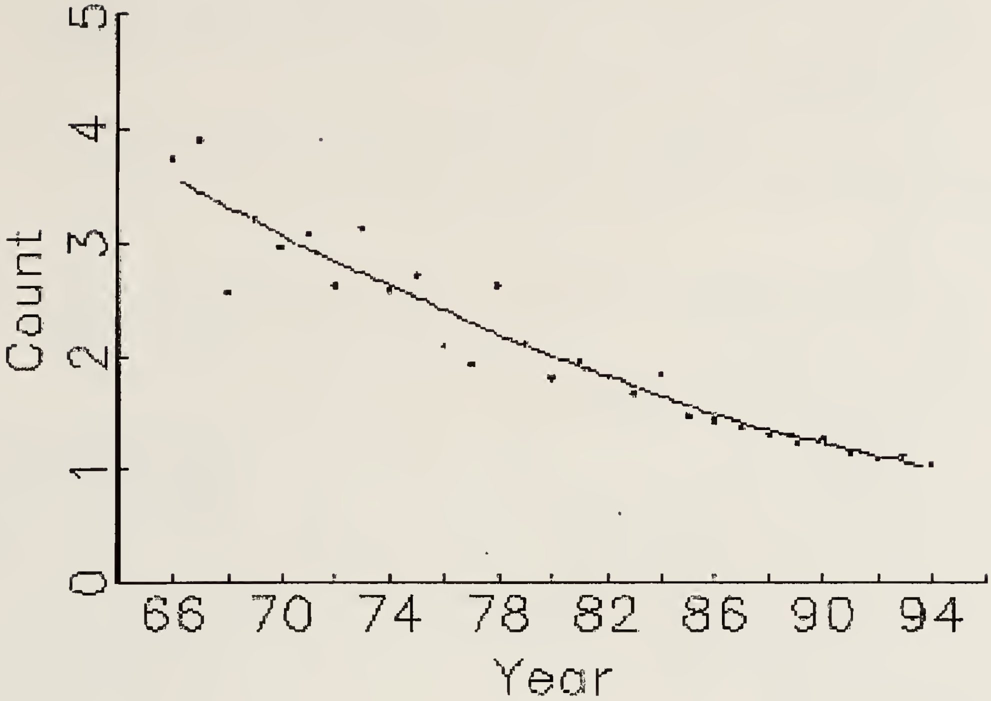
Benefits to approach:
- if a species is selected whose population is highly dependent on agricultural habitat, and easily affected by poor agricultural management practices, it could be a very sensitive early warning indicator of habitat change.

Limitations to approach:
- there may be difficulty linking the species to changes in agricultural management practices
- for example: what is the cause of the species trends? agriculture, hunting, non-agricultural related habitat loss, habitat loss outside of Canada, climatic fluctuations, disease outbreaks.

Availability of data for the development of indicator in Canada:
- data availability depends on the species
- a lot of data is available on birds, less on other animals.

Datasets: Breeding Bird Survey
Canadian Wildlife Service Surveys
Provincial Population Monitoring

Figure 1. Trend in Northern Pintail annual indices (taken from Sauer *et al.* 1996)



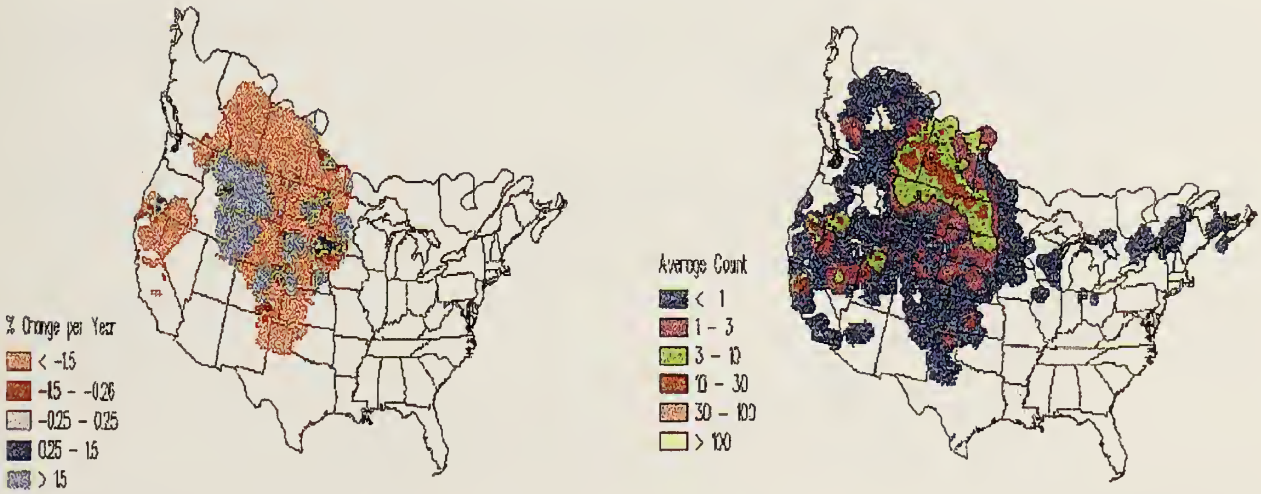


Figure 2. Maps showing % change per year and average counts of Northern Pintail populations in North America (taken from Sauer et al. 1996).

Checklist of criteria used to assess the suitability of Indicator #1. (Trends in abundance or occurrence of an indicator species)

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?	✔			
2. Relevant to stated objectives?	✔			
3. Is the indicator quantifiable?	✔			
4. Data: is it a) available?			✔	*- depends on species*
b) reliable/ scientifically valid?			✔	
c) updateable?			✔	
5. Ease of interpretation?	✔			
6. Sensitive to change?		✔		
7. Able to measure cumulative impact?	✔			
8. Responsive to a wide range of stresses/ pressures?			✔	
9. Targets or thresholds to compare it to?		✔		
Additional criteria for species:				
10. Are species habitat needs impacted by agricultural practices: a) directly?	✔			*- nests in upland areas sometimes far from wetlands (needs buffer)*
b) indirectly?				
11. Are there any other strong pressures acting on the population?	✔			*- hunting, environmental fluctuations, disease (botulism)*
12. Is the response to management practices rapid?			✔	
13. Does the species have a) special habitat needs?	✔			*- pintail can nest elsewhere, but success is lower*
b) poor dispersal abilities?		✔		
c) low density?		✔		
14. Does the species encompass the geographical range of interest?			✔	*- part of range (Prairies)*

Suitability of Indicator #1 for AEI project: High if limitations are addressed - Potential "Good" depending on species chosen.

Indicator #2. Trends in the number of species which occupy a portion of their former range (Criteria and Indicators Technical Committee 1996). The former range refers to the range of the species prior to agricultural development/settlement in Canada.

Benefits to approach:

- index combines species information
- can be used as a proxy for habitat loss
- can be used at a variety of spatial scales, possibly nationally.

Limitations to approach:

- not very sensitive, requires major changes in species numbers before the indicator changes

- would be very difficult to calculate for all species, you would need to use a subset of species and then there would be the standard problem of which species would be the most appropriate
- there may also be some problems in identifying the original pre-settlement range of most species (e.g. white-tailed deer in Eastern Canada) (this may not be an appropriate management goal either)
- may be difficult to attribute species habitat losses solely to agriculture.

Availability of data for the development of indicator in Canada:
- this depends on the species, a lot of data is available on birds, less on other animals and plants.

Datasets: Breeding Bird Survey
Canadian Wildlife Service Surveys
Ducks Unlimited Surveys.

Checklist of criteria used to assess the suitability of Indicator #2. (Trends in numbers of species which occupy a portion of their former range):

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?			✔	*- we don't know that our goals are*
2. Relevant to stated objectives?			✔	*to bring back populations to*
3. Is the indicator quantifiable?	✔			*presettlement levels*
4. Data: is it a) available?			✔	*- depends on species*
b) reliable/ scientifically valid?			✔	
c) updateable?			✔	
5. Ease of interpretation?	✔			
6. Sensitive to change?		✔		
7. Able to measure cumulative impact?	✔			
8. Responsive to a wide range of stresses/ pressures?	✔			
9. Targets or thresholds to compare it to?		✔		
Additional criteria for species:				
10. Are species habitat needs impacted by agricultural practices: a) directly?			✔	*- all of these additional criteria*
b) indirectly?			✔	*depend on whether a subset of*
11. Are there any other strong pressures acting on the population?			✔	*species is carefully chosen to meet the criteria*
12. Is the response to management practices rapid?		✔		
13. Does the species have a) special habitat needs?			✔	
b) poor dispersal abilities?				
c) low density?				
14. Does the species encompass the geographical range of interest?			✔	

Suitability of Indicator #2 for the AEI project: Low-Moderate if limitations are addressed.

Indicator #3. Guild population trends as indicators of habitat change (Criteria and Indicators Technical Committee 1996; Croonquist and Brooks 1991). Guilds are defined as groups of species that share resources in a community (Smith 1980). An example of a guild is a group of duck species such as canvasback, redhead and ruddy duck which all require deep water as a component of their habitat needs (D. Neave, interview). These species are all divers feeding on submerged vegetation and bottom feeding invertebrates.

There are two ways to use guilds to develop indicators. Guilds of species tend to use similar habitat, and the presence of one species in the guild tends to imply its suitability for all species. **With a range of species in a guild, one species may be more sensitive to change than others, making the guild a more sensitive indicator than the use of single indicator species.** Response guilds can also be used to develop indicators of habitat change. Species within response guilds react in a similar manner to habitat perturbation (Croonquist and Brooks 1991). It is therefore possible to focus on one or two species from a response guild, knowing that the other species will react to habitat change in a similar way.

Benefits to approach:

- if an appropriate guild of species could be chosen, (i.e. a guild highly dependent on agricultural habitat and sensitive to change in agricultural management practices) it could be a sensitive early warning indicator.
- the guild of may be more sensitive to change than individual species.

Limitations to approach:

- it might be difficult to pick an appropriate guild of species, especially one that could apply across agro ecosystems in Canada, or even across large regions.

Availability of data for the development of indicator in Canada:

- depends on the species selected
- a lot of data is available for birds and mammals, but not for other species.

Datasets: Breeding Bird Survey
Canadian Wildlife Service Surveys
Ducks Unlimited Surveys.

Checklist of criteria used to assess the suitability of Indicator #3. (Guild population trends):

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?	✓			*- if guild is strongly linked to agricultural management practice*
2. Relevant to stated objectives?	✓			
3. Is the indicator quantifiable?	✓			
4. Data: is it a) available?			✓	*- depends on species in guild*
b) reliable/ scientifically valid?			✓	
c) updateable?			✓	
5. Ease of interpretation?			✓	
6. Sensitive to change?			✓	
7. Able to measure cumulative impact?			✓	
8. Responsive to a wide range of stresses/ pressures?			✓	
9. Targets or thresholds to compare it to?		✓		
Additional criteria for species:				
10. Are species habitat needs impacted by agricultural practices: a) directly?			✓	*- all these criteria are dependent on the species chosen for the guild*
b) indirectly?			✓	*- with careful selection of the species this could be an effective indicator*
11. Are there any other strong pressures acting on the population?			✓	
12. Is the response to management practices rapid?			✓	
13. Does the species have a) special habitat needs?			✓	
b) poor dispersal abilities?				
c) low density?				
14. Does the species encompass the geographical range of interest?			✓	
And for Guilds:				
15. Does the guild include:				
a) taxa with short generation times?			✓	
b) taxa with different trophic or habitat requirements?			✓	
c) taxa with varying sensitivities to change?			✓	

Suitability of Indicator #3 for the AEI project: Moderate if limitations are addressed.

Indicator #4. Number of species dependent on agricultural habitat classified as threatened/endangered/rare/vulnerable, relative to the known number of species (Criteria and Indicators Technical Committee 1996; Indicators Task Force 1991)

Benefits to approach:

- highlights historical problems with habitat loss
- targets may exist for individual species populations.

Limitations to approach:

- not a sensitive indicator of habitat change
- requires major changes in species numbers for the indicator to change

Limitations to approach:

- not a sensitive indicator of habitat change
- requires major changes in species numbers for the indicator to change
- aggregates all causes of species decline, not just those due to agricultural management practices.

Availability of data for the development of indicator in Canada:

- potentially high, there is available on endangered species, nationally and by province.

Examples:

Figure 3. Proportion of birds and terrestrial mammals threatened or endangered in all Canadian ecoregions (taken from Indicators Task Force 1991)

(Note - this example ignores vegetation, fish, insects, etc.)

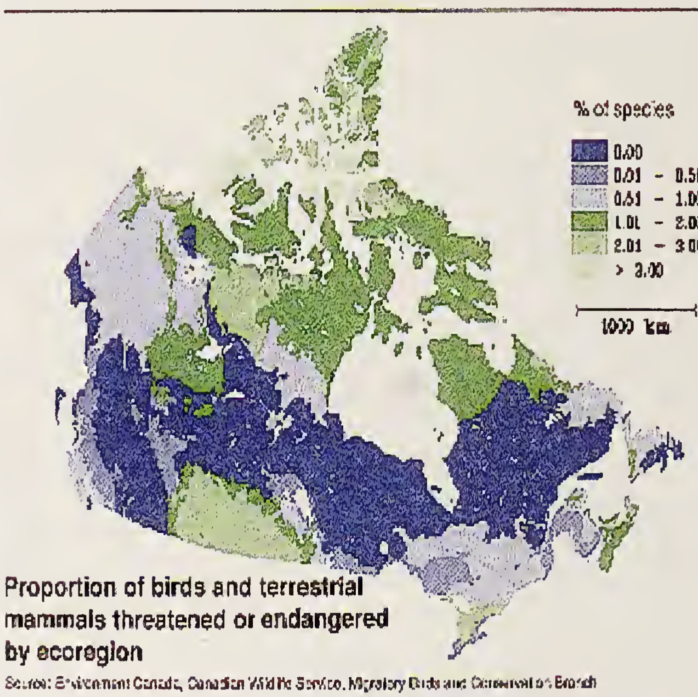
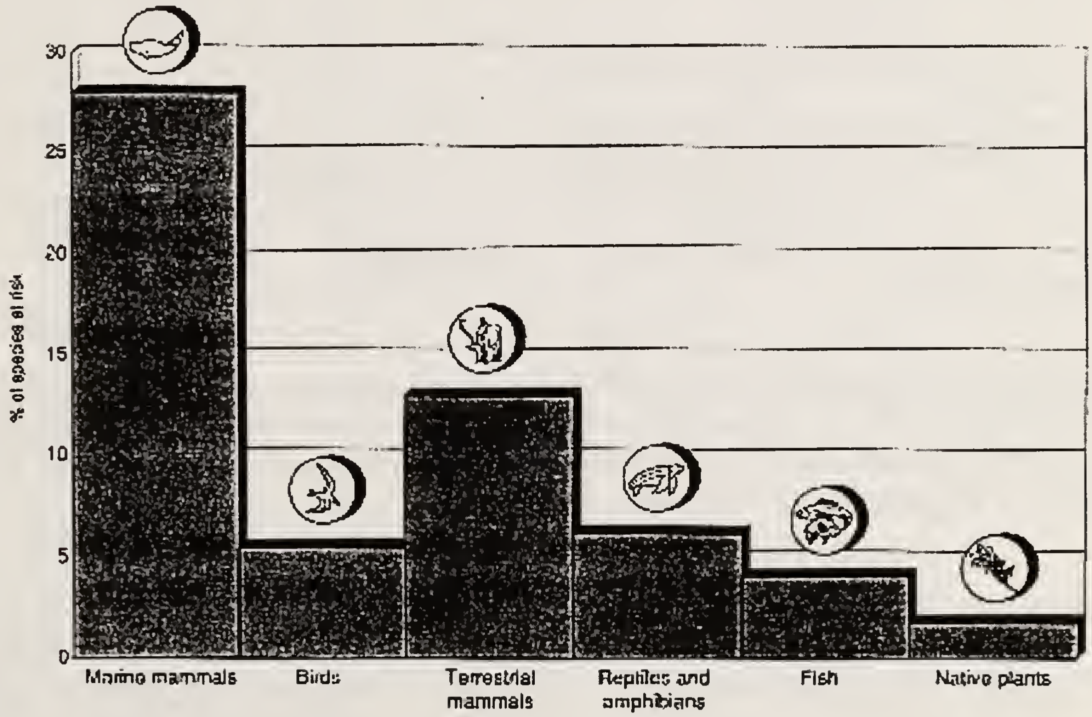


Figure 4. Number of Wildlife Species at Risk (threatened, endangered, rare or vulnerable) in all Canadian Ecosystems (taken from Indicators Task Force 1991)

Wildlife species at risk

Mid-term objective	Under the National Program of Recovery of Nationally Endangered Wildlife, all the recovery teams and the recovery plans for the currently identified endangered birds and terrestrial mammals will be established by 1992.
Targets	Each recovery plan will have specific rehabilitation targets. For example, for the Whooping Crane, rehabilitation targets are as follows: in Canada, by the year 2000, 40 breeding wild pairs in Wood Buffalo National Park; at the continental level, by the year 2010: in addition to the Canadian target, 1–2 other wild groups of 25 breeding pairs and 2–3 captive groups of 5–15 breeding pairs.



Wildlife species at risk, as reported by COSEWIC* in 1990

* Committee on the Status of Endangered Wildlife in Canada.

Source: Environment Canada, Canadian Wildlife Service

Checklist of criteria used to assess the suitability of Indicator #4. (Number of species dependent on agricultural habitat classified as threatened/ endangered/ rare/ vulnerable relative to the known number of species):

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?			✔	
2. Relevant to stated objectives?			✔	
3. Is the indicator quantifiable?	✔			
4. Data: is it a) available?	✔			*- for vertebrate species mostly*
b) reliable/ scientifically valid?	✔			
c) updateable?	✔			
5. Ease of interpretation?	✔			
6. Sensitive to change?		✔		
7. Able to measure cumulative impact?		✔		
8. Responsive to a wide range of stresses/ pressures?			✔	
9. Targets or thresholds to compare it to?		✔		
Additional criteria for species:				
10. Are species habitat needs impacted by agricultural practices: a) directly?			✔	
b) indirectly?			✔	
11. Are there any other strong pressures acting on the population?			✔	
12. Is the response to management practices rapid?		✔		
13. Does the species have a) special habitat needs?			✔	
b) poor dispersal abilities?			✔	
c) low density?			✔	
14. Does the species encompass the geographical range of interest?			✔	

Suitability of Indicator #4 for the AEI project: Low-Moderate. Endangered species are useful potential indicators of past habitat losses, however they are poor indicators of current habitat trends on agricultural land, (and specific management strategies and programs are already in place to address endangered species).

Indicator #5. Selected indicator species which represent specific habitats (Environment Canada *et al.* 1992; Bird and Rapport 1986). This approach ties specific indicator species chosen based on the strong impact of agricultural practices on their habitat. Changes in the populations of these species could serve as an early warning indicator of a change in habitat quality and/or quantity.

- examples:
    - Saskatchewan Forest Habitat Project chose six wildlife indicator species to represent different forest habitat types supporting 250 species of birds and mammals
    - relation between ducks and the number of potholes (U.S. Fish and Wildlife Survey).

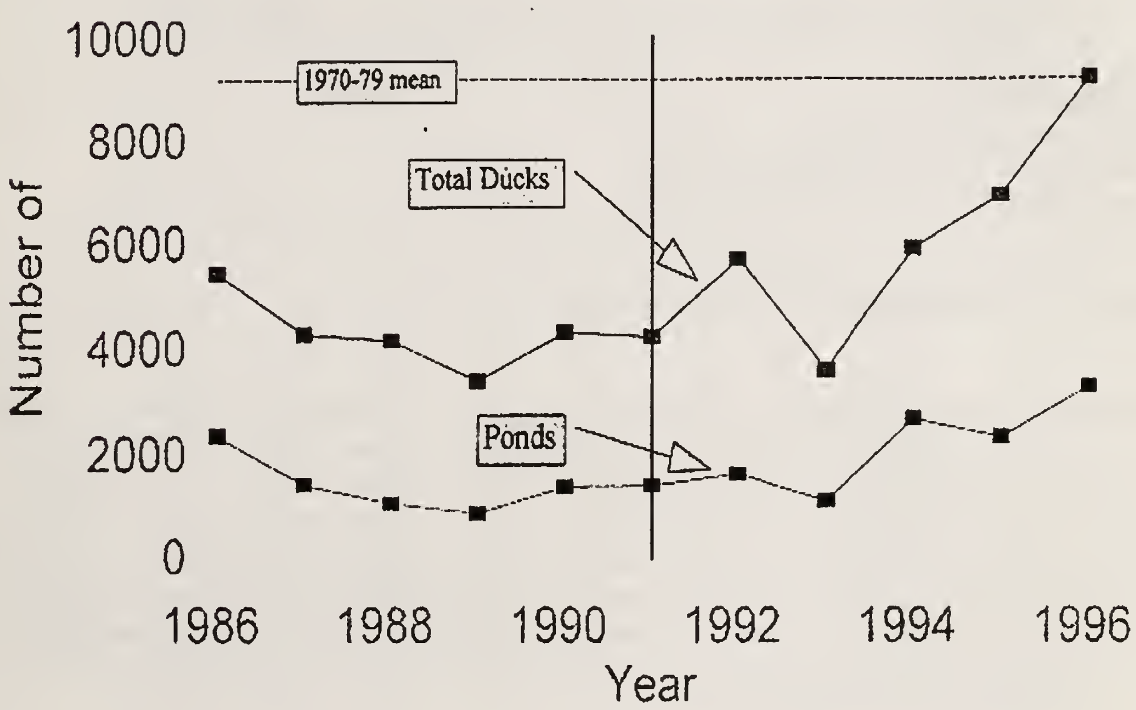
Benefits to approach:

- easy for people to identify with, as the general concept of habitat is linked to species which people may be more familiar with
- habitat is specifically linked to species in this approach.

Limitations to approach:

- use of this indicator in isolation gives only the response of a selected group of species
- it may be difficult to choose the appropriate species
- it might be tempting to use species well known to the public rather than the most sensitive species
- agricultural management practices may not be the only impact on the species or its habitat.

Figure 5. Trend in total ducks and total ponds in Saskatchewan (000's) (Canadian Wildlife Service and the U.S. Fish and Wildlife Service 1996)



Availability of data for the development of indicator in Canada:

- depends on the species, there is a lot of data on birds and mammals, less on other species.

Datasets: - species: Breeding bird survey
Canadian Wildlife Service Surveys
- habitat: Ducks Unlimited Habitat Inventory
Canadian Wildlife Service Surveys
Provincial Forest Inventories

Checklist of criteria used to assess the suitability of Indicator #5. (Selected indicator species which represent specific habitats):

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?	✔			
2. Relevant to stated objectives?	✔			
3. Is the indicator quantifiable?	✔			
4. Data: is it a) available?			✔	*- data is correlative, not cause effect*
b) reliable/ scientifically valid?			✔	
c) updateable?			✔	
5. Ease of interpretation?	✔			
6. Sensitive to change?	✔			
7. Able to measure cumulative impact?			✔	
8. Responsive to a wide range of stresses/ pressures?			✔	
9. Targets or thresholds to compare it to?		✔		

Suitability of Indicator #5 for the AEI project: Low-Moderate

Indicator #6. Area, percentage and representativeness of habitat types in protected areas (Criteria and Indicators Technical Committee 1996; Saskatchewan Environment and Resource Management 1996; OECD 1995; Statistics Canada 1994). This indicator measures the trend in the amount of land specifically protected for wildlife. The land could be protected in the form of a park, reserve or conservation area, or may be protected for its habitat value by a broader range of land stewardship programs such as easements or grazing leases. The World Resources Institute (Reid *et al.* 1993) suggested a related indicator as the percent (extent) of area dominated by non-domesticated species occurring in patches greater than 1000 km^2.

Benefits to approach:

- provides an estimate of the trend in habitat directly protected for wildlife
- can also include agricultural land with specific habitat protection (e.g. Provincial grazing leases, Saskatchewan's Wildlife Habitat Protection Act, NAWMP projects).

Limitations to approach:

- protected area strategies tend to ignore the habitat on managed land, which although it may not be as concentrated, may be far more abundant for many species (Myers 1994)
- protected areas such as parks are not directly linked to agricultural management practices (exceptions being fresh water and marine habitat which may) (be affected by farm inputs and parks which allow livestock grazing) so they are not direct indicators of sustainable agriculture.

Availability of data for the development of indicator in Canada:

- data is available from Environment Canada (summary of Federal and Provincial initiatives), provincial data is also available.

Datasets: National Conservation Areas Database
North American Waterfowl Management Plan National Reporting system
Province protected area databases.

Table 3. Protected Land for IUCN Categories I to IV by Ecozone, Selected Years, 1900-1993 (taken from Statistics Canada 1994).

Ecozone	Area Protected					Change in land area protected 1960-1993	Ecozone area km^2	Protected area as a percentage of ecozone area	
	1900	1930	1960	1990	1993	(percent)		1960	1993
Atlantic Maritime	46	2 155	6 674	17 592	17 677	165	163 428	4.1	10.8
Mixed Wood Plains	1 097	1 124	1 307	5 305	5 316	307	151 812	0.9	3.5
Boreal Shield	26 874	27 709	102 393	190 128	190 847	86	1 718 285	6.0	11.1
Prairie	1 185	1 795	2 502	7 195	7 208	188	521 880	0.5	1.4
Boreal Plains	819	49 584	52 555	67 290	67 464	28	820 833	6.4	8.2
Montane Cordillera	10 421	25 812	32 014	53 546	76 690	140	433 238	7.4	17.7
Pacific Maritime	-	1 970	2 029	37 914	41 683	1 954	282 594	0.7	14.8
Boreal Cordillera	-	-	7 059	25 646	35 416	402	380 113	1.9	9.3
Tundra Cordillera	-	-	10	10 178	14 578	149 266	282 346	0.1	5.2
Taiga Plains	3 000	7 427	7 427	12 241	12 247	65	548 208	1.3	2.1
Taiga Shield	-	-	1 425	33 309	33 324	2 238	1 385 003	0.1	2.4
Hudson Plains	-	-	3 544	174 701	174 701	4 830	392 082	0.9	44.6
Southern Arctic	-	23 960	25 449	90 376	90 386	255	928 475	2.7	9.7
Northern Arctic	-	-	2 512	45 342	79 794	3 076	1 426 724	0.2	5.6
Arctic Cordillera	-	-	-	59 244	59 244	-	260 256	0.0	22.8
Canada	43 443	141 537	246 900	830 008	906 576	267	-	-	-

Examples:

Figure 6. Maps illustrating representation of various habitat types in Moist Mixed Grassland Ecoregion (left) and Mixed Grassland Ecoregion (right) in Saskatchewan's Representative Areas Network (from Saskatchewan Environment and Resource Management 1996)

Checklist of criteria used to assess the suitability of Indicator #6. (Area, percentage and representativeness of habitat types in protected areas):

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?			✔	
2. Relevant to stated objectives?			✔	
3. Is the indicator quantifiable?	✔			
4. Data: is it a) available?	✔			
b) reliable/ scientifically valid?	✔			
c) updateable?	✔			
5. Ease of interpretation?	✔			
6. Sensitive to change?		✔		
7. Able to measure cumulative impact?		✔		
8. Responsive to a wide range of stresses/ pressures?		✔		
9. Targets or thresholds to compare it to?	✔			*- the 12% benchmark, (i.e. from World Wildlife Fund) however this has a political foundation, not ecological*

Suitability of Indicator 6 for the AEI project: Moderate. (However there is little agriculture in most protected areas and change in area protected cannot be extrapolated to define overall changes in habitat from agricultural management practices).

Indicator #7. Trends in habitat diversity as measured by richness and evenness (Magurran 1988) (Hellkamp *et al.* 1993; Barret and Peles 1994, and Criteria and Indicators Technical Committee 1996) Habitat diversity is comprised of two separate components, richness and evenness. Richness is the number of habitat types in a unit area (i.e. a farm). Evenness is the equitability of distribution of these habitats. For example, consider these two farms:

Farm A

Habitat type	Area
corn	10 acres
wheat	10 acres
woodlot	10 acres
wetland	10 acres
pasture	10 acres
5 types	50 acres

Farm B

Habitat type	Area
corn	42 acres
asparagus	2 acres
woodlot	2 acres
wetland	2 acres
potatoes	2 acres
5 types	50 acres

In both farms, there are 5 habitat types, Richness=5. The area is also the same. However the equitability of distribution of the five habitats is not the same. Evenness at farm A is much higher than farm B.

The habitat diversity is therefore higher at farm A. Evenness is calculated using the following formula:

$$\text{Evenness} = \frac{1/\sum pi^2}{-\sum pi \ln pi}$$

where pi is the proportion of the total area habitat type (I) occupies (Hill 1973).

Benefits to approach:

- considers all potential habitat and summarizes it in the form of an index
- the higher the value of richness and evenness the more diverse the landscape.

Limitations to approach:

- doesn't consider habitat fragmentation
- there is no quantifiable goal for richness, evenness or diversity. This indicator would need well defined thresholds and targets to be useful, because maximum diversity is not necessarily what we want, as it may not reflect the highest habitat quality.

Availability of data for the development of indicator in Canada:

- you would need to consider a group of habitat types such as:
  - small grain and oilseeds crops
  - permanent cover crops (alfalfa, orchards)
  - potatoes, corn, tobacco
  - pastures
  - old field/ meadow
  - wetlands
  - woodlands
  - shelterbelts/ fencerows
  - riparian.

Datasets:

- the Census of Agriculture will cover the first five types on the list, the last four would have to come from other sources such as the Canadian Wildlife Service, Forest Resource Inventories, PFRA and provincial land cover databases.

***Checklist of criteria used to assess the suitability of Indicator #7. (Trends in habitat diversity as measured by richness and evenness)*:**

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?	✔			
2. Relevant to stated objectives?	✔			
3. Is the indicator quantifiable?	✔			
4. Data: is it a) available?			✔	*- difficult to combine crop and*
b) reliable/ scientifically valid?			✔	*natural habitat data*
c) updateable?			✔	
5. Ease of interpretation?	✔			
6. Sensitive to change?	✔			
7. Able to measure cumulative impact?			✔	*- just change in habitat quantity*
8. Responsive to a wide range of stresses/ pressures?		✔		*- just change in habitat quantity*
9. Targets or thresholds to compare it to?		✔		

Suitability of Indicator #7 for the AEI project: Moderate-High.

Indicator #8. Trends in habitat degradation (Indicators Task Force 1991). This type of indicator examines the impact of factors which decrease habitat quality. Some examples include the invasion of exotic species in upland/ wetland transition areas, the contamination of freshwater ecosystems through nutrient loading of phosphorous and nitrogen and pesticide contamination.

Benefits to approach:

- if agriculture is strongly linked to the pollutants, this is an excellent indicator of agricultural impact on habitat quality
- indicators of water quality are sensitive, and are strongly related to habitat quality for all organisms, particularly for wetland, freshwater and marine organisms
- links other components of the Agri-Environmental Indicator Project.

Limitations to approach:

- agriculture may not be the only contributor to the degradation (e.g. phosphorous loading in the Great Lakes)
- ecosystem impacts by some exotic species is not always clear
- invading/exotic species of concern may differ across the country and across regions
- cannot consider this indicator alone, habitat loss is also degradation (see Indicator #10).

Availability of data for the development of indicator in Canada:

- data is available for water quality (Environment Canada, Provincial agencies, Prairie Farm Rehabilitation Administration).
- information on the distribution of invading species may be available for some very problematic species such as purple loosestrife, zebra mussel.

***Checklist of criteria used to assess the suitability of Indicator #8. Trends in habitat degradation)*:**

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?	✔			
2. Relevant to stated objectives?	✔			
3. Is the indicator quantifiable?	✔			
4. Data: is it a) available?	✔			
b) reliable/ scientifically valid?	✔			
c) updateable?	✔			
5. Ease of interpretation?	✔			
6. Sensitive to change?			✔	*- it may take a while for management practices to impact downstream*
7. Able to measure cumulative impact?	✔			
8. Responsive to a wide range of stresses/ pressures?	✔			
9. Targets or thresholds to compare it to?	✔			*- for human consumption (fish) and guidelines for the protection of aquatic life*

Suitability of Indicator #8 for the AEI project: High (Note - There are two issues described here which are not equivalent in scope).

Figure 7. Concentrations of nitrate and nitrite, total phosphorous and dissolved phosphorous in water (taken from Indicators Task Force 1991).

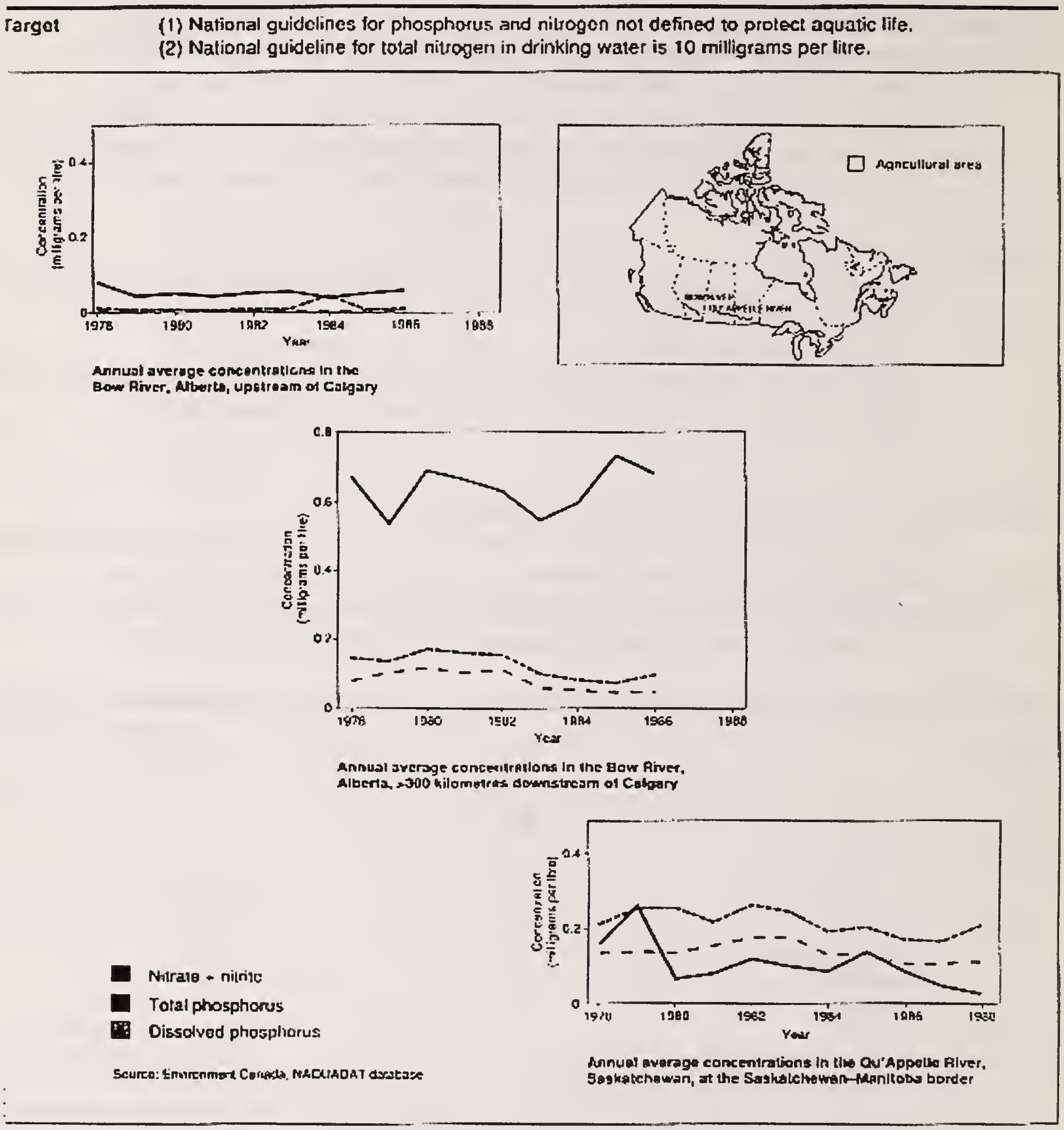
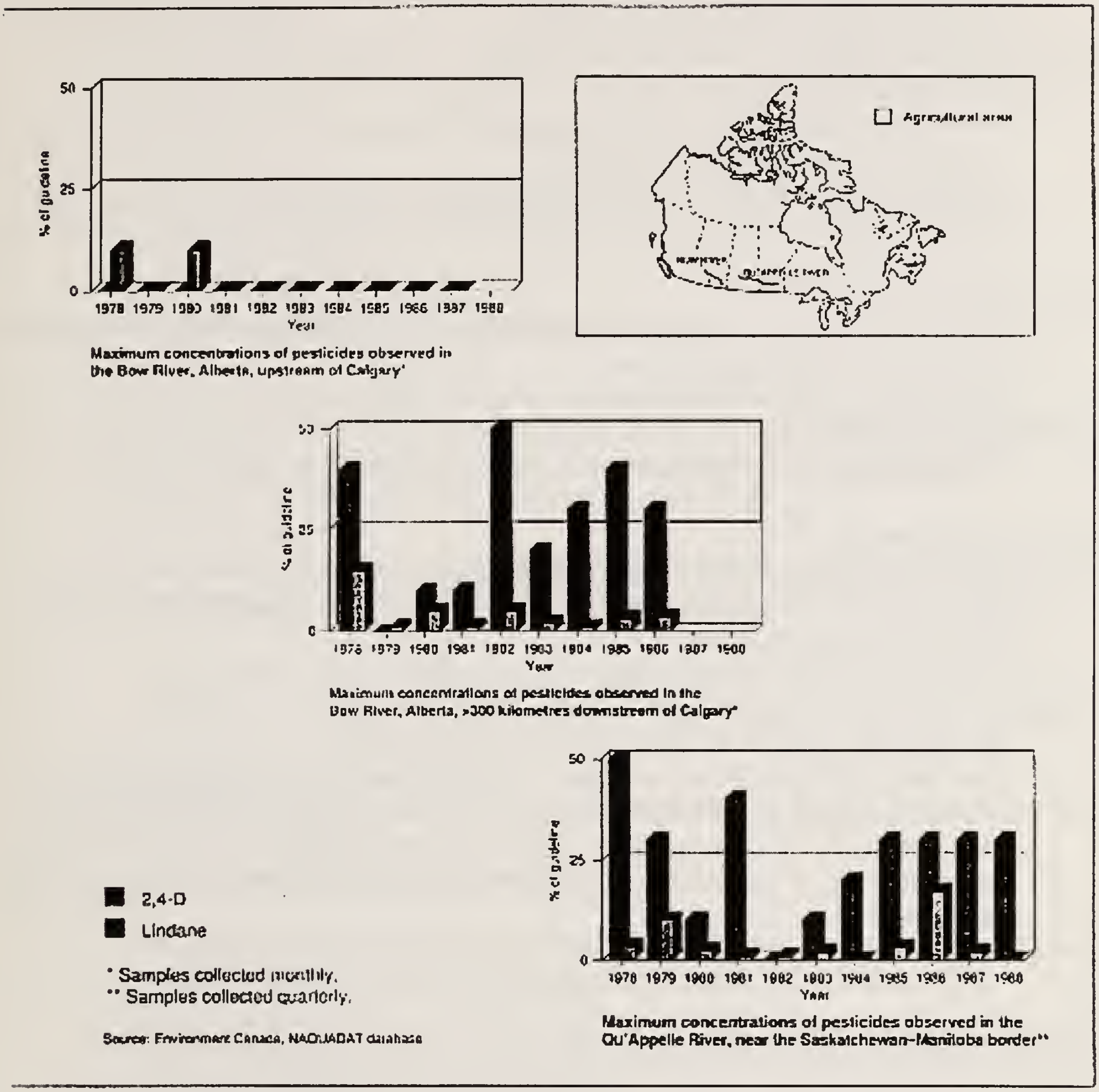


Figure 8. Concentrations of pesticides in water (taken from Indicators Task Force 1991)

Target — Canadian Water Quality Guidelines for Protection of Aquatic Life:
2,4-D — 4.0 micrograms* per litre in water
Atrazine — 2.0 micrograms* per litre in water
Lindane — 10.0 nanograms** per litre in water



Indicator #9. Trends in fragmentation and connectedness of habitat components (Criteria and Indicators Technical Committee 1996; Merriam 1994; Agriculture and Agri-Food Canada 1993b).

Potential indices which can be used to calculate fragmentation and connectance include:
- Shannon Weiner index of landscape diversity, composition, patch size
- abundance (Barrett and Peles 1994, Merriam *et al.* 1993)
- Habitat isolation (Knaapen *et al.* 1992)
- Habitat contagion (Li and Reynolds 1993)
- Mosaic diversity index (Merriam *et al.* 1993)
- Dominance, contagion, fractal geometry (O'Neill *et al.* 1988)
- Patch cohesion (Schumaker 1996)
- Perimeter and Length of habitats (OECD 1996)
- Change in the number of patches (OECD 1996)

Benefits to approach:
- fragmentation and connectivity are key habitat quality concerns for species with specific area or edge requirements
- the presence of habitat components in an area is crucial, however, so is their connectedness
- if habitat patches are not connected, many species will not be able to use them.

Limitations to approach:
- there are numerous methodologies to assess fragmentation; however, they are all different ways of measuring the same thing, and there is no standardized approach, threshold or target defined.

Availability of data for the development of indicator in Canada:
- the landscape would have to be divided into habitat types
- some data is available from the Census, but this would need to be supplemented for habitat types such as woodlands, wetlands, shelterbelts (agencies such as the Prairie Farm Rehabilitation Administration, and the Ontario Ministry of Natural Resources may have some of this land cover information) (and GIS capabilities to help measure fragmentation).

Checklist of criteria used to assess the suitability of Indicator #9. (Trends in fragmentation and connectedness of habitat components):

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?	✔			
2. Relevant to stated objectives?	✔			
3. Is the indicator quantifiable?	✔			
4. Data: is it a) available?		✔		*- not all of the habitat types are*
b) reliable/ scientifically valid?	✔			*available/ updateable at present,*
c) updateable?		✔		*however the habitat types derived*
5. Ease of interpretation?			✔	*from the Census are*
6. Sensitive to change?	✔			
7. Able to measure cumulative impact?	✔			
8. Responsive to a wide range of stresses/ pressures?		✔		*- only to land use change*
9. Targets or thresholds to compare it to?			✔	

Suitability of Indicator #9 for the AEI project: Moderate

10. Trends in habitat loss/ habitat availability as a proportion of farmland area (United States Department of Agriculture 1996; Weins 1996; Saskatchewan Wetland Conservation Corporation 1993; Statistics Canada 1994).

Two similar indicators were suggested by the World Resources Institute (Reid *et al.* 1993)

1. Percentage (extent) of area dominated structurally by non-domesticated species

2. Rate of change from dominance of non-domesticated species to domesticated species.

This indicator can be expanded into:

- trends in cropland, wetland, woodland, native grassland as a percent of farmland area

- trend in area of endangered habitats (OECD 1994)

- percent and extent of habitat types relative to historical condition and total farmland area (modified from Criteria and Indicators Technical Committee 1996)

- area of farmland converted to non-agricultural land use (modified from Criteria and Indicators Technical Committee 1996).

Benefits to approach:

- gets directly at the habitat loss conversion issue, and when expressed as a proportion of total farmland, examines agricultural impact only
- (indirectly could also help assess impact of agricultural policy).

Limitations to approach:

- Census of Agriculture lacks consistent time series data on wetland, woodland, native grassland and shelterbelts
- difficulty in interpretation, need to link habitat types to species needs.

Availability of data for the development of indicator in Canada:

- Data is available on cropland, pasture, etc. from the Census of Agriculture
- provincial governments have an idea of how much native grassland remains
- woodlot data could be obtained from provincial forest inventories (but possibly not for all agriculture land)
- wetland data could be obtained from provincial inventories, Ducks Unlimited and the Canadian Wildlife Service

***Checklist of criteria used to assess the suitability of Indicator #10. (Trends in habitat loss, habitat available as a proportion of farmland area)*:**

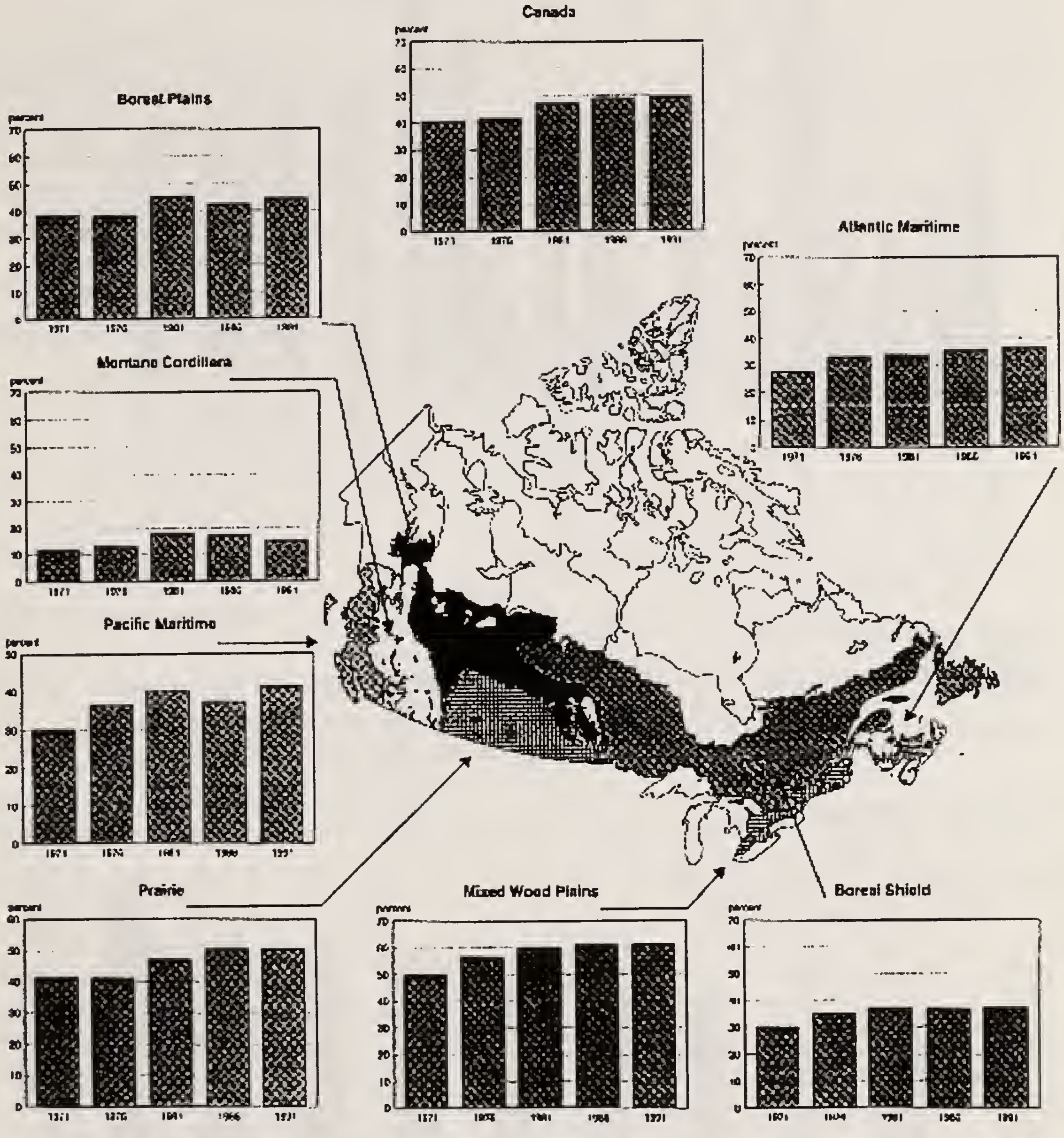
Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?	✔			
2. Relevant to stated objectives?	✔			
3. Is the indicator quantifiable?	✔			
4. Data: is it a) available?			✔	
b) reliable/ scientifically valid?			✔	
c) updateable?			✔	
5. Ease of interpretation?	✔			
6. Sensitive to change?	✔			
7. Able to measure cumulative impact?		✔		*- just change in land use, changes*
8. Responsive to a wide range of stresses/ pressures?		✔		*in biodiversity not presently*
9. Targets or thresholds to compare it to?		✔		*measured*

Suitability of Indicator #10 for the AEI project: Moderate

Example 1: Indicator #10

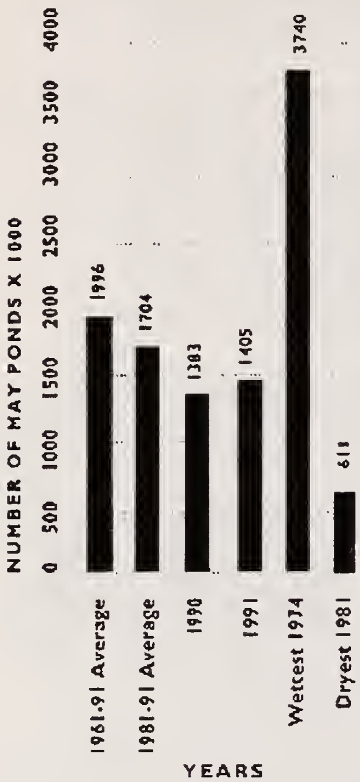
Figure 9. Cropland as a proportion of farmland (taken from Statistics Canada 1994)

Cropland as a Proportion of Farmland by Ecozone, 1971-1991



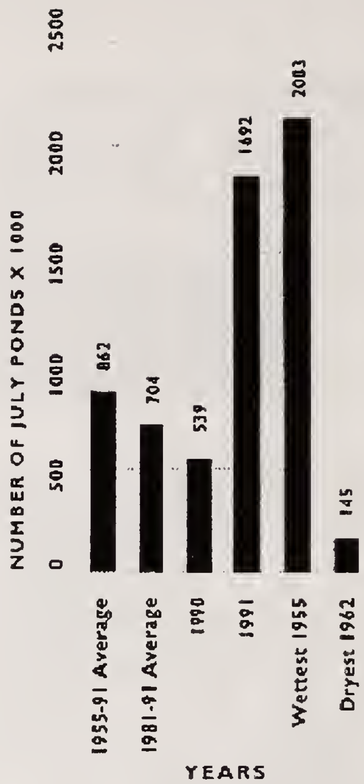
Notes:
The amount of farmland allocated to the production of crops has been increasing steadily. Growth in cropland areas indicates not only an increase in agricultural output but also potentially higher levels of environmental stress on existing arable land.
Agricultural areas are depicted by grid shading.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Example 2: Indicator #10



Numbers of Wetlands of Various Size Classifications in the Agricultural Zone of Saskatchewan

Source: Canadian Wildlife Service, U.S. Fish and Wildlife Service



Surface Area (acres) of Wetlands of Various Size Classes in the Agricultural Zone of Saskatchewan

Source: Canadian Wildlife Service, U.S. Fish and Wildlife Service

Figure 10. May and July ponds long-term trends showing an example of the variability of wetland availability due to climate and long term agricultural impact (taken from Saskatchewan Wetland Conservation Corporation 1993)

Example 3: Indicator #10

Item	1954-74[1]	1974-83[2]	1982-87[3]	1987-91[4]
	Thousands of acres per year			
To:				
Cropland	600.0	237.5	50.0	29.3
Urban use	55.0	14.1	56.0	58.3
Other	35.0	171.7	24.8	20.3
Total	690.0	423.2	130.8	107.8
	Percent of total annual conversion			
To:				
Cropland	87.0	56.1	38.2	27.2
Urban use	8.0	3.3	42.8	54.1
Other	5.1	40.6	19.0	18.8
Total	100.0	100.0	100.0	100.0

[1]Source: Frayer, Monahan, Bowden, and Graybill, 1983 (excludes Alaska and Hawaii).

[2]Source: Dahl and Johnson, 1991 (excludes Alaska and Hawaii).

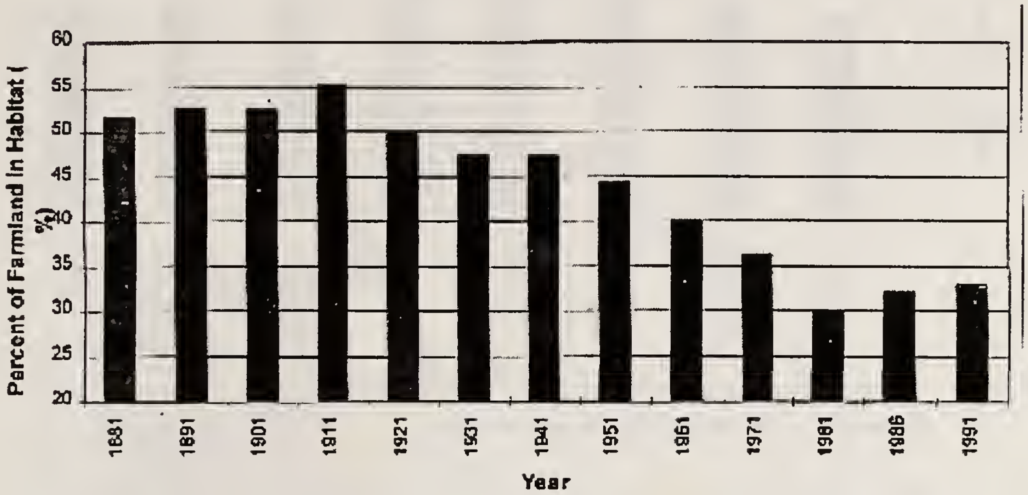
[3]Source: USDA, SCS, 1982 and 1987 National Resources Inventory data (includes only rural, nonfederal land; excludes Alaska).

[4]Source: USDA, SCS, 1987 National Resources Inventory data; 1991 (includes only rural, nonfederal land; excludes Alaska).

Table 4. U.S. wetlands conversion from 1954-1991 (taken from United States Department of Agriculture 1996)

Example 4: Indicator #10

Figure 11. **Portion of Farmland in Habitat in Canada (where "unimproved" land was used as a proxy for habitat)(taken from PFRA 1996b)**
Source: Census of Agriculture data.



Example 5: Indicator #10

Figure 12. **Percent of Prairie Farmland in Habitat (where "unimproved" land was used as a proxy for habitat)(taken from PFRA 1996b)**
Source: Census of Agriculture data.

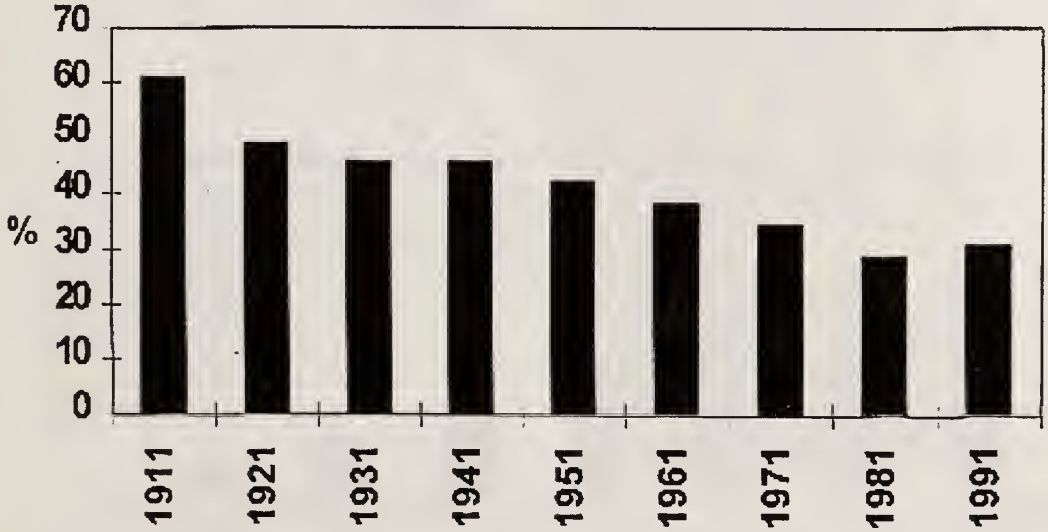


Figure 13. Prairie Grassland Acres (where natural or "unimproved" pasture was used as a proxy for habitat) (taken from PFRA 1996b) Source: Census of Agriculture data.

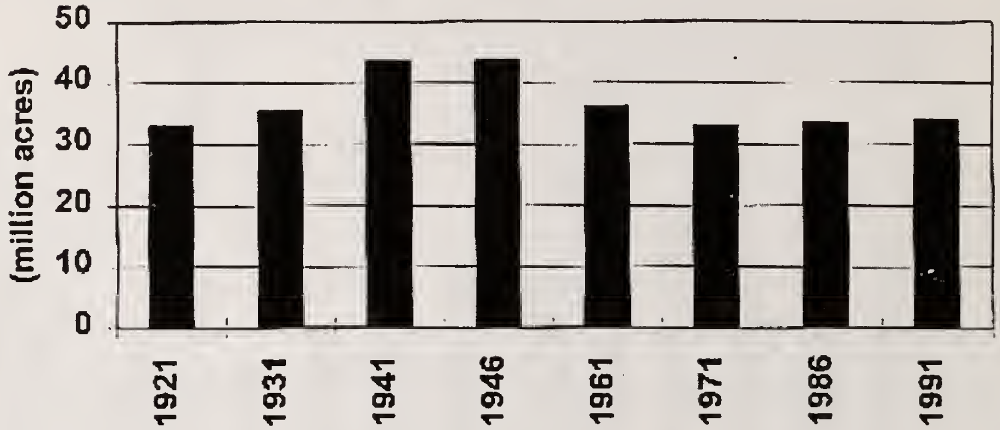


Figure 14. Prairie Wetland Acres (taken from PFRA 1996b) Source: Census of Agriculture data.

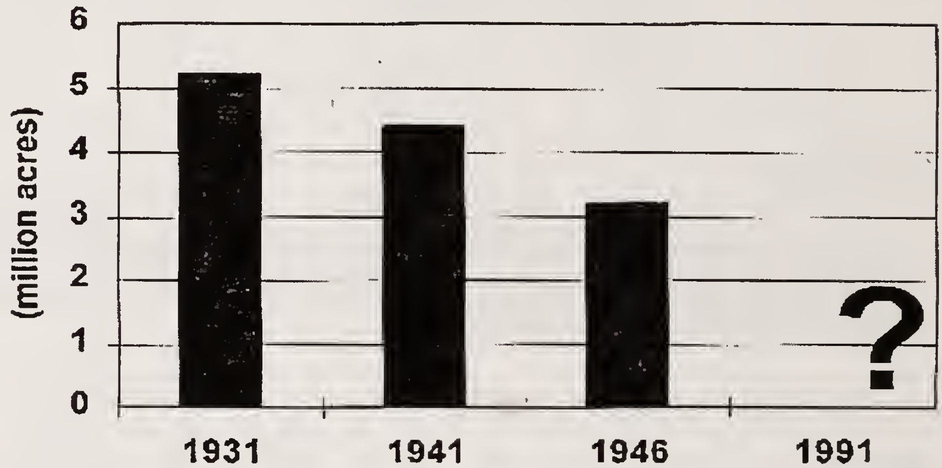


Figure 15. Trend in Prairie Woodland Acres (taken from PFRA 1996b) Source: Census of Agriculture

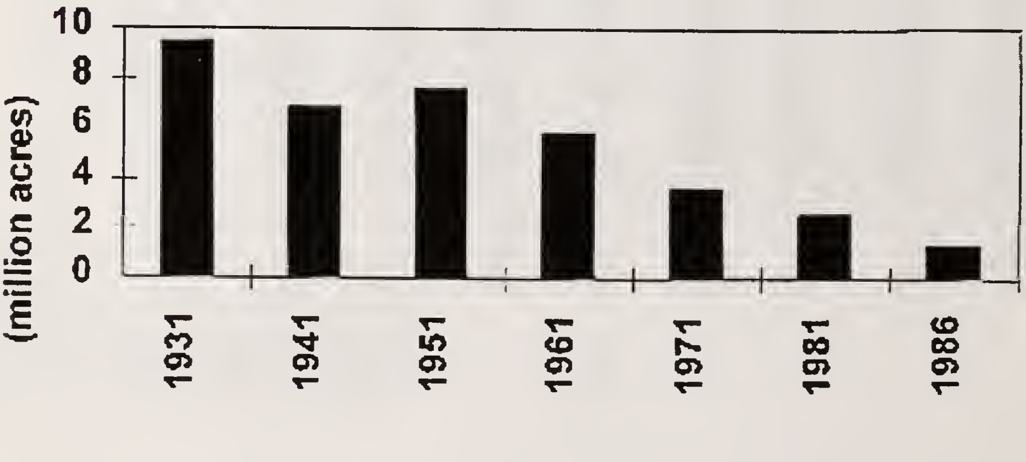
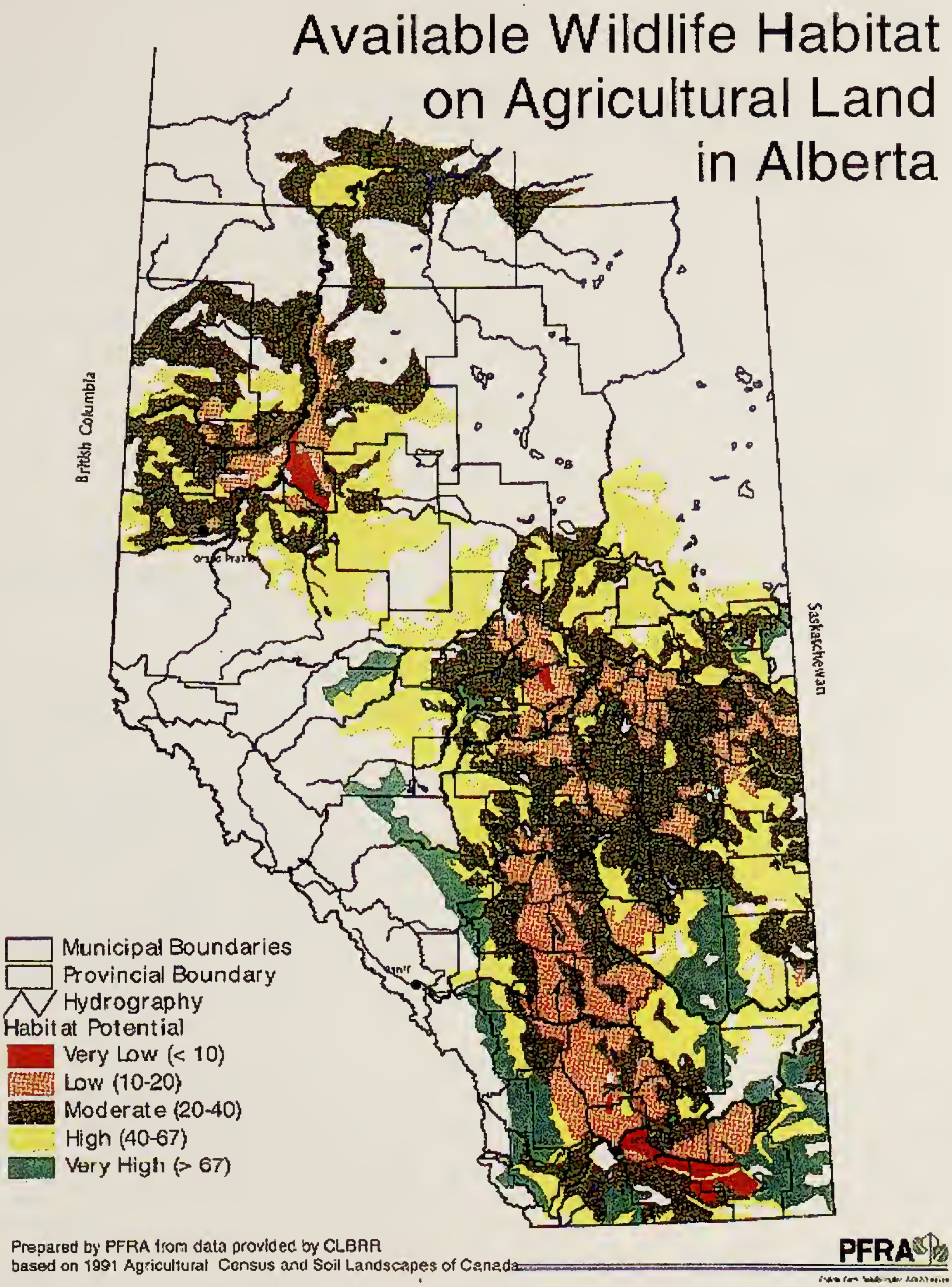


Figure 16. **Available Wildlife Habitat on Agricultural Land in Alberta determined from the proportion of "unimproved" farmland in the census districts (taken from PFRA 1996b)**



Indicator #11. Indicators related to environmental accounting

Environmental Accounting is an accounting system which considers environmental costs.

One common approach is to consider a natural resource stock as capital. The resource is then depreciated like other capital stock. This depreciation effects net profit, and also suggests a need for compensation (Costanza 1991).

For example, when losses of topsoil, organic matter, soil and water quality and wildlife are considered in any farming system, the profit margin may well be negative; profit margin will certainly be less than when resource depletion is not considered (High *et al.* 1991). Negative profit margins imply economic unsustainability, and when they are made negative by environmental depletion, they also imply environmental unsustainability.

Environmental accounting has not yet been implemented in Canada's agricultural economics, however there are numerous examples of similar methodologies. Josephson (1993) estimated the economic gains or losses realized by farmers using different conservation practices in southwestern Manitoba.

Benefits to approach:

- addresses sustainability in one of the simplest ways to understand: i.e. financially
- financial considerations have clearcut thresholds and targets (i.e. 0 dollars)
- environmental accounting equalizes all considerations in determining sustainability, you are no longer comparing apples and oranges.

Limitations to approach:

- it is very difficult to place a monetary value on ecosystems, habitat or wildlife (Wandschneider 1993)
- although promising, the approach is not ready to be implemented for wildlife habitat and habitat availability.

Availability of data for the development of indicator in Canada:

- we could not find any information or examples specifically referring to the comparison of production costs with and without wildlife habitat loss. We did find some related material however.

Table 5. Effect on Net Farm Income of Land Conserving Use Changes, Southwest Manitoba, 1992 (taken from Josephson 1993)

Conservation Category	Acres Surveyed	Number of Observations	Changes in Revenue Total	Changes in Revenue Per Acre	Change in Cost Total	Change in Cost Per Acre	Change in N.F.I. Total	Change in N.F.I. Per Acre
Idle land set aside	3 209	28	168 189	52.41	126 279	39.35	41 910	-13.06
Rotational Grazing	4 497	19	171 915	38.23	129 156	28.72	42 759	-9.51
Tillage Modification	30 187	50	354 108	11.73	194 046	6.43	548 154	-18.16
Summerfallow Modification	2 535	22	6 398	2.52	20 200	7.97	26 598	+10.49
Increase Forage	4 379	34	85 070	19.43	195 227	44.58	110 157	+25.16
Forage Modification	2 185	30	20 851	9.54	13 170	6.03	7 681	-3.52
Other	50	1	3 828	76.56	3 317	62.74	691	-13.82
Totals	47 042	184	241 687	5.14	382 503	8.13	624 190	+13.27

Some conservation practices decreased farm income, others increased it. When all practices were included, net farm income increased $ 13.27 per acre. This type of economic information can be cross referenced with wildlife habitat information. An example from North Dakota follows:

Table 6. Waterfowl nesting data for a variety of grazing systems in North Dakota (taken from Environment Canada *et al.* 1992)

Waterfowl Nesting Data for Grazing Systems at the Central Grasslands Research Station, Stockton, North Dakota

	Number of nests found per 100 acres	Nest success %	Successful nests per 100 acres
Twice-over rotation	13.2	34.7	6.6
Short duration rotation	13.0	25.6	5.3
Continuous grazing	9.6	26.6	4.6
Ungrazed	18.7	11.3	5.9

Source: K. Sedivek, North Dakota State University, Fargo.
Research has shown that more ducklings may be produced in grazed native grasslands than in adjacent idle grassland. Some grazing systems appear to be better for ducks than continuous grazing.

Josephson found rotational grazing increased profit, and rotational grazing supported more successful nests per acre than continuous grazing.

Another example of including the environment in financial considerations is the decoupling of subsidy payments from land area. Prior to 1994, agricultural subsidies had the (potential impact) of encouraging marginal land cropping as subsidiary were based on area in crop production. A proposed solution to this problem would be to extend subsidies to cover all land uses, including pasture, forage and wildlife habitat (Gray *et al.* 1994).

Another example involves estimating the area of land which is economically or environmentally unsustainable. It was estimated in 1995 that 75% of the farm land in Saskatchewan is economically and environmentally sustainable. Of the remaining land, 15% is considered to be economically unsustainable, and 10% is considered to be environmentally and usually economically unsustainable (Saskatchewan Agriculture and Food *et al.* 1995).

***Checklist of criteria used to assess the suitability of Indicator #11. (Environmental Accounting)*:**

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?	✔			
2. Relevant to stated objectives?	✔			
3. Is the indicator quantifiable?	✔			
4. Data: is it a) available?		✔		
b) reliable/ scientifically valid?			✔	
c) updateable?		✔		
5. Ease of interpretation?			✔	
6. Sensitive to change?	✔			
7. Able to measure cumulative impact?	✔			
8. Responsive to a wide range of stresses/ pressures?		✔		
9. Targets or thresholds to compare it to?	✔			

Suitability of Indicator #11 for the AEI indicator project: Moderate, high if data was available.
(Note - Future potential may be moderate to high now that Canada has a sustainable development strategy for agriculture)

Indicator #12. Roads per land area (km/ km2) or new roads per land area (km/ km2/ year, time series) (OECD 1995).

Benefits to approach:

- provides an indirect measure of fragmentation (and therefore an indirect measure for potential as a habitat indicator).

Limitations to approach:

- has little information value in Canadian agriculture where road networks have been established for long periods of time
- would have more application in forestry, particularly virgin areas, or in tropical countries where new land areas are being opened up for agriculture
- also has application in western Canada in areas where oil and gas exploration and extraction is taking place, however this is not an agricultural impact.

Availability of data for development of the indicator in Canada:

- Data exists, but not in a summarized form
- provincial and municipal road networks could be pulled from digital map sheets, however private roads, logging roads, field access roads would have to be obtained from air photo interpretation.

Checklist of criteria used to assess the suitability of Indicator #12. (Roads per land area):

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?			✔	
2. Relevant to stated objectives?			✔	
3. Is the indicator quantifiable?			✔	
4. Data: is it a) available?			✔	
b) reliable/ scientifically valid?			✔	
c) updateable?	✔			
5. Ease of interpretation?			✔	
6. Sensitive to change?		✔		
7. Able to measure cumulative impact?		✔		
8. Responsive to a wide range of stresses/ pressures?		✔		
9. Targets or thresholds to compare it to?		✔		

Suitability of Indicator #12 for the AEI indicator project: Low

Indicator #13. Trends in the use of agricultural practices which provide/ enhance wildlife habitat. Some examples of practices which benefit wildlife habitat are conservation tillage, chemical fallow and water erosion control practices (Dumanski *et al.* 1994; Neave *et al.* 1995).

Benefits to approach:

- highlights potentially positive actions by farmers
- deals with agricultural land as habitat instead of focussing on remnants only.

Limitations to approach:

- not always clear that the practice benefits wildlife, for example, some people believe conservation tillage is a trap for nesting birds, luring them from better areas where productivity would be higher (Best 1986)
- currently there is little information on habitat-species relationships for agricultural practices such as conservation tillage or chemical fallow.

Availability of data for the development of the indicator in Canada:

- the 1991 and 1996 Census of Agriculture included a Land Management Practices Category

Checklist of criteria used to assess the suitability of Indicator #13. (Trends in the use of agricultural practices which provide/ enhance wildlife habitat):

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?	✔			
2. Relevant to stated objectives?	✔			
3. Is the indicator quantifiable?	✔			
4. Data: is it a) available?	✔			
b) reliable/ scientifically valid?	✔			
c) updateable?	✔			
5. Ease of interpretation?			✔	*- depends on habitat suitability link*
6. Sensitive to change?	✔			
7. Able to measure cumulative impact?		✔		*- only responsive to changes in area*
8. Responsive to a wide range of stresses/ pressures?		✔		*of land under the management*
9. Targets or thresholds to compare it to?		✔		*practice, however the more the better applies*

Suitability of Indicator #13 for the AEI indicator project: Moderate-high if habitat suitability linkages are determined.

Indicator #14. Vertical Habitat Structure Index (OECD 1996)

The Vertical Habitat Structure Index (VHSI) is a coarse filter approach to assess the biotic community. Habitat structure is assessed in vertical layers (subsurface, surface, midstory, tree bole, tree canopy, air/elsewhere) and the model produces an index of vertical habitat complexity which can then be related to species or guilds (OECD 1996).

Benefits to approach:

- links habitat structure to species or species guilds.

Limitations to approach:

- does not examine horizontal diversity or patchiness (has been found that species/habitat relations are greatly enhanced by adding spatial dimension)
- model is good with natural classes of vegetation, but in an agricultural setting, results are very subjective
- vertical structure is not that different between native prairie and a hayfield, however with harvest at intervals over the growing season in the hayfield the habitat value becomes very different (OECD 1996).

Availability of data for the development of the indicator in Canada:

- U.S. uses a digital National Resources Inventory updated on 5 year intervals, this type of data is not available on a large scale in Canada

Checklist of criteria used to assess the suitability of Indicator #14. (Vertical Habitat Structure Index):

Criteria	*Yes*	*No*	*Maybe*	*Notes*
1. Relevant to stated goals?			✔	
2. Relevant to stated objectives?			✔	
3. Is the indicator quantifiable?	✔			
4. Data: is it a) available?		✔		
b) reliable/ scientifically valid?	✔			
c) updateable?	✔			
5. Ease of interpretation?		✔		
6. Sensitive to change?			✔	
7. Able to measure cumulative impact?			✔	
8. Responsive to a wide range of stresses/ pressures?		✔		
9. Targets or thresholds to compare it to?		✔		

Suitability of Indicator #14 for the AEI indicator project: Low for agricultural land, moderate for woodlands, the potential is high when spatial attributes are considered

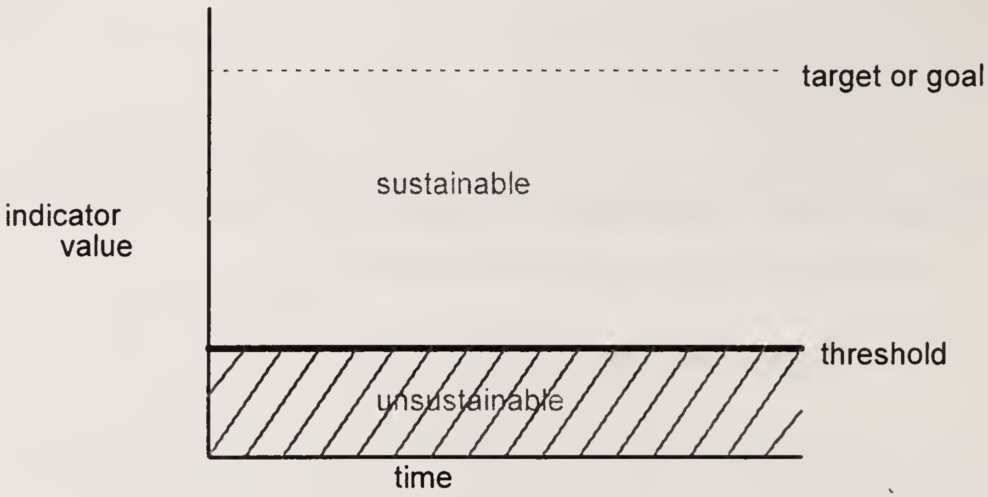
Indicators reviewed and assessed for use by the AEI program of Agriculture and Agri-Food Canada.

Indicator	Suitability for the AEI project
1. Trends in abundance or occurrence of a species which is an indicator of habitat quality	High
2. Trends in the number of species which occupy a portion of their former range	Low-Moderate
3. Guild population trends as indicators of habitat change	Moderate
4. Number of species dependent on agricultural habitat classified as threatened/ endangered/ rare/ vulnerable relative to the known number of species	Low-Moderate
5. Selected indicator species which represent specific habitats	Low-Moderate
6. Area, percentage and representativeness of habitat types in protected areas	Moderate
7. Trend in habitat diversity as measured by richness and evenness	Moderate
8. Trend in habitat degradation	High
9. Trend in fragmentation and connectedness of habitat components	Moderate
10. Trends in habitat loss/ habitat availability as a proportion of farmland area	Moderate
11. Environmental Accounting	Moderate
12. Roads per land area (km/km^2) or new roads per land area	Low
13. Trends in the use of agricultural practices which provide/ enhance wildlife habitat	Moderate-high
14. Vertical Habitat Structure Index	Low

2. *Thresholds and Targets*

One of the limitations of most of the 14 indicators assessed is the lack of a well defined target, threshold or goal. **Thresholds are defined as the values of an indicator beyond which the system can no longer be considered to be sustainable** (Neave *et al.* 1995).

Figure 17. Graph illustrating thresholds and targets or goals.



Targets or goals are what we aim for. These could be either the ideal situation, or a realistic compromise.

An example of a threshold is a minimum viable population size. Minimum viable population sizes are defined as the minimum number of a species that can reproduce and maintain a healthy population without inbreeding or isolation effects (Begon *et al.* 1990). If populations fall below this level, extinction becomes more likely.

Few efforts have been made to set targets and goals for wildlife habitat and habitat availability in a Canadian context. An attempt was made in the United States by the Wildlife Management Institute (1995) where goals were set for specific species groups (guilds) by region, and then habitat objectives were set to meet these goals. For example, in the Northeast Region goals were set for populations of grassland nesting species (including northern bobwhite and ringnecked pheasants) followed by a specific objective to restore 90 000 acres of high quality grassland habitat in the region.

The North American Waterfowl Management Plan has also set goals for breeding duck populations for each species based on their 1970-79 population means (NAWMP 1996). Figures 19 and 20 give an example of two species populations which are both increasing with time. One species population (the Green-winged teal) has reached the goal of the 1970-79 mean (Figure 19), however the other species (Pintail) breeding population although increasing, is no where near the 1970-79 mean goal (Figure 20).

Figure 18. Breeding population (000's) of Green-winged teal from 1986-1996 relative to the 1970-79 mean (NAWMP 1996)

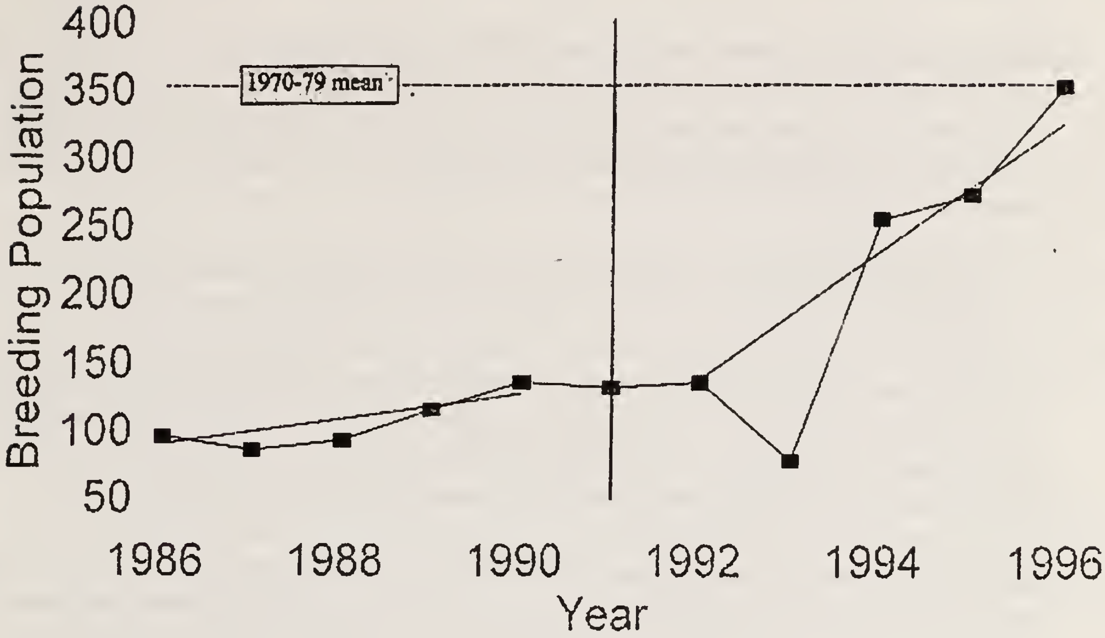
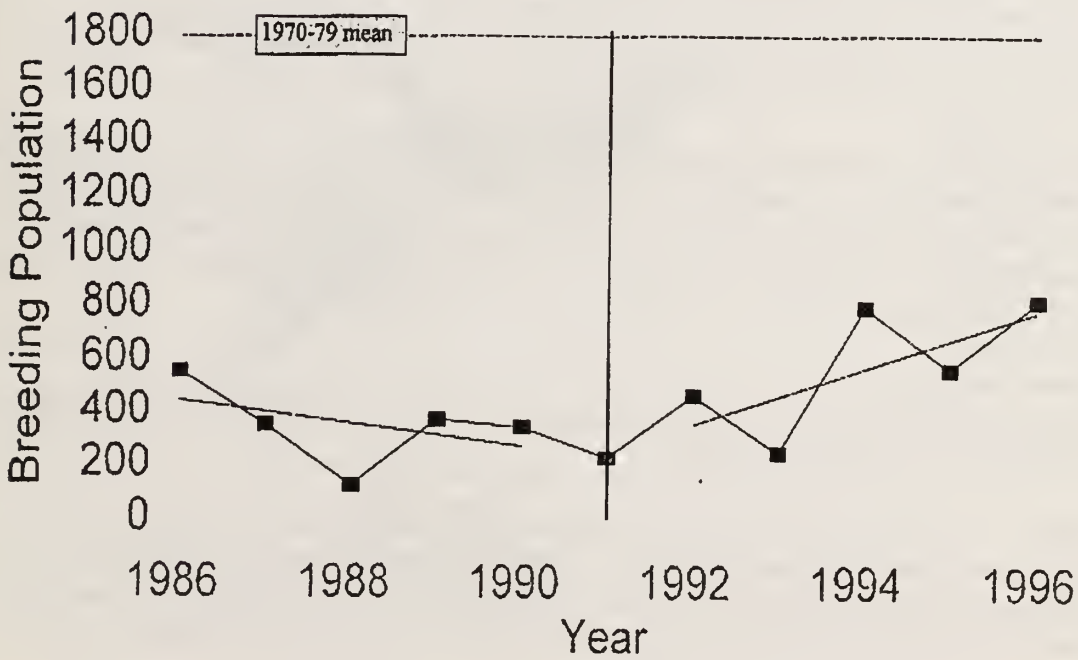


Figure 19. Breeding population (000's) of Pintails from 1986-1996 relative to the 1970-79 mean (NAWMP 1996)



Time trends are useful to determine whether values are increasing or decreasing, however without targets or thresholds, there is no frame of reference to compare indicator values, and managers and policy makers will find it difficult to promote effective and beneficial changes.

3. Habitat assessment and modelling tools

Several tools have recently been developed using geographic information systems (GIS) and related technology. These tools are briefly assessed for their potential use in indicator development.

1. GAP analysis (Johnson *et al.* 1994; Scott *et al.* 1993; website = www.gap.~idaho.edu/gap/

What is it for? GAP analysis is a method for identifying suitable areas for the protection of conservation values (Johnson *et al.* 1994). The overall goal is the maintenance of all ecosystem types in a protected areas/conservation strategy. Satellite imagery and geographic information systems are used to overlay maps of certain species distributions, species richness, land ownership and management (Scott *et al.* 1993).

How could the tool benefit the project? In a protected area strategy indicator, GAP analysis might give a target to aim for. However protected area strategies tend to ignore the habitat available on the rest of the landscape and we cannot afford to ignore this potentially much larger area for its habitat value (Merriam *et al.* 1993). Therefore a protected areas strategy should only be a small part of a larger habitat conservation strategy (Myers 1994).

GAP analysis uses vegetative communities as an indicator of habitat. This has limitations as some species may react to different features of the landscape than vegetation alone. Also smaller scale habitat features which may be critical to some species, may not be seen at the resolution of the mapping units (Scott *et al.* 1993).

What indicators could be potentially developed using this tool? Specific indicators of habitat availability could not be identified from GAP analysis. However, gaps identified in the protection of species and communities can provide information on the percentage of community types protected. They can also provide information on species rich areas and habitat fragmentation (Reid *et al.* 1993).

2. Habitat mapping

Examples include NATGRID (Forestry Canada, 1997) and the Environmental Resource Information Network from Australia.

What is it for? NATGRID is the National Georeferenced Resource Information for Decision Makers developed by Forestry Canada. Climatic domains for species are obtained from recent and historical observations, and are combined with Digital Elevation Models and Climate Surfaces to make maps of potential habitat for many species (see the Figure 20).

How could the tool benefit the project? One of the indicators (Number 2) previously reviewed was the number of species depending on agricultural habitat that occupy a portion of their former range. Maps of potential habitat could be used as proxies for the former habitat of many species, caution would have to be exercised in using this kind of information.

What indicators could be potentially developed using this tool? The maps of "potential" habitat are useful for forestry purposes. However their use in agriculture is severely limited as they may have little application on the ground for many species because the habitat has been modified extensively from it's original condition.

Habitat is not based on climate alone in these areas, but often on the location of small habitat patches such as shelterbelts and small woodlots. For example, southwestern Ontario may have all of the climatic habitat qualities to support Red shouldered hawks, but the reality is that the scarcity of relatively large woodlots (their required breeding habitat) has caused decreases in their numbers to the point where they are uncommon. Modelled potential habitat might be more useful for generalist species, such as white-tailed deer.

Techniques such as Digital Elevation Models, Climate Surfaces and Land Cover AVHRR maps might have use in assessing landscape change. However this is highly dependent on resolution. One kilometre, 100 metre or even 30 metre resolution might not provide information on smaller components of wildlife habitat such as shelterbelts, windbreaks and potholes.

Climatic Domain of the Five-lined Skink in Ontario

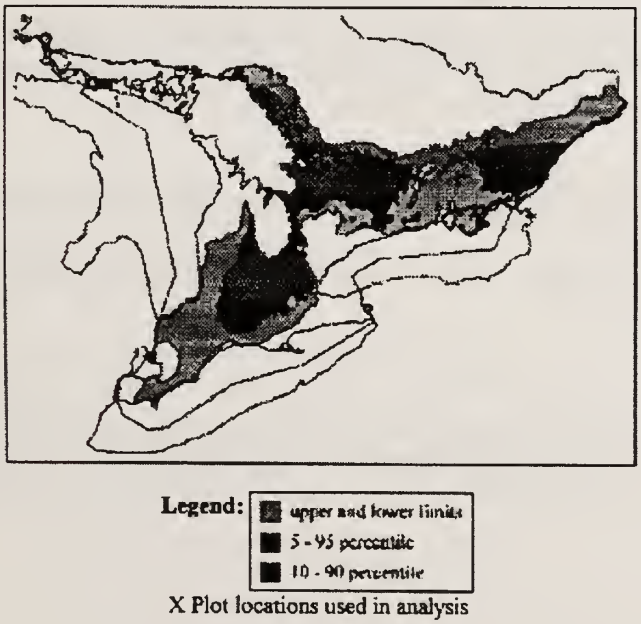


Figure 20. Climatic Domain Maps from NATGRID for the Five Lined Skink in Ontario (taken from Forestry Canada 1997)

3. **Cowardin or Mallard Model:** developed by the Northern Prairie Wildlife Research Centre (Johnson *et al.* 1994)

What is it for? The Mallard Model is used to develop and evaluate projects for the North American Waterfowl Management Plan. The model links population processes to landscape attributes. Regression predicts the breeding population from the amount and type of wetland habitat available. Input variables include: availability of nesting habitat, attractiveness of nesting habitat, hatch rates of nests. These factors are combined to estimate recruitment rate and when applied to the breeding population, estimate the number of young produced.

How can the tool benefit the indicator project? The Mallard Model identifies critical habitat components. The model might be able to help determine thresholds or targets for sustainability. Once habitat indicators for landscape components are identified, models could be run to simulate impact on breeding populations. However the model is still in the development stages and an evaluation of the program is ongoing.

What indicators can potentially be developed? None could be identified.

4. **Habitat Suitability Index Models (HSI)** (Stoneman *et al.* 1993; Watt 1992)

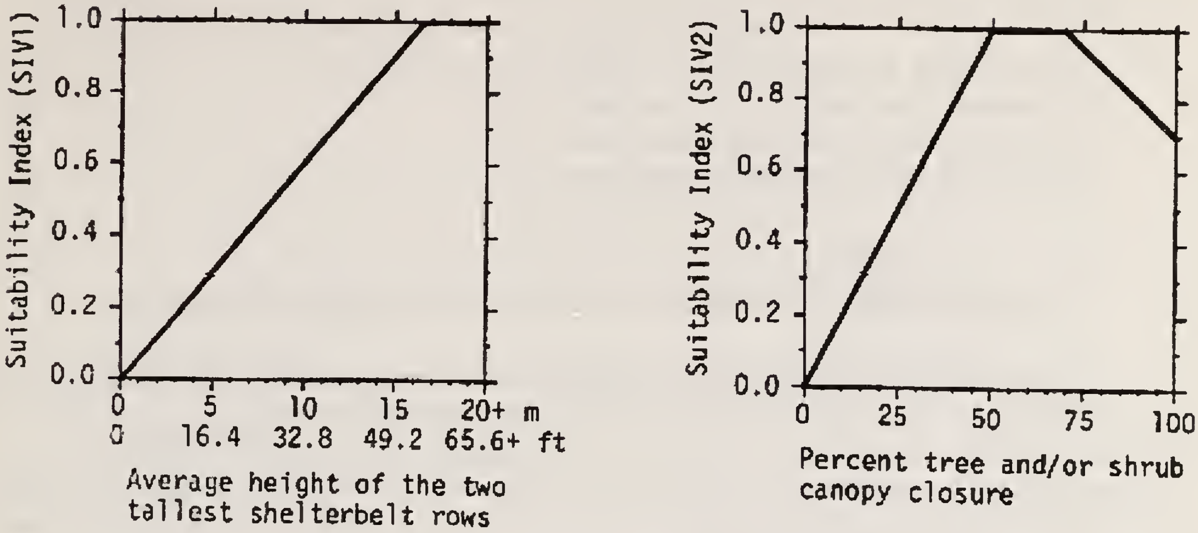
What is it for? Habitat suitability index models are developed to link species to habitat. Habitat-species relationships are determined through expert review and the literature and are translated into models. Future habitat availability can be predicted for a variety of management options. There is some skepticism, however that model predictions and actual numbers may not correspond (Johnson *et al.* 1994).

An example related to agriculture is the wildlife species richness in shelterbelts HSI models of the U.S. Fish and Wildlife Service (Schroeder 1986). Six factors were identified which were most related to species richness in shelterbelts:

1. Average height of the two tallest shelterbelt rows
2. Percent tree or shrub canopy closure
3. Number of shelterbelt rows
4. Number of woody plant species
5. Shelterbelt configuration
6. Shelterbelt size.

These six factors were related to habitat suitability in simple curves and the six suitability index values were combined in a formula to create a habitat suitability index score for the shelterbelt.

Figure 21. Example of curves developed to determine habitat suitability of shelterbelts



How can the tool benefit the indicator project? For the few species assessed in Canada, these models offer direct linkage between habitat and species.

(Note: The shelterbelt HSI appears related to Indicators of Habitat loss/availability resulting from agricultural management practices. Further analysis of this approach may prove beneficial to the AEI project).

What indicators can potentially be developed? None identified however the shelterbelt HSI illustrates the need to distinguish quality of habitat.

V. Identification of approaches for developing indicators of agro-ecosystem habitat availability

There are numerous frameworks available to help choose and identify potential indicators of sustainable agriculture. We used four of these frameworks to identify potential indicators of wildlife habitat and habitat availability: Three are landscape approaches, and one is a species-habitat approach. **The issues of wildlife habitat and habitat availability are too broad to be evaluated by one indicator alone.** In the Canadian forest environment, temporal and spatial variability, and impacts of disturbance preclude the use of a simple indicator of forest ecosystem quality or condition (Kimmins 1990). However, efforts are being made to develop an index of forest ecosystem health based on a number of data sources (A. Kerr, Environment Canada - 1997, personal communication). In agricultural landscapes, habitat patchiness, differences in habitat quality, impacts by man and fragmentation also preclude the use of one simple indicator.

The three landscape-oriented frameworks help to develop multiple indicators to assess specified goals and objectives. We have outlined several indicators for wildlife habitat and habitat availability using each of the four frameworks below:

1. Framework for Evaluating Sustainable Land Management
2. Pressure-State Response Framework
3. Lake Superior Ecosystem Health Framework
4. Sensitive-Species-Habitat Framework

1. Framework for Evaluating Sustainable Land Management

The Framework for Evaluating Sustainable Land Management (FESLM) was developed by Agriculture and Agri-Food Canada and the International Board for Soil Research and Management. The framework was designed as a pathway to ensure that all dimensions of sustainability are considered, and that all relevant factors are incorporated and sorted to yield indicators and thresholds of sustainability. FESLM is built on five pillars of sustainable land management:

1. Productivity: maintain or enhance productivity
2. Security: reduce the level of production risk
3. Protection: protect natural resources and prevent soil and water degradation
4. Viability: be economically viable
5. Acceptability: be socially acceptable

All five pillars must be achieved for a system to be sustainable. Wildlife habitat indicators fall under the protection pillar (Heald 1997).

Using the Framework for Evaluating Sustainable Land Management, an example follows for the wildilfe habitat and habitat availability indicator:

A. Objectives or purpose:

- to maintain the quality of the wildlife habitat we currently have
- to identify and quantify critical issues of wildlife habitat and habitat availability on agricultural land
- to enhance habitat and habitat availability where needed.

B. Means by which objectives are to be achieved:

- by defining habitat and habitat availability
- by identifying habitat types on agricultural land
- by linking species to habitat (i.e. create a habitat suitability matrix)
- by evaluating trends in quantity of habitat types and quantifying critical issues such as fragmentation.

C. Evaluation factors:

Physical:

1. intensity of production:
   - cropping intensity
   - grazing
   - field size
   - use of marginal lands
   - type of crop/ farm operation
   - quality of the land
   - improvements in farm machinery
   - historical landuse patterns/ impacts
2. fragmentation:
   - spatial arrangement of resources
   - corridors/ connectivity
3. urbanization
4. climate

Biological/ Agronomic:

1. water quality/ soil erosion and leaching
2. pesticides
3. conservation tillage/ chemical fallow
4. invasion of weedy species and exotics

Social:

1. policy:
   - taxation
   - wetland conversion
   - marginal land conservation
2. community interest in wildlife
3. influence of conservation agencies

Economic:

1. subsidies/ incentives
2. economic conditions:
   - grain price/ cattle price ratio
   - influence of grain price on marginal land conversion
3. change in minimum viable farm size

D. Diagnostic criteria (cause-effect)

Category	Cause (evaluation factor)	Effect
Physical	- Increased intensity of production	- loss of habitat as woodlands/ wetlands/ grasslands are converted to cropland - marginal land brought into production lowering its quality as habitat
	- Fragmentation	- habitat patches of wetlands/ woodlands/ grasslands become smaller and less connected
	- Urbanization	- loss of agricultural land and the habitat it provides to urban and rural development
	- Climate (Precipitation)	- seasonal variation in wetland quantity and stability
	- Shelterbelt availability	- increase in available nest cover, predator cover etc.
Biological	- Water quality/ soil erosion and leaching	- nutrient, pesticide and solid particle loading of aquatic habitats, tissue contamination, eutrophication
	- Pesticides	- impact on non-target areas and organisms
	- Conservation tillage and Chemical fallow	- increased cover on soil surface for wildlife - improved nesting opportunities - decreased erosion
Social	- Policy	- farmers bring wetlands, marginal lands into production lowering their quality as habitat
	- Community interest in wildlife/ Landowner-ethic/ influence of conservation agencies	- without landowner interest, conservation programs are less likely to be successful - increased potential for on-farm habitat enhancement
	- Taxation	- different land types are taxed at different rates; may provide incentive to put marginal land into production with hab. impact

Category	Cause (evaluation factor)	Effect
Economic	- Subsidies	- some subsidies were/are based on area in production encouraging the use of marginal lands
	- Economic conditions	- as the grain/cattle price ratio increases, farmers may bring pasture into cropland - increased grain prices also increases the profitability of bringing marginal land into production - higher grain prices also encourage farmers to switch from a more diverse farm to grain production only
	- Minimum viable farm size	- farmers buy more land and strive to make production more efficient, eliminating obstacles such as fencerows, shelterbelt and bringing more marginal land into production.
	- Market opportunity	- sectioning of farmland for housing developments (due to market opportunities) - takes land out of agriculture production with permanent impact on habitat for many species.

E. Indicators and Thresholds

Physical:

- trends in the proportion of total farmland area in:
  - cropland
  - wetland
  - woodland
  - native grassland
  - shelterbelts/ windbreaks
- trend in habitat diversity
  - richness (the number of habitat types/per farm)
  - evenness(the equitability of distribution)
- trend in habitat fragmentation
- trends in loss of farmland to urbanization

Biological:

- trends in conservation tillage use
- trends in chemical fallow use
- soil cover index (already being developed by Agri-Environmental Indicator Project)
- water quality (Phosphorous and Nitrogen concentrations are already being developed by Agri-Environmental Indicator Project, Environment Canada has data on pesticides and faecal coliform)
- grazing patterns.

Social:

- trend in adoption of best management practices for wildlife/agriculture
- rural interest in conservation of habitat on their land
- preservation of habitat through protected areas strategies
- lifestyle changes.

Economic:

- grain/ cattle price ratio (on a per acre basis)
- trend in profitability of bringing marginal land into grain production
- tax rates on different/and types.
- trend in housing development on prime agricultural land.

List of Potential Indicators for the AEI project of Agriculture and Agri-Food Canada using the Framework for Evaluating Sustainable Land Management (FESLM)

Category of indicator	Indicator
Physical	- trends in the proportion of total farmland area in: cropland, wetland, woodland, native grassland, shelterbelts/ windbreaks - trend in habitat diversity as measured by richness and evenness - trend in habitat fragmentation - trend in loss of farmland to urbanization
Biological	- trends in use of conservation tillage - trends in chemical fallow use - soil cover index - water quality
Social	- trend in adoption of best management practices for wildlife - rural interest in conservation of habitat on private land - preservation of habitat through protected areas strategies
Economic	- grain/ cattle price ratio - trend in profitability of bringing marginal land into grain production

2. ***Pressure State Response Framework*** (Organization for Economic Co-operation and Development 1993)

- the Pressure-State-Response Framework can be summarized in a series of questions:

Question	Answer	Type of indicator
1. What is happening to the state of the environment and natural resources?	Trends in physical or biological state of the world	*State*
2. Why is it happening?	Stresses or pressures causing environmental change	*Pressure*
3. What are we doing about it?	Measures of policies/actions that respond to environmental problems	*Response*

Using the Pressure State Response Framework, an example follows for the wildilfe habitat and habitat availability indicator:

A. *State* Indicators

Habitat loss: - trends in the proportion of farmland in grassland/meadow, woodland, wetland etc.
Diversity: - trends in richness and evenness of habitats
Fragmentation: - trends in fragmentation of existing high quality/ native habitat
Degradation: - pesticides in water etc.
Marginal land usage: - trends

B. *Pressure* Indicators

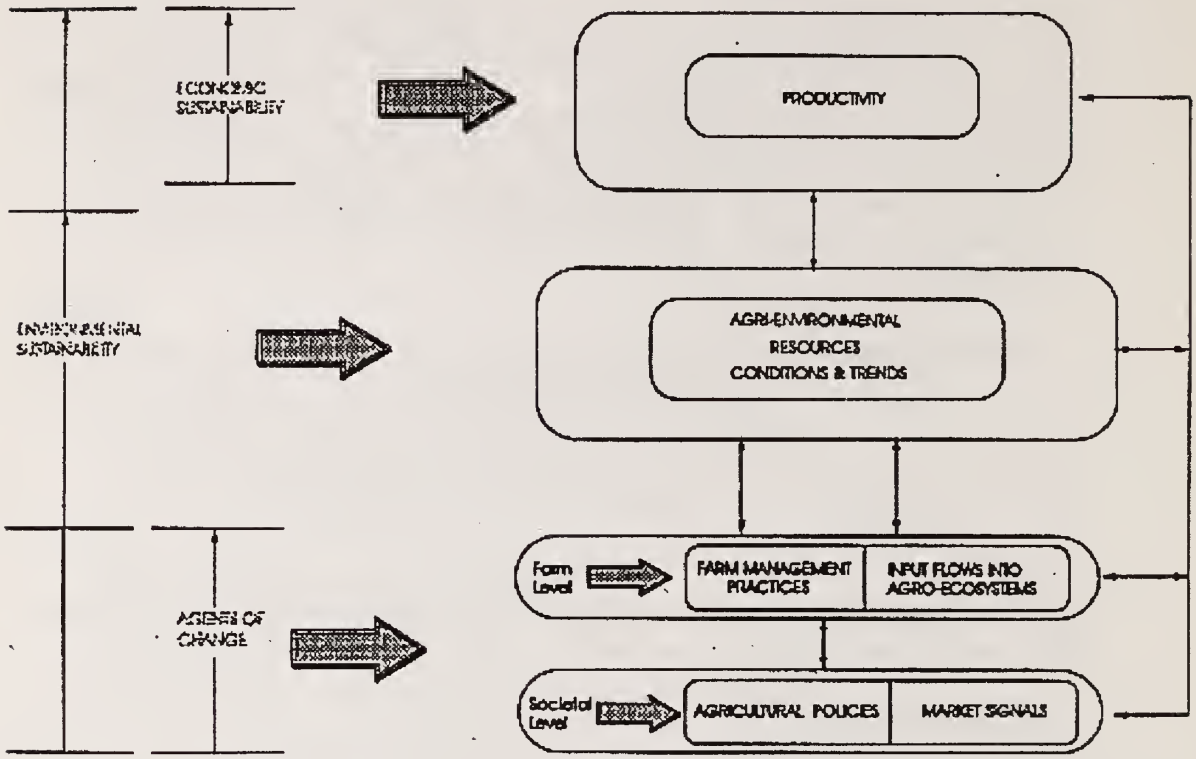
Grain prices
Trends in area of cropland as a proportion of total farmland

C. *Response* Indicators

Protected area: trends in area
Area of land / total area where habitat is conserved by landowner incentives.

Agriculture and Agri-Food Canada has developed a similar framework to the OECD Pressure State Response Framework. The Agriculture and Agri-Food Canada Framework is illustrated in Figure 22.

Figure 22. Conceptual Framework for the Agri-Environmental Indicator project (taken from McRae *et al.* 1995)



The framework is circular and based on feedback as follows:

- management decisions and practices on the farm are influenced by economic and policy signals, and the availability of technology. Decisions and practices can be beneficial or harmful to the environment (*pressure.*)
- the *state* of the resource base along with improved genetics and climate, effect farm productivity and competitiveness.
- change in resource base condition and agricultural productivity triggers societal *response*, via policy decisions and farm level management actions.

3. *Lake Superior Ecosystem Health Indicator Framework*

Lake Superior Ecosystem Health Framework (Steedman 1994)

- for the ecosystem under consideration:
    - outline a *vision*
    - use the *vision* to identify a more specific *purpose/ ecosystem objectives*
    - use the *ecosystem objectives* to develop *indicators*

Using the Lake Superior Ecosystem Health Indicator Framework, an example follows for the wildlife habitat and habitat availability indicator:

Vision:
- to maintain the quality of the wildlife habitat we currently have
- to identify critical issues of wildlife habitat and habitat availability on agricultural land
- to enhance habitat and habitat availability where needed

Purpose: using the vision to identify more specific *ecosystem objectives*
1. Reduce pressures that affect the quality of existing habitat for wildlife
2. Maintain or increase habitat diversity in the agricultural landscape (with consideration of the impacts of fragmentation)
3. Preserve a portion of the landscape as wildlife habitat

Ecosystem Objectives:
1. Reduce pressures that affect the quality of existing habitat for wildlife
   Pressure: Habitat loss
   Potential indicators: - trend in area/total farm area of woodlands / wetlands/ shelterbelts/ grassland
   - trend in cropland area/ total farm area
   - trend in soil cover
   - trend in loss of agricultural land to urban expansion

   Pressure: Habitat Fragmentation
   Potential Indicators: - connectance of patches of habitat
   - dominance of certain habitat types (e.g. cropland) (MacArthur's Broken Stick Model) (Please contact authors for information)

   Pressure: Habitat Degradation
   Potential Indicators: trends in contamination of surface water by pesticides and nutrients
   - proportion of habitat invaded by exotic species (e.g. purple loosestrife, leafy spurge, zebra mussel)

2. Maintain or increase habitat diversity in the agricultural landscape
   Potential indicators: habitat diversity
   - habitat richness/ evenness

3. Preserve a portion of the landscape as wildlife habitat
   Potential indicators: protected areas as a proportion of total farmland area
   - area of land protected under private land stewardship programs/ area of farmland.

The evaluation of these three frameworks (Framework for Evaluating Sustainable Land Management, Pressure State Response, and the Lake Superior Ecosystem Health Framework) suggest similar indicators. **However we recommend the use of the Framework for Evaluating Sustainable Land Management because:**

1. The FESLM provides for a statement of objectives and purpose

2. The FESLM provides for the development of cause-effect relationships

3. The FESLM creates indicators for the five pillars of sustainable land management, all of which are equally important in a system's sustainability.

The following Table 7 links the indicators developed using the Framework for Evaluating Sustainable Land Management (FESLM) to the 14 indicators reviewed in section IV.

Indicators 1 through 5 (section IV) are not represented in the indicators developed using the Framework for Evaluating Sustainable Land Management. Indicators 1 to 5 involve the monitoring of wildlife species whose habitat is directly impacted by agricultural practices, and changes in habitat quality and quantity are reflected in their numbers. At the moment, few of these species have been identified and there is little agreement on which species are the most appropriate. The development of the habitat suitability matrix and subsequent expert review should help identify potential species. Several species can be presented in tandem with the indicators developed using the Framework for Evaluating Sustainable Land Management. The two approaches are complementary.

4. Sensitive Species-Habitat Framework

Along with the indicators proposed in the Framework for Evaluating Sustainable Land Management, we are recommending that several wildlife species with specific habitat needs which are strongly impacted be agricultural management practices be developed as indicators. These two approaches complement each other as one is a broad approach (coarse filter) and the other is more specific (fine filter) and directly links habitat to species.

Through the interview process, we tried to identify species whose habitat is impacted directly by agricultural management practices and that would be sensitive indicators of habitat change. Most people interviewed did not want to commit to any species, and those who did, often had conflicting opinions.

We did not find a lot of information in the literature on indicator species for agriculture, however **the development of a habitat-suitability matrix for agriculture (Appendix I) would help to identify potential indicator species or guilds for various habitat types**.

Table 7. Table linking indicators developed using FESLM to the indicators reviewed in section IV

Framework for Evaluating Sustainable Management Indicator	Related reviewed indicator
1. Trend in the proportion of farmland in: - cropland - wetland - woodland - native grassland - shelterbelts/ windbreak	10. Trends in habitat loss/ habitat availability as a proportion of farmland area
2. Habitat diversity : - richness - evenness	7. Trends in habitat diversity as measured by richness and evenness
3. Fragmentation	9. Trends in fragmentation and connectedness of habitat components
4. Loss of farmland due to urbanization	10. Trends in habitat loss/ habitat availability as a proportion of farmland area
5. Trend in conservation tillage use	13. Trends in the use of agricultural practices which provide/ enhance wildlife habitat
6. Trend in chemical fallow use	13. Trends in the use of agricultural practices which provide/ enhance wildlife habitat
7. Soil cover index	13. Trends in the use of agricultural practices which provide/ enhance wildlife habitat
8. Water quality	8. Trends in habitat degradation
9. Trend in the adoption of best management practices for wildlife	13. Trends in the use of agricultural practices which provide/ enhance wildlife habitat
10. Rural interest in conservation of habitat on their land	13. Trends in agriculture practices which enhance habitat
11. Preservation of habitat through protected area strategies	6. Area, percentage and representativeness of habitat types in protected areas
12. Grain/ cattle price ratio	Potentially related to indicator # 11 (Environmental Accounting)
13. Trends in profitability of bringing marginal land into grain production	Potentially related to indicator # 11 (Environmental Accounting)

VI. Databases for Potential Use

The following **databases may be of some value in developing wildlife habitat and habitat availability indicators**. Sources, unless identified as otherwise were: Snell *et al.*1994, Statistics Canada 1994, Statistics Canada 1992. Databases are grouped by their potential use.

A. Land Stratification for Indicator Development and Presentation

1. Agriculture and Agri-Food Canada
   a) Agroecological Resource Areas: land is stratified based on crop production capability and ability to withstand risk from natural sources.
   b) Land Potential for Agriculture database: soil units are described in terms of soil characteristics, physiography, climate, agricultural potential and risk of degradation.
   c) Soil Landscapes of Canada (SLC's)
2. Environment Canada
   a) Canadian Committee on Ecological Land Classification (CCELC): Canada is divided from Ecozones down to Ecodistricts based on vegetation, physiography, soils and climate.

B. Species Population Changes/ Habitat for specific species

1. Environment Canada:
   a) Avian Census Plots
   b) Avian use of agrohabitats
   c) Breeding bird biology and habitat of prairie ducks
   d) Co-operative Breeding Bird Survey (Canadian Wildlife Service): data has been collected from 1966- present, along 250 transects
   e) Information system on the aquatic birds of Quebec
   f) May breeding population survey - waterfowl: annual aerial surveys from Ontario west in Canada and the Northern United States from 1955- present
   g) Migratory bird surveys: in prairie provinces 1965-1986
   h) Migratory game bird population status: purpose is to establish trends in population size and monitor pattern of waterfowl abundance, 1955- present, annually
   I) Prairie Habitat Monitoring Project: purpose is to provide baseline habitat information to NAWMP (North American Waterfowl Management Plan). Data on area and descriptive information on individual sample quarter sections, interpreted from air photos in the prairie provinces.
   j) Spring breeding waterfowl survey - Eastern Canada: aerial and ground surveys of waterfowl annually from 1990- present
   k) Threatened and endangered species database: examines relationship between threatened and endangered species and pesticide use
   l) Ecological Monitoring and Assessment Network (EMAN): long term monitoring and trend analysis of breeding waterfowl populations
   m) Canadian Wildlife Service: monitors trends in wildlife populations

2. Canadian Landbird Conservation Strategy: includes data on selected birds
3. Ontario Ministry of Natural Resources:
   a) Landsat-based deer habitat mapping project: maps land cover types suitable for deer habitat using landsat data
4. Breeding Bird Survey

C. Land Use / Land Cover

1. Environment Canada:
   a) Maritime Provinces Strategic Land Use database: has 21 classes of land activity, including agriculture, forestry etc. obtained through Landsat imagery for New Brunswick, Nova Scotia and Prince Edward Island in 1968 and 1987.
   b) Maritime Wetlands Inventory: wetland inventory for New Brunswick, Nova Scotia and Prince Edward Island from 1978-1988
   c) Ecological Monitoring and Assessment Network (EMAN): water fluctuations in prairie potholes
   d) Canada Land Inventory (and Ontario Land Inventory, Ontario Ministry of Natural Resources): the suitability of the land for agriculture, forestry and wildlife was estimated. Based on potential suitability, the data does not reflect actual suitability. Estimates on the degree of effort to bring the land up to its potential were made. This degree of effort might be more useful for developing indicators (K. Coleman, interview).
   e) Canadian Centre for Inland Waters
   f) Wetland inventory of Southern Ontario
2. Forestry Canada:
   a) Forest Inventory: summarizes potential inventories, GIS based, conducted for 1986, supposed to be updated every 5 years
   b) National Forestry Database Program: general forestry statistics, updated annually since 1990
3. Statistics Canada
   a) Census of Agriculture: extensive data on crops and improved lands, less data on farm wetlands, woodlands, conservation practices etc., updated every 5 years
   b) Census of Forestry: annual
5. Provincial data
   a) Prince Edward Island 1980 and 1990 Forest inventory
   b) Nova Scotia Forest Database and Forest Inventory
   c) New Brunswick Forest Inventory
   d) Quebec Census of Agriculture and Agricultural Statistics
   e) Ontario Ministry of Natural Resources:
      - Air Photo Library time series
      - Aquatic Invertebrate data
      - Biological and Conservation data system
      - Forest Resource Inventory Reports (Current and Historical)
      - Ontario Forest Resource Inventory
      - Ontario Land Inventory
      - Ontario Wildlife Information System

- Satellite imagery: land cover mapping, infrared colour photography

f) Ontario Ministry of Agriculture and Food
   - GIS Digital Map coverage

g) Manitoba water quality monitoring

h) Saskatchewan
   - Forest inventory
   - Terrestrial Wildlife Habitat Inventory: critical habitat
   - Township Inventory of Forests
   - Wildlife Habitat Protection Act Lands
   - Saskatchewan Conservation Data Centre: maps vegetation communities and occurrence of species of concern
   - Saskatchewan Wetland Conservation Corporation: waterfowl dedicated lands, wetland distribution

I) Alberta Agriculture
   - air photos
   - agricultural land base monitory study

j) Alberta Environmental Protection
   - vegetation inventory
   - avian nest data
   - environmentally significant areas

k) British Columbia Agriculture, Fisheries and Food: agricultural statistics

l) British Columbia Ministry of Environment, Lands and Parks
   - wildlife occurrence file
   - biological conservation database
   - biological database inventory
   - habitat monitoring database
   - ungulate inventory database
   - vertebrate species/ groups database

6. Ontario Hydro
   a) Forest Landscapes of Southern Ontario
      - maps woodlots and evaluates them for their "interior value" to provide input for planning
      - data on fragmentation, connectivity for the greater Toronto area
7. University of Western Ontario Forest Cover Patterns in Southwestern Ontario:
      - describes patterns of fragmentation in two case study areas
8. Ontario Ministry of Culture, Tourism and Recreation
   a) pre-settlement forest maps of southwestern Ontario
9. Ducks Unlimited
   a) project database
   b) wetlands inventory database

D. Water Quality/ Freshwater and Marine habitats

1. Environment Canada
   a) Great Lakes Water Quality Database

b) National Water Quality Database: monitors aquatic organisms, sediments, bacteria, chemical and physical properties, precipitation
c) Water Quality Branch Atlantic Region Map Inventory
2. Fisheries and Oceans
a) Contaminants database
b) Great Lakes Contaminants surveillance program
3. Provincial
a) Nova Scotia Water analysis database
b) New Brunswick Water Quality database
c) Quebec-Network for Monitoring Toxic Substances in the Aquatic Environment
d) Manitoba Water Quality Monitoring
e) Saskatchewan Water Corporation
f) Alberta Agriculture Water Quality Database
g) British Columbia Water Quality Criteria, Assessments, and Objectives

E. Protected Areas

1. Environment Canada
a) Conservation Areas Database: lists potential environmental sites across Canada with type, size, kind of protection

F. Habitat degradation

1. Environment Canada
a) Impacts of Pesticides on songbirds: pesticide contamination, reproductive success and growth rate of chicks in New Brunswick and Newfoundland from 1977-present
b) Canadian Wildlife Service: monitors contaminants in wildlife

G. Other

1. Environment Canada
a) Importance of Wildlife to Canadians (1986, 1991): attempts to assess the social and economic value of wildlife to Canadians
2. Agriculture and Agri-Food Canada
a) changes in cropping, tillage and land management practices in southwestern Ontario 1986 and 1991. Includes general information on soil conservation practices, some of which improve habitat quality. A survey of 1200 farms.
3. Ontario Ministry of Agriculture and Food
a) inventory of tile and municipal drainage systems

VII. Recommendations

From our review and assessment of existing indicator options and tools **we are recommending the following approach to developing a small set of habitat and habitat availability indicators:**

1. **Develop a habitat suitability matrix similar to that of D'Eon and Watt 1994 (Appendix 1).** This type of matrix will answer the question: habitat for what? Much of the information required to complete this matrix exists in the literature and in wildlife managers local knowledge. We have included several good review papers in our annotated bibliography. **We are recommending a literature review to complete the habitat suitability matrix followed up by an expert review of the matrix.** Part of the expert review process could be to identify possible indicator species.

2. **Develop the recommended indicators from the Framework for Evaluating Sustainable Land Management. See Table 8 for a proposed work plan.**

Table 8: Proposed Workplan

Indicator	Presentation/ Data availability	Approach to filling gaps	Next step
1. Trends in the proportion of farmland in:			
- cropland	- use Census data 1. by Ecozone (Prairie and Mixed Wood Plains could have two subzones, also Boreal Plains, Atlantic Maritime (as in Figure 10) - the benefit of this approach is that it would be easy to show long term trends or: 2. Map of trend using soil landscape units (i.e. could show percent change in cropland) - the benefit of this approach is that it would be able to focus on hotspots such as southwestern Ontario, instead of averaging entire ecoregions	- it will take some effort to match crop data from the Census of Agriculture to woodland/ wetland etc. data from other databases	- this process might be best handled initially with a pilot project in Ontario and the Prairies
- wetlands	- Ducks Unlimited database, Maritime Wetland Inventory, Wetland Inventory of Southern Ontario, Saskatchewan Wetland Conservation Corporation (presentation would be the same as cropland)		
- woodlands	- Forestry Canada Database, Provincial Forest Inventories, Census data for pre-1986 years (presentation would be the same as cropland)		
- native grasslands	- Possibly use "uninproved" pasture as a proxy, also provincial inventories		
- shelterbelts/ windbreaks	- Prairie Farm Rehabilitation Administration has data on the prairies (see Figure 24), possibility of using air photo of Ontario and Quebec		
2. Habitat diversity			
- richness	- long term trend graphs for ecozones - use Census data as a somewhat improved crop diversity on a per farm basis - find potential sources to incorporate woodland, wetland, shelterbelts in case studies	- as above	- pilot study using data from indicator 1 in case study areas
- evenness	- long term trend graphs		

Indicator	Presentation/ Data availability	Approach to filling gaps	Next step
3. Fragmentation	- may not be able to get a time trend but can compare index values to reference values (i.e. areas with relatively low fragmentation, theoretical maximums) - databases include Ontario Hydro, University of Western Ontario forest covers patterns of southwestern Ontario (2 case study areas)	- as above	- use available data for a case study in southwestern Ontario - use data organized for indicator 1 with a chosen fragmentation index for an ecozone fragmentation index
4. Loss of farmland to urbanization	- possibly Census of Agriculture data	- look for available data sources (municipal boards)	- look for available data sources (municipal boards)
5. Trend in conservation tillage use	- 1991 and 1996 Census of agriculture - map with categories of percent increase/ decrease from 1991-1996 (Figure 25)	- not applicable	- proceed with Census data
6. Trend in chemical fallow use	- 1991 and 1996 Census of agriculture - map with categories of percent increase/ decrease from 1991-1996	- not applicable	- proceed with Census data
7. Soil cover index	- already developed for the Agri-Environmental Indicator Project - data is available in the format presented in Table 9a - need to identify critical nesting periods for each ecozone (or several subzones) and critical levels of cover on crop fields for nesting birds - use these figures and data on traffic on the fields to calculate potential nesting quality (as shown in Table 9b) - this could be calculated back to 1971	- identification of critical nesting period for birds - identification of minimum nesting residue cover	- use other indicators
8. Water quality	- part of Agri-Environmental Indicator Project - data on pesticides and shellfish contamination available from Environment Canada	- not applicable	- use other indicators
9. Trend in adoption of best management strategies for wildlife habitat	- might be limited to certain study areas - data: Ontario/ Agriculture Canada Best Management Practices for Wildlife Habitat and Environmental Farm Plans - NAWMP, Ducks Unlimited	- look for other data sources	- proceed with development of case studies

Indicator	Presentation/ Data availability	Approach to filling gaps	Next step
10. Rural interest in conservation of wildlife habitat	- might be limited to certain study area, several one time studies are available (Wildlife Habitat Conservation Study, NAWMP survey of Sask. Farmers 1990) - may be difficult to get data for an indicator (time trend), data is also scattered across the country	- look for other data sources	- data might be best presented as supplemental information for the habitat indicator
11. Preservation of habitat through protected areas strategies	- PFRA, Environment Canada: Conservation Areas Database, Ducks Unlimited, Carolinian Canada, Conservation Authorities - could present by ecozone (or subzone) as proportion of total farmland where habitat is protected	- pool all data - assess provincial data	
12. Grain/ cattle price ratio	- PFRA, Wheat Board and Provincial data (Figure 26)		
13. Trends in profitability of bringing marginal land into production	- data on subsidies (production, drainage), grain prices, grain price/ cattle price ratio - compare proportion of land that is cultivated and environmentally or economically sustainable with time		- compare wheat price trends with gross margin on CLI class 1-3 and 4-7 lands (Figure 27) in case study areas

Figure 23. Prairie Shelterbelt Miles (taken from PFRA 1996a)

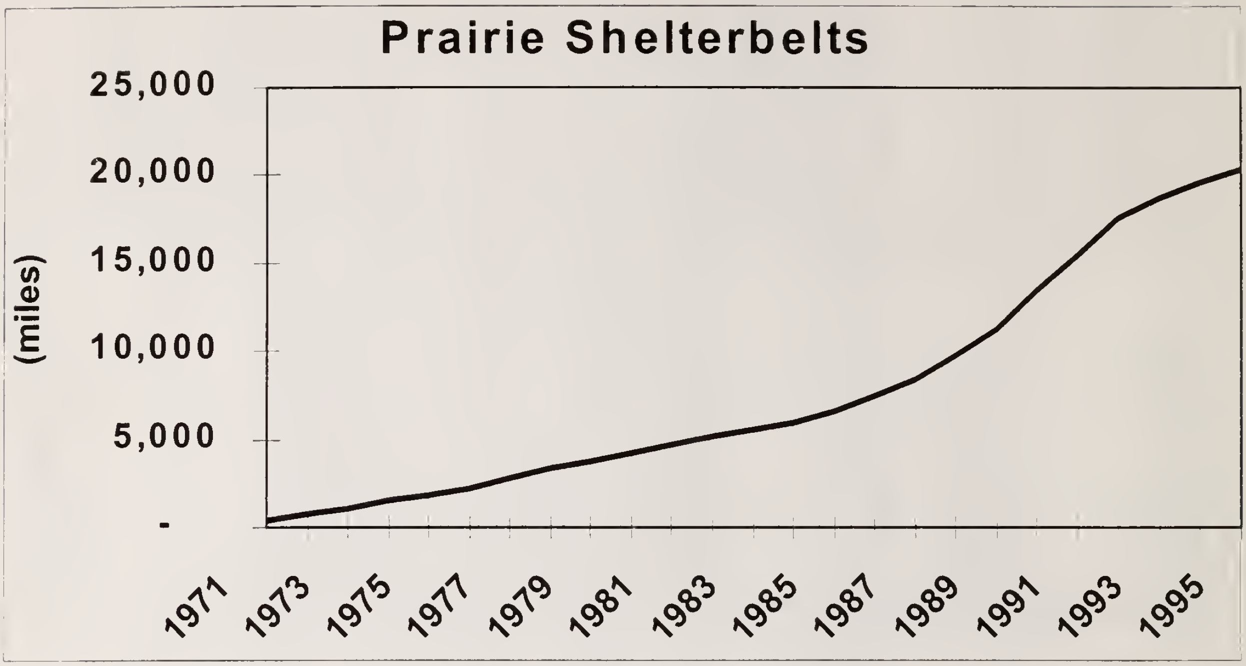


Figure 24. Map showing the Proportion of Cropland under Conservation Tillage in the Canadian Prairies (Neave *et al.* 1995)

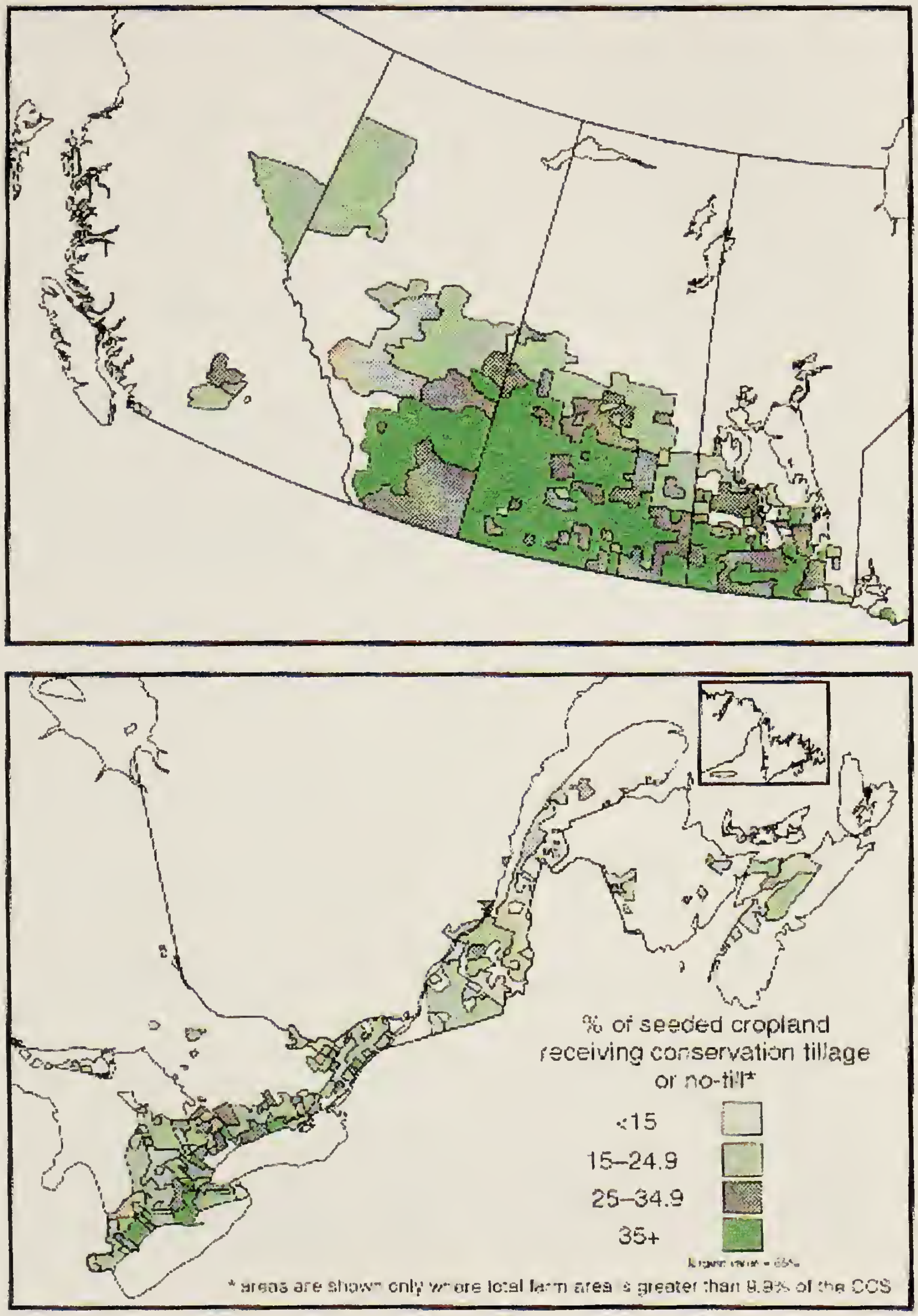


Table 9a. Data from the soil cover indicator component of the AEI project (courtesy of Dr. T. Huffman)

	132		Region:	Ottawa	
Practice:	conventio	(fall plow)			
Crop:	soybeans				
	Date	Day	%Cover	ElapsTim	BS Days
SpringTh	15-Mar	74	3	83	0
PreplantC	10-May	130	0	56	54
Planting	17-May	137	0	7	7
10% Canc	01-Jun	152	10	15	15
50% Canc	15-Jun	166	50	14	13
75% Canc	01-Jul	182	75	16	8
Max Canc	15-Jul	196	90	14	4
Harvest	07-Oct	280	20	84	8
Fall Tillag	10-Oct	283	5	3	2
Freeze Up	22-Dec	356	100	73	69
					181

	132		Region:	Ottawa	
Practice:	conventional				
Crop:	beans	(as vegetable)			
	Date	Day	%Cover	ElapsTim	BS Days
SpringTh	15-Mar	74	0	83	0
PreplantC	20-May	140	0	66	66
Planting	10-Jun	161	0	21	21
10% Canc	30-Jun	181	10	20	20
50% Canc	15-Jul	196	50	15	14
75% Canc	30-Jul	211	75	15	8
Max Canc	15-Aug	227	80	16	4
Harvest	25-Sep	268	25	41	8
Fall Tillag	10-Oct	283	0	15	11
Freeze Up	22-Dec	356	100	73	73
					224

	132		Region:	Ottawa	
Practice:	conventio	(straw baled, fall plow or disc)			
Crop:	grain	(barley, oats, wheat)			
	Date	Day	%Cover	ElapsTim	BS Days
SpringTh	15-Mar	74	1.5	83	0
PreplantC	25-Apr	115	0	41	40
Planting	25-Apr	115	0	0	0
10% Canc	10-May	130	10	15	15
50% Canc	22-May	142	50	12	11
75% Canc	01-Jun	152	75	10	5
Max Canc	12-Jun	163	90	11	3
Harvest	07-Aug	219	50	56	6
Fall Tillag	10-Sep	253	5	34	17
Freeze Up	22-Dec	356	100	103	98
					194

	132		Region:	Ottawa	
Practice:	conservation				
Crop:	grain				
	Date	Day	%Cover	ElapsTim	BS Days
SpringTh	15-Mar	74	30	83	0
PreplantC	25-Apr	115	15	41	29
Planting	25-Apr	115	5	0	0
10% Canc	10-May	130	15	15	14
50% Canc	22-May	142	50	12	10
75% Canc	01-Jun	152	75	10	5
Max Canc	12-Jun	163	90	11	3
Harvest	07-Aug	219	50	56	6
Fall Tillag	10-Sep	253	35	34	17
Freeze Up	22-Dec	356	100	103	87
					150

Table 9b. Example of how to calculate potential nesting quality (related to the soil cover index)(here we assume that critical nesting residue cover was 30 % and that the critical no-traffic period is April 25-May 20)

> 30 % residue cover	Traffic on field from Apr.25 to May 20	Potential nesting habitat quality
no	no	poor
yes	no	high
no	yes	moderate
yes	yes	moderate

Figure 25. Trend in Grain and Cattle Price, 1959-1995 (taken from PFRA 1996a)

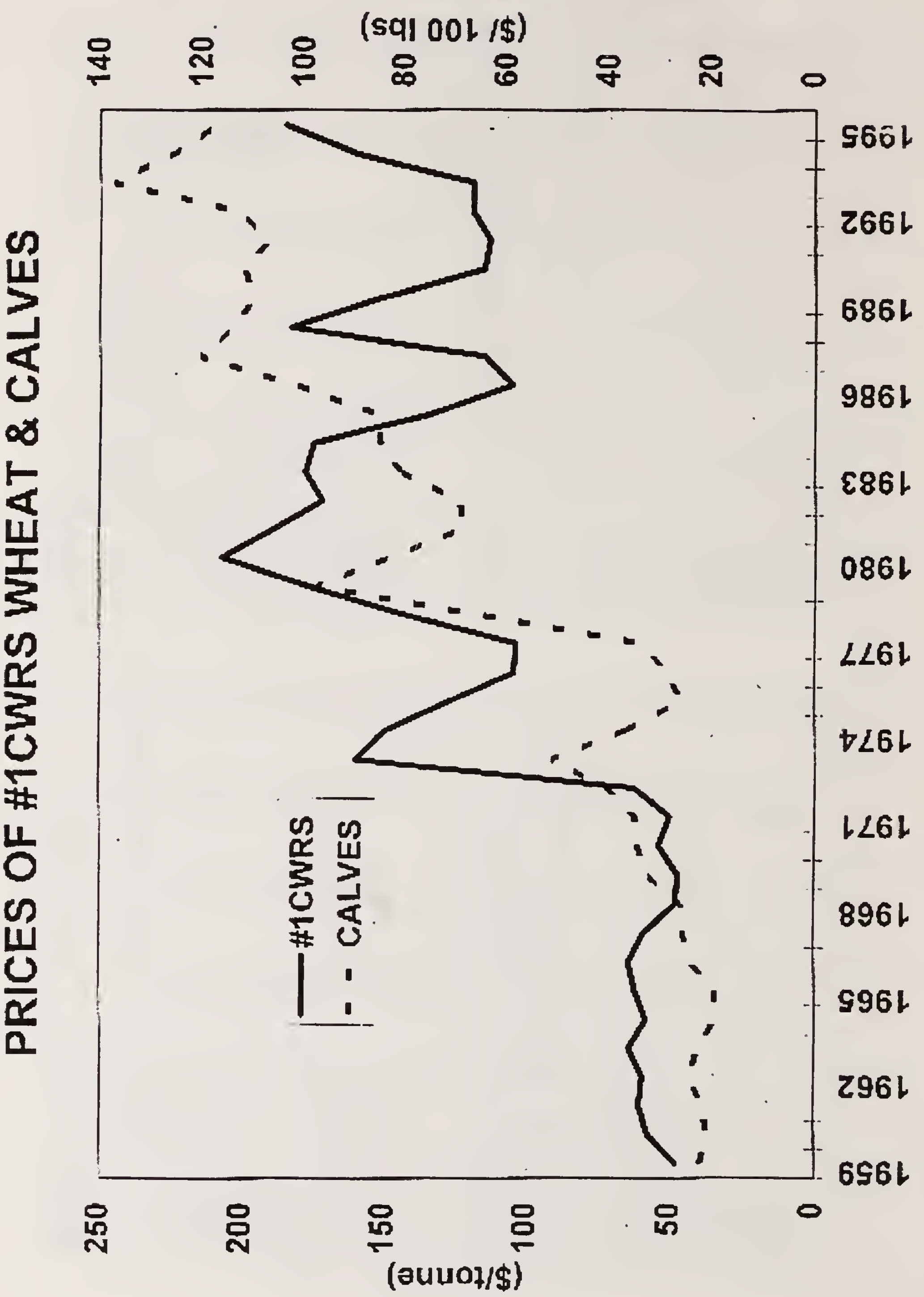
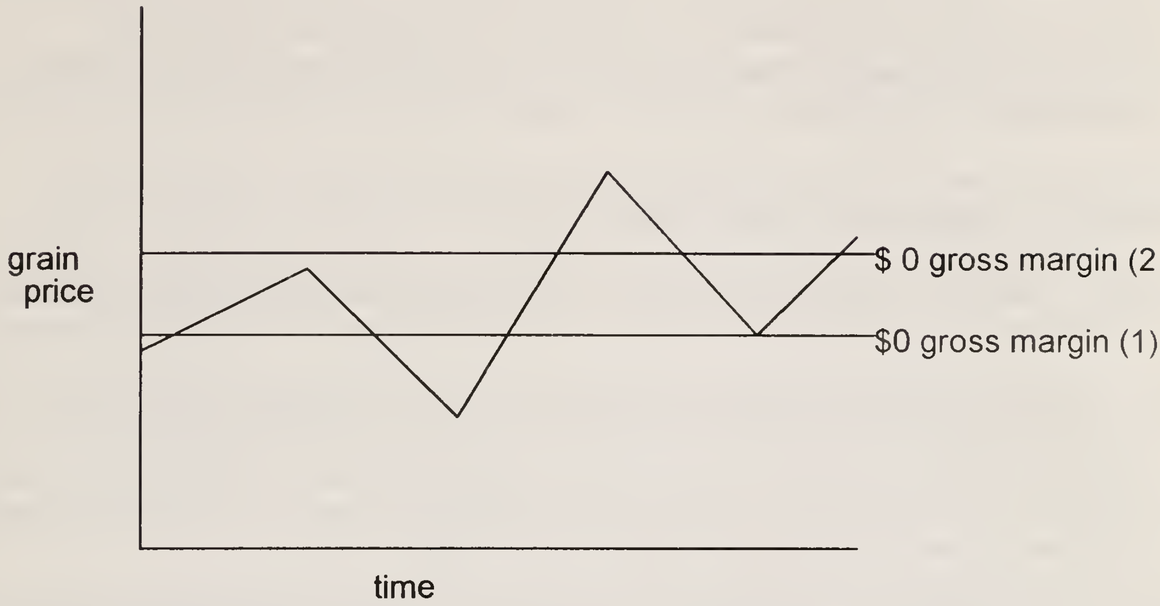


Figure 26. Trend in grain prices with thresholds (example)



1. Canada Land Inventory class I-III: good- high quality land
2. Canada Land Inventory class IV-VII: low to marginal quality

- Gross margin can also be calculated for study areas with and without subsidy payments

- Gross margin calculated yearly or adjusted for inflation

Grain price is compared to the $0 gross margin for high and low quality land. When grain prices is above the gross margin, the farming system is more economically sustainable. When gain price is above the $0 gross margin for low quality land, there will be increased pressure to convert these marginal lands to cropland.

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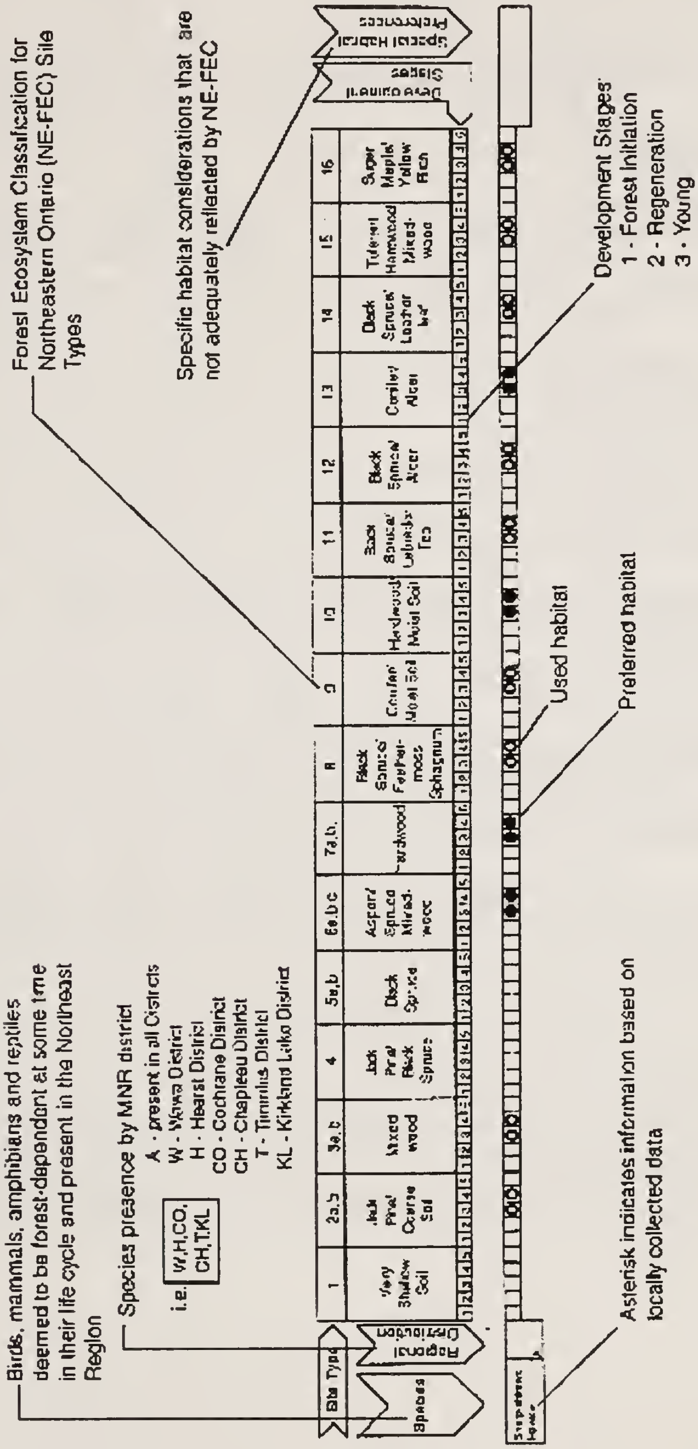
Appendices

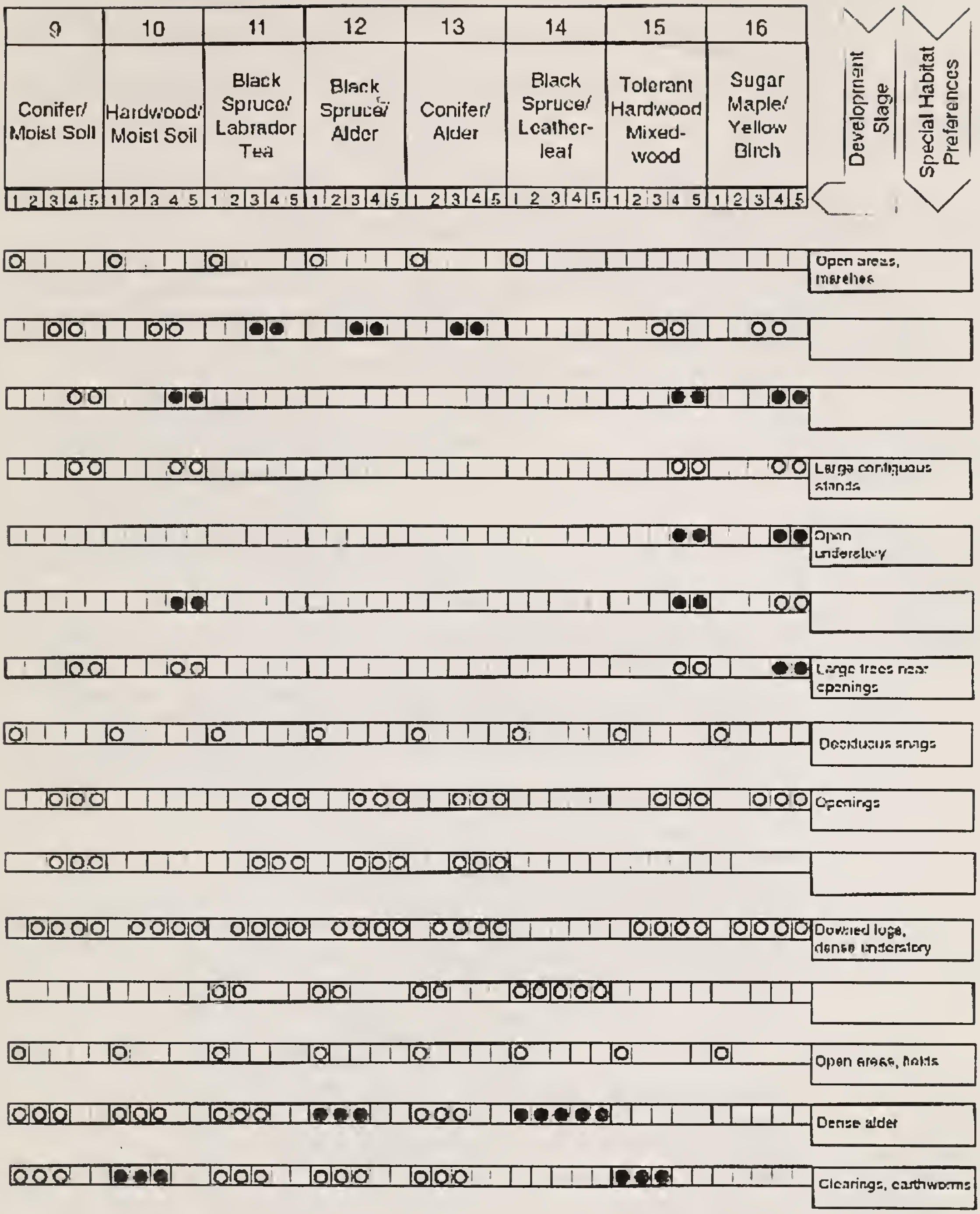
Appendix I: Example of a Habitat Suitability Matrix for Forest Habitat in North-Eastern Ontario (includes legend to symbols and columns and two pages of the matrix for birds) (taken from D'Eon and Watt 1994)

Legend



Species	Regional Distribution	1 Very Shallow Soil	2a,b Jack Pine/ Coarse Soil	3a,b Mixed-wood	4 Jack Pine/ Black Spruce	5a,b Black Spruce	6a,b,c Aspen/ Spruce Mixed-wood	7a,b, Hardwood	8 Black Spruce/ Feather-moss Sphagnum
Northern Harrier	A							○	○
Sharp-shinned Hawk	A		○○	○○	●●	●●	○○	○○	●●
Cooper's Hawk	W CH,T,KL	○○	○○	○○	○○	○○	○○	○○	
Northern Goshawk	A	○○	○○	○○	○○	○○	○○	○○	○○
Red-shouldered Hawk	KL								
Broad-winged Hawk	A			○○				○○	
Red-tailed Hawk	A	●●	●●	●●	●●	●●	●●	●●	○○
American Kestrel	A	○	○	●	○	○	●	●	○
Merlin	A	○○○	○○○	○○○	○○○	○○○	○○○	○○○	○○○
Spruce Grouse	A	○○○	●●○	○○○	○○○	○○○	○○○		
Ruffed Grouse	A			●●●●	○○○○	○○○○	○○○○	●●●●	○○○○
Sharp-tailed Grouse	H,CO T								
Killdeer	A	○	○	○	○	○	○	○	○
Common Snipe	A							○○○	○○○
American Woodcock	A							○○○	○○○

Part 1 of 2



9 Conifer/ Moist Soil
10 Hardwood/ Moist Soil
11 Black Spruce/ Labrador Tea
12 Black Spruce/ Alder
13 Conifer/ Alder
14 Black Spruce/ Leather-leaf
15 Tolerant Hardwood Mixed-wood
16 Sugar Maple/ Yellow Birch
1 2 3 4 5
Development Stage
Special Habitat Preferences
Open areas, marshes
Large contiguous stands
Open understory
Large trees near openings
Deciduous snags
Openings
Downed logs, dense understory
Open areas, fields
Dense alder
Clearings, earthworms

Part 2 of 2

Appendix II. Summary of interview results and list of participants

Question	Answers	Notes
1. How would you define:		
Habitat	- traditional, simple definition of food, water cover, territory (space) - the requirement and availability of resources through time and space - the location where plants and animals can survive and live - elements of the landscape that can provide wildlife with the support system they need to survive and reproduce successfully	- there are critical components of habitat (i.e. nesting, staging habitats) - there is an operational problem with the definition of habitat as it can be defined by geographical (sites), functional (critical elements) or ecological (eco-systems) approaches - all agricultural land provides some habitat/ habitat potential - some participants consider remaining natural habitat (i.e. woodlands, wetlands, native grassland) to be the best habitat quality
Habitat Availability	- a species by species issue, each species needs will be different - each species requires a combination of food/ water/ cover/ territory and the distribution of these factors across the landscape is habitat availability - refers to the value or quality of habitat in terms of availability, access, surroundings, functionality, mix of habitats, links - some participants suggested that this is related to the percent native or near native species - undisturbed lands may be the best habitat but cultivated lands can provide some habitat attributes - quality and quantity of components of habitat	- quality of habitat is the critical issue here - issues such as fragmentation, location, connectivity, juxtaposition of habitat elements came into the discussion here
2. What factors determine habitat availability on agricultural landscapes? and what are the critical issues affecting habitat availability on agricultural landscapes?	- absence of ecological disturbances - natural variations in climate (moisture conditions, temperature) - presence of natural features (geology, soils, drainage patterns) - human activities: - cultivating and clearing land - roads - drainage systems/ wetland drainage - erosion - grazing intensity - use of marginal land	

Question	Answers	Notes
Question # 2 continued	- overgrazing of areas left in trees - urban development	- removal of habitat for one organism makes habitat for another
	- type of crop/ farm operation - improvements in farm machinery	- you will get shifts in species composition with every disturbance
	- planting shelterbelts/ windbreaks - intensity of land use - frequency of activity - historical land use patterns	-locally a critical issue such as cover may be limiting, however on a landscape scale the issue would be continuity across the landscape
	- quality of agricultural land - field size increases - monocultures versus mixed farming	- only the poorer classes of land still have abundant habitat (i.e. Eastern Ontario
	- landuse policy - subsidies - tax policy - economic conditions dictate the amount of grassland put into or taken out of production - market prices of grain/ oil seeds vs livestock - land owner attitudes/ ethic - influence of conservation agencies - proximity of food to cover (spatial arrangement of resources - species behavioural patterns in response to the landscape - species life stage - biological processes (predation, competition, parasitism) - highland habitat or corridors for wildlife - size of area (patch), perimeter of area, corridors - quality and stability of patches - invasion of weedy and exotic species - barriers to dispersal - pesticide contamination - contamination of aquatic habitats - siltation of wetlands - species extinction through habitat loss - soil degradation	- in Canada we have a "frontier policy framework" where it is perceived to be good to develop your land and make it more productive
3. How would you summarize these issues in the form of an indicator?	- mix of habitat types (pasture, prairie, woodland, wetland, etc.) - water quality - landscape change with time - roads (length/area, density/ area) - change in wetland numbers with time - number of acres of native prairie remaining	- could define what you would like a landscape to look like and measure progress towards this goal

Question	Answers	Notes
Question #3 continued	- change in land use cover (i.e. perennial vs. annual crops)	
	- levels of pesticides/ contaminants in water systems	
	- rate of habitat conversion	
	- proportion of natural unused land vs. land in production	
	- abundance and distribution of native or near native habitats	
	- classes and abundances of wetland types	
	- number of windbreaks, shelterbelts	
	- measure of connectivity of woodlots/ shelterbelts/ etc.	
	- a single simple indicator: percent of the landscape in non-farmed permanent cover, dominated by grasses - community interest in wildlife - recreational use of an area (intensity will impact, but also use by naturalists, bird watchers will be an indication of the presence of wildlife in the area) - farm resource policy - habitat distribution (patch size, connectivity, configuration)	- a threshold was suggested to be between 5 and 10 % of the landscape managed in permanent cover will give good potential for wildlife on the landscape - some participants stressed the need to set targets/ thresholds - we need to know what it is that we would prefer to see happen - there is a need for some public consensus as to what they want
	- width of buffer zones/ field borders	
	- habitat quality X habitat quantity index	- quantity estimated from the Census data (cropland, grassland, unimproved land) - quality harder to estimate, possibly number of species
	- soil cover indicator as a proxy for habitat availability (tracking change in land use)	
	- guilds of species - body weight as an indicator of habitat quality	- if these species are there in good numbers, then the variability of habitats are there also)
	- number and extent of exotic species - managing for top predators	- illustrating the level of degradation of the landscape
	- rate of spread of trees into grassland areas	
	- overall numbers of breeding populations of ducks	
	- change in species populations - species diversity and abundance - diversity of successional stages of plant communities - endangered species populations - link a potential indicator group to a land cover type (i.e. marsh birds for wetlands) - insect production out of small potholes/ wetlands - white-tailed deer beam diameter as an indication of habitat quality	- there was a lot of criticism of species based indicators as they may not be a fair indicator of habitat change in a certain area (possibly indicating change along a migratory route, etc.) - there is also the problem of establishing what is good or bad (an increase in the population of one species may occur at the same time as a decrease in another) - also a problem in separating out natural population fluctuations

Question	Answers	Notes
4. What data is necessary and available to support these indicators?	- property taxation data	- 5 year farm land appraisal, maps land in different uses on each quarter section
	- Canada Land Inventory	
	- Census of Agriculture	
	- Ecological Framework	
	- LANDSAT imagery	
	- Manitoba State of the Environment Report	
	- wildlife habitat inventories (CLI, O LI)	
	- Ontario Ministry of Agriculture and Food and Agriculture Canada's soils maps	
	- Physiography of Southern Ontario maps	
	- Climate maps and Moisture maps	
	- Climate models (Dan McKenny Forestry Canada)	
	- Habitat suitability matrix	
	- Conservation Data Centres	
	- Wetland Satellite Inventories	- Ducks Unlimited has done priority areas
	- Representative Areas Network (RAN) Saskatchewan Environment and Resource Management)	
	- Canadian Wildlife Service waterfowl population data since 1955	
	- Duck Unlimited Wetland Inventory (in digital format for prairie pothole region)	
	- Saskatchewan Research Council (SRC) Satellite data	
	- Saskatchewan Conservation Data Centre	
	- number of May ponds (Canadian Wildlife Service)	
	- pond classification (Canadian Wildlife Service)	
	- Agriculture & Agri-Food Canada (PFRA) Permanent Cover Program	
	- U.S. Conservation Reserve Program	
	- State of the Environment Report for Saskatchewan	
	- Ducks Unlimited data on ~5000 projects	- aggregated to soil polygons of Canada on a point file basis
	- Duck Unlimited wetlands habitat inventory	
	- Ontario Land Cover mapping	
	- Canada Land Use Monitoring Program	
	- SWEEP data mapping watersheds	
	- NAWMP Prairie Pothole Wetland Mapping	
5. Are you aware of any current initiatives related to this topic?	- Ducks Unlimited evaluation of NAWMP lands using satellite imagery	
	- Partners in Flight program monitoring changes in species and mapping critical habitat areas	
	- Critical Habitat Program (Manitoba)	
	- Endangered species programs	
	- Alberta Environmental Protection: Alberta's State of the Environment Comprehensive Report	
	- Ecological Monitoring and Assessment Network (EMAN)	
	- OECD work in United States and Switzerland developing habitat indicators	
	- Prairie Conservation Action Plan: 5 year plans to protect and enhance native prairie	
	- Saskatchewan Wetland Conservation Corporation: Prairie Stewardship Programs	

Question	Answers	Notes
Question #5 continued	- Crown Land in Saskatchewan: 3 million acres under the Wildlife Habitat Protection Act - Protected areas networks - Conservation easement legislation - Conservation Reserve Program (CRP) of the USDA	

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