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Report No. 1-15

A Literature Review of Risks and Benefits of Agriculture to Biodiversity and Biodiversity to Agriculture



Technical Series 2005

Photos:

Bottom Left- clockwise

Fraser Valley near Abbotsford, B.C.: Wayne Belzer, Pacific Yukon Region, Environment Canada

Crop spraying: Corel CD photo # 95C2840

Elk Creek, BC: Joseph Culp, National Water Research Institute, Environment Canada

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**A LITERATURE REVIEW OF RISKS AND BENEFITS OF
AGRICULTURE TO BIODIVERSITY AND BIODIVERSITY TO
AGRICULTURE**

Report No. 1-15

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NOTE TO READERS

The National Agri-Environmental Standards Initiative (NAESI) is a four-year (2004-2008) project between Environment Canada (EC) and Agriculture and Agri-Food Canada (AAFC) and is one of many initiatives under AAFC's Agriculture Policy Framework (APF). The goals of the National Agri-Environmental Standards Initiative include:

- Establishing non-regulatory national environmental performance standards (with regional application) that support common EC and AAFC goals for the environment
- Evaluating standards attainable by environmentally-beneficial agricultural production and management practices; and
- Increasing understanding of relationships between agriculture and the environment.

Under NAESI, agri-environmental performance standards (i.e., outcome-based standards) will be established that identify both desired levels of environmental condition and levels considered achievable based on available technology and practice. These standards will be integrated by AAFC into beneficial agricultural management systems and practices to help reduce environmental risks. Additionally, these will provide benefits to the health and supply of water, health of soils, health of air and the atmosphere; and ensure compatibility between biodiversity and agriculture. Standards are being developed in four thematic areas: Air, Biodiversity, Pesticides, and Water. Outcomes from NAESI will contribute to the APF goals of improved stewardship by agricultural producers of land, water, air and biodiversity and increased Canadian and international confidence that food from the Canadian agriculture and food sector is being produced in a safe and environmentally sound manner.

The development of agri-environmental performance standards involves science-based assessments of relative risk and the determination of desired environmental quality. As such, the National Agri-Environmental Standards Initiative (NAESI) Technical Series is dedicated to the consolidation and dissemination of the scientific knowledge, information, and tools produced through this program that will be used by Environment Canada as the scientific basis for the development and delivery of environmental performance standards. Reports in the Technical Series are available in the language (English or French) in which they were originally prepared and represent theme-specific deliverables. As the intention of this series is to provide an easily navigable and consolidated means of reporting on NAESI's yearly activities and progress, the detailed findings summarized in this series may, in fact, be published elsewhere, for example, as scientific papers in peer-reviewed journals.

This report provides scientific information to partially fulfill deliverables under the Biodiversity Theme of NAESI. This report was written by E. Neave. The report was edited and formatted by Denise Davy to meet the criteria of the NAESI Technical Series. The information in this document is current as of when the document was originally prepared. For additional information regarding this publication, please contact:

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NOTE À L'INTENTION DES LECTEURS

L'Initiative nationale d'élaboration de normes agroenvironnementales (INENA) est un projet de quatre ans (2004-2008) mené conjointement par Environnement Canada (EC) et Agriculture et Agroalimentaire Canada (AAC) et l'une des nombreuses initiatives qui s'inscrit dans le Cadre stratégique pour l'agriculture (CSA) d'AAC. Elle a notamment comme objectifs :

- d'établir des normes nationales de rendement environnemental non réglementaires (applicables dans les régions) qui soutiennent les objectifs communs d'EC et d'AAC en ce qui concerne l'environnement;
- d'évaluer des normes qui sont réalisables par des pratiques de production et de gestion agricoles avantageuses pour l'environnement;
- de faire mieux comprendre les liens entre l'agriculture et l'environnement.

Dans le cadre de l'INENA, des normes de rendement agroenvironnementales (c.-à-d. des normes axées sur les résultats) seront établies pour déterminer les niveaux de qualité environnementale souhaités et les niveaux considérés comme réalisables au moyen des meilleures technologies et pratiques disponibles. AAC intégrera ces normes dans des systèmes et pratiques de gestion bénéfiques en agriculture afin d'aider à réduire les risques pour l'environnement. De plus, elles amélioreront l'approvisionnement en eau et la qualité de celle-ci, la qualité des sols et celle de l'air et de l'atmosphère, et assureront la compatibilité entre la biodiversité et l'agriculture. Des normes sont en voie d'être élaborées dans quatre domaines thématiques : l'air, la biodiversité, les pesticides et l'eau. Les résultats de l'INENA contribueront aux objectifs du CSA, soit d'améliorer la gérance des terres, de l'eau, de l'air et de la biodiversité par les producteurs agricoles et d'accroître la confiance du Canada et d'autres pays dans le fait que les aliments produits par les agriculteurs et le secteur de l'alimentation du Canada le sont d'une manière sécuritaire et soucieuse de l'environnement.

L'élaboration de normes de rendement agroenvironnementales comporte des évaluations scientifiques des risques relatifs et la détermination de la qualité environnementale souhaitée. Comme telle, la Série technique de l'INENA vise à regrouper et diffuser les connaissances, les informations et les outils scientifiques qui sont produits grâce à ce programme et dont Environnement Canada se servira comme fondement scientifique afin d'élaborer et de transmettre des normes de rendement environnemental. Les rapports compris dans la Série technique sont disponibles dans la langue (français ou anglais) dans laquelle ils ont été rédigés au départ et constituent des réalisations attendues propres à un thème en particulier. Comme cette série a pour objectif de fournir un moyen intégré et facile à consulter de faire rapport sur les activités et les progrès réalisés durant l'année dans le cadre de l'INENA, les conclusions détaillées qui sont résumées dans la série peuvent, en fait, être publiées ailleurs comme sous forme d'articles scientifiques de journaux soumis à l'évaluation par les pairs.

Le présent rapport fournit des données scientifiques afin de produire en partie les réalisations attendues pour le thème de la biodiversité dans le cadre de l'INENA. Ce rapport a été rédigé par E. Neave. De plus, il a été révisé et formaté par Denise Davy selon les critères établis pour la Série technique de l'INENA. L'information contenue dans ce document était à jour au moment de sa rédaction. Pour plus de renseignements sur cette publication, veuillez communiquer avec l'organisme suivant :

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TABLE OF CONTENTS

NOTE TO READERS.....	I
NOTE À L'INTENTION DES LECTEURS.....	II
TABLE OF CONTENTS.....	3
LIST OF TABLES	4
LIST OF APPENDICES.....	5
INTRODUCTION.....	6
SCOPE OF THE ASSESSMENT	8
A BRIEF PERSPECTIVE ON AGRICULTURE IN CANADA.....	9
ANALYSIS.....	17
ANALYSIS OF FARM RISK AND/OR BENEFIT TO BIODIVERSITY	18
<i>Native Habitats</i>	18
<i>Farm Field Management</i>	29
<i>Grazing</i>	35
<i>Pesticide Contamination</i>	41
<i>Nutrient Contamination</i>	48
<i>Siltation/ Sedimentation</i>	57
<i>Genetically Modified Crops</i>	62
<i>Agricultural Intensification</i>	69
<i>Invasive Species</i>	77
<i>Diseases</i>	85
<i>Wildlife Damage</i>	90
<i>Ecological Services</i>	95
OBSERVATIONS AND CONCLUSIONS	101
REFERENCES.....	104
APPENDICES	138

LIST OF TABLES

TABLE 1: TOP FIVE FIELD CROPS BY AREA BY PROVINCE AND LIVESTOCK NUMBER BY PROVINCE FROM THE 2001 CENSUS OF AGRICULTURE (STATISTICS CANADA 2001) 12

TABLE 2: FARM ELEMENTS WITH POTENTIAL IMPACT BIODIVERSITY 15

TABLE 3: 1997 ESTIMATED VALUE OF WILDLIFE DAMAGE (\$000) (CANADIAN FEDERATION OF AGRICULTURE AND WILDLIFE HABITAT CANADA 1998) 91

LIST OF APPENDICES

APPENDIX A: DATABASE STRUCTURE.....	138
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INTRODUCTION

This assessment examines the documented and potential interactions between agricultural practices and biodiversity in order to identify those with the greatest impact and posing greatest risk. The goal of the Environment Chapter, under the Agricultural Policy Framework is to decrease risk and increase benefits of agriculture to air, water, biodiversity and soil (environmental themes). Environment Canada (EC) has signed an MOU with Agriculture and Agri-Food Canada (AAFC) to develop Agri-environmental standards within a four year time period. The National Agri-environmental Standards Initiative (NAESI) is the EC program to set performance standards, for agriculture, that address each of the environmental themes. A working group has been established for each environmental theme. This project is part of the work plan for the Biodiversity Thematic Group and will serve as background information in developing voluntary environmental performance standards for agriculture in Canada.

The adoption of biodiversity conservation measures within different agricultural landscapes across Canada has been guided by the Canadian Biodiversity Strategy (1995) and the Agriculture and Agri-Food Canada Biodiversity in Agriculture Action Plan (1997). These strategies have provided direction and commitment but have also identified the complexity of addressing biodiversity issues. To assess the extent of risk and benefits between biodiversity and agriculture, this review had to address the following dimensions of biodiversity conservation:

- the inter-relationship among community, species and genetic diversity often within a very modified landscape that includes terrestrial and aquatic habitats;
- underlying issues of fragmentation, connectivity and ecological integrity across these modified landscapes;

- the extent of stability and/or resilience within a ecosystem that can maintain biodiversity;
- temporal and spatial scale issues around fixed agricultural events; and,
- the cumulative impacts of agricultural practices as well as by other land uses across the landscape.

While agricultural practices continue to have a major influence on native biodiversity within Canada's southern landscapes, the extent of farmland has not changed appreciably since the 1950s. However periods of agricultural intensification continue to occur due to changes in commodity prices often at the expense of remnant habitats and with impacts on aquatic ecosystems. Farmland can provide resources and habitat for wildlife, and while many native species have been adversely affected by agricultural-induced changes on the landscape, many others (often "game" species) have benefited from the combination of loss of predators and abundance of food (Neave et al. 2000).

With the growing recognition of the importance of biodiversity as the foundation of sustainable agriculture and appreciation that farmers are stewards of the land, there is an opportunity to establish and achieve goals for biodiversity conservation. It is unlikely that managers should or could restore the full complement of native habitats and diversity of species on the agricultural landscape, but goals should be established that ensure sufficient natural habitats are maintained on all farmland to maintain natural ecological processes. The mix of interest, programs and knowledge of mitigative measures indicates that farmers can play a positive role in biodiversity conservation.

SCOPE OF THE ASSESSMENT

The terms of reference of this review were to “analyze and summarize, in both report and searchable database format, current information that is relevant to the assessment of risk to biodiversity from agriculture and risk to agriculture from elements of biodiversity”. This report therefore provides an assessment of the current literature regarding the nature and severity of positive as well as negative effects in different agricultural regions of Canada. This assessment builds on the agricultural section within the Biodiversity Science Assessment completed for Environment Canada in 1994. Other, similar work is currently being developed associated with the NAESI program including a species at risk assessment which examines: the extent that species ranges overlap with agricultural land use; primary, secondary and contributing threats relating to agricultural land use; habitat requirements; mitigation strategies and extent of application; and information gaps. Environmental scans, which identify key issues and risks to biodiversity in agricultural landscapes on a regional basis, are also completed (or underway) in every province.

The framework for the literature report and the companion searchable database (see the database structure in Appendix 1) examines the ‘end points’ of farm production practices in each agricultural region. For example, the intensification of farm practices is not the actual impact on biodiversity. An end point is land conversion that results in fragmentation, habitat degradation and disappearance of species. The report also synthesizes information on the severity of impacts, type and degree of use of mitigative measures and future research needs. This format permits a subjective assessment of the current degree of risk facing biodiversity and/or agriculture producers.

While this assessment is drawn from the current literature, it is important to recognize the diversity of agricultural producers and biodiversity issues across Canada. It is very easy to generalize but equally very difficult to understand the interactions, prioritize risks and define responsible mitigative measures. Consider the following:

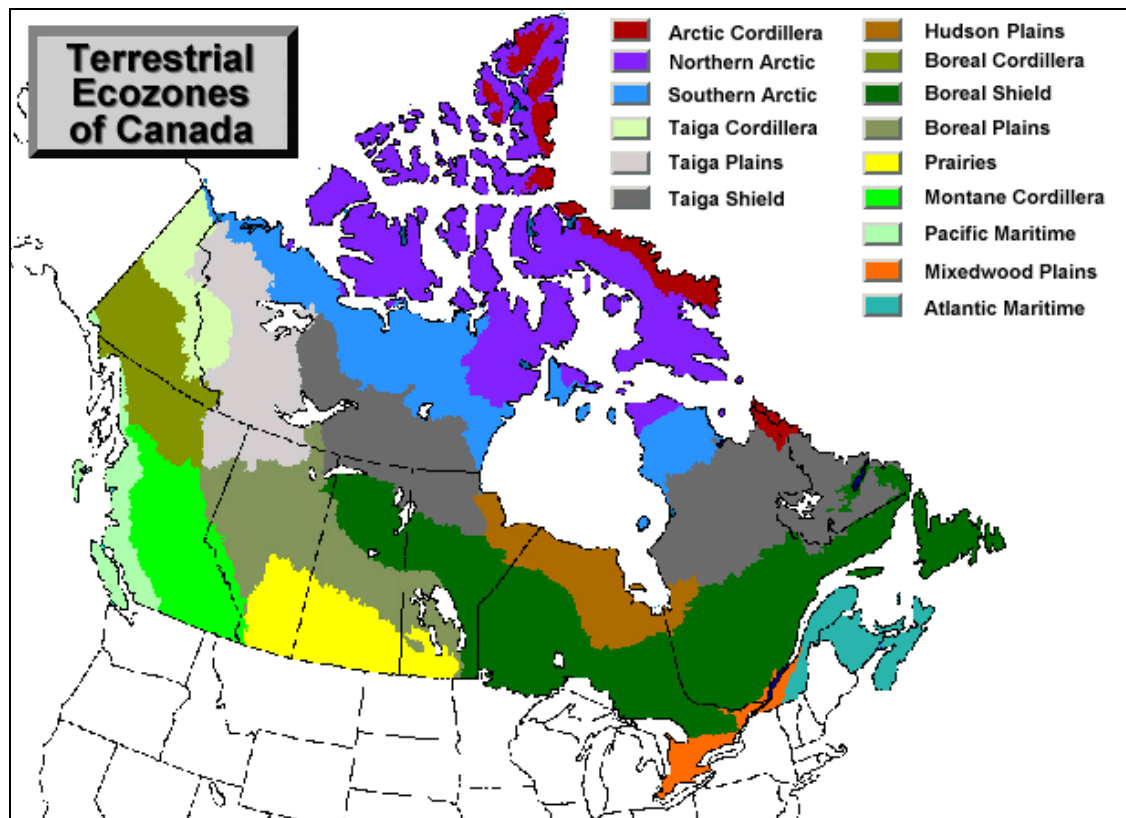
- 80% of the agricultural land base is within one region of the country;
- much of Canada's prime agricultural land (and prime habitat) is disappearing under urban sprawl;
- the explanation for the extensive decline of many bird populations on agricultural areas in Canada (the bulk of scientific biodiversity information) is complex as southern wintering habitats are often degraded;
- there is a great diversity of opinion within the farm community on the interpretation and acceptance of ensuring that "reasonable" mitigative measures are implemented;
- federal and provincial policies and incentives are still largely production based and maintain practices that degrade biodiversity on the landscape; and,
- research and analysis of the impact of new and modified agriculture programs in Canada is very limited with delayed reporting of results.

A BRIEF PERSPECTIVE ON AGRICULTURE IN CANADA

Approximately 8% of Canada's land is used for agriculture (McRae et al. 2000). These landscapes are located in the southern, most productive regions of the country, and are generally a mosaic of croplands, pasture, wetlands, woodlands and riparian areas. The extent of impacts to biodiversity in these regions are variable, determined by both the history of land use in the region,

and current trends in agricultural production .

The most heavily impacted regions of the country are the Prairie and Mixedwood Plains Ecozones (with 90% and 40% of the land area in agriculture respectively (Baydack et al. 2000). These areas occupy the southern regions of Alberta, Saskatchewan and Manitoba, and Southern Ontario and the St. Lawrence River valley of eastern Ontario and Quebec (Figure 1). The Boreal Plain Ecozone has 20% of its landbase in agriculture, and is the only ecozone where the proportion of agricultural land is increasing (13% increase from 1981-1996) (Neave et al. 2000). The other 4 ecozones with agricultural production include the Pacific Maritime, Montane Cordillera, Boreal Shield and Atlantic Maritime. While the total area in agricultural production is smaller in these ecozones, regionally, impacts on biodiversity may still be significant with intensive production in areas including the Fraser River Delta/Georgia Basin of the Pacific Maritime, the Okanagan Valley of the Montane Cordillera, and the St. John River Valley and portions of P.E.I. in the Atlantic Maritime (Baydack et al. 2000).



<http://www.ccea.org/ecozones/terr.html>

The Census of Agriculture is conducted every 5 years in Canada, and provides information on the extent and change in farm activities in Canada's agricultural regions. Table 1 provides a brief overview of dominant activities in each Canadian province, including the area in the 5 most planted crops, and total numbers of common livestock.

Table 1: Top five field crops by area by province and livestock number by province from the 2001 Census of Agriculture (Statistics Canada 2001)

Province	Total number of farms (2001)	Top five field crops by area		Total # cattle/calves by % of total farms and avg. #/farms reporting	Total # pigs by % of total farms and avg. #/farm reporting	Total # sheep/lambs by % of total farms and avg./farm reporting	million kg chickens and turkeys
		crop	million ha				
British Columbia	20 290	other tame hay/fodder alfalfa/alfalfa mixtures forage seed for seed barley oats	0.21 0.20 0.04 0.03 0.03	814 949 on 38.1% farms avg. 105/farm	165 816 on 5.5% farms avg. 148/farm	83 307 on 9.2% farms avg. 45/farm	193
Alberta	53 652	spring wheat barley alfalfa/alfalfa mixtures canola (rapeseed) other tame hay/fodder	2.35 1.98 1.58 1.07 0.92	6 615 201 on 59.2% farms avg. 208/farm	2 027 533 on 5.0% farms avg. 757/farm	307 302 on 5.6% farms avg. 103/farm	120
Saskatchewan	50 598	spring wheat canola (rapeseed) barley durum wheat alfalfa/alfalfa mixtures	4.32 1.90 1.86 1.72 1.14	2 899 502 on 44.6% farms avg. 129/farm	1 109 797 on 3.3% farms avg. 662/farm	149 389 on 3.4% farms avg. 88/farm	36.8
Manitoba	21 071	spring wheat canola (rapeseed) alfalfa/alfalfa mixtures barley oats	1.49 0.75 0.65 0.47 0.36	1 424 427 on 53.8% farms avg. 126/farm	2 540 220 on 7.9% farms avg. 1523/farm	84 798 on 3.5% farms avg. 116/farm	61

Table 1: Top five field crops by area by province and livestock number by province from the 2001 Census of Agriculture (Statistics Canada 2001)

Province	Total number of farms (2001)	Top five field crops by area		Total # cattle/calves by % of total farms and avg. #/farms reporting	Total # pigs by % of total farms and avg. #/farm reporting	Total # sheep/lambs by % of total farms and avg./farm reporting	million kg chickens and turkeys
		crop	million ha				
Ontario	59 728	soybeans corn for grain alfalfa/alfalfa mixtures other tame hay/fodder winter wheat	0.91 0.81 0.65 0.36 0.22	2 140 731 on 47.2% farms avg. 76/farm	3 457 346 on 8.3% farms avg. 695/farm	337 625 on 6.7% farms avg. 85/farm	421
Quebec	32 139	other tame hay/fodder corn for grain alfalfa/alfalfa mixtures barley soybean	0.55 0.44 0.24 0.16 0.15	1 362 788 on 50.1% farms avg. 85/farm	4 267 365 on 8.5% farms avg. 1556/farm	254 053 on 4.3% farms avg. 186/farm	335
New Brunswick	3 034	other tame hay/fodder potatoes barley alfalfa/alfalfa mixtures oats	0.07 0.02 0.02 0.01 0.001	91 176 on 6.8% farms avg. 64/farm	137 006 on 6.4% farms avg. 703/farm	9 601 on 4.9% farms avg. 65/farm	30.3
Nova Scotia	3 923	other tame hay/fodder alfalfa/alfalfa mixtures barley corn for silage corn for grain	0.06 0.01 <0.001 <0.001 <0.001	108 401 on 43.5% farms avg. 64/farm	124 935 on 5% farms avg. 637/farm	24 896 on 7% farms avg. 90/farm	40.9
Prince Edward Island	1 845	other tame hay/fodder potatoes barley alfalfa/alfalfa mixtures spring wheat (excluding durum)	0.05 0.04 0.04 0.01 <0.001	84 791 on 58.1% farms avg. 79/farm	126 065 on 10.5% farms avg. 653/farm	3 589 on 3.7% farms avg. 53/farm	3.4

Table 1: Top five field crops by area by province and livestock number by province from the 2001 Census of Agriculture (Statistics Canada 2001)

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		crop	million ha				
Newfoundland	643	other tame hay/fodder alfalfa/alfalfa mixtures potatoes mixed grains corn for silage	0.001 <0.001 <0.001 <0.001 <0.001	9483 on 26.6% farms avg. 55/farm	2689 on 4.8% farms avg. 9/farm	7888 on 17% farms avg. 72/farm	-

Farm production activities have varied impacts on biodiversity, from direct conversion of native habitats (impacting habitat quantity for a variety of species) to indirect impacts on both farm habitats and native habitats (habitat quality issues including fragmentation, and degradation of both aquatic and terrestrial habitats through a variety of practices). Historical habitat conversion of wetlands, woodlands and grasslands for cultivation has been extensive in some agricultural regions with an estimated 90% loss of wetlands and 80% loss of woodlands in southern Ontario's intensively farmed areas (Baydack et al. 2000). On the prairies it has been estimated that less than 1% of tall grass, 19% of mixed grass and 16% of aspen parkland remains in native cover (Mineau et al. 1994). Estimates of degradation of habitat quality, have been difficult to assess based on available data, and the inherent variability in farm practices locally and regionally. Table 2 outlines some of the elements of farm management which may impact biodiversity recognizing that the application of mitigative measures and best management practices by individual farmers can reduce risks both locally and regionally.

Table 2: Farm Elements with Potential Impact Biodiversity

Farm Production Type	Farm element with potential to impact biodiversity	Endpoint impacts of agriculture on the environment	Mitigative measures – Best Management Practices to reduce risk
Crop Production	till and plant fields	potential for soil erosion and runoff to aquatic systems potential for soil degradation and compaction	reduced tillage/ no-till systems crop rotation intercropping, contour farming, strip cropping to reduce erosion buffers, grassed waterways, riparian habitats to reduce/slow pathways
	Nutrient application (fertilizers/manure)	- potential for nutrient contamination to surface and ground water sources - potential for nutrient contamination of soil ecosystems resulting in acidification/salinization - potential for contamination of neighboring terrestrial habitats and impacts on plant species (shift to dominant species, increase in weeds/exotic species)	- nutrient management planning (rates calculated based on soil/plant needs/uptake) - storage/mixing/loading areas appropriate distance from water sources, proper disposal of fertilizer solutions, leachate management in greenhouses - maintain riparian habitats and buffers to limit risk of contamination
Crop Production continued	Pesticide application	- potential for pesticide contamination of surface and ground water sources - potential for pesticide contamination of soil and impacts on non-target organisms - potential to “clean” fields of all weeds (beyond economic thresholds) which provide resources for wildlife at certain times of the year	- use of integrated pest management or elements of IPM including crop rotation, pest resistant varieties, biological controls, physical barriers - avoid application in native habitats, buffer strips, field margins and right of ways maintained in permanent cover - maintain riparian areas, plant buffer strips to reduce runoff/exposure of aquatic habitats to pesticides - storage/mixing/handling areas appropriate distance from water sources, proper disposal of rinsate, containers, treated seed - apply more selective herbicides targeting specific problem weeds
	haying/harvest	- potential for soil erosion and runoff to aquatic systems - potential destruction of wildlife nesting habitat particularly in forage crops - wildlife mortality	- leave crop residues to reduce risk of erosion and increase organic matter - reduce risk of wind erosion with shelterbelts/ windbreaks/ woodlots/ narrow grass strips - plant cover crops followed by herbicide application or incorporation as green manure - avoid summerfallow - ensure timing of harvest/haying is after fledging, use flushing bar

Table 2: Farm Elements with Potential Impact Biodiversity

Farm Production Type	Farm element with potential to impact biodiversity	Endpoint impacts of agriculture on the environment	Mitigative measures – Best Management Practices to reduce risk
	Irrigation	potential for surface runoff of soil, nutrients and pesticides as well as leachate contamination of ground water often limited water resources	plant crops adapted to regional climate ensure water use efficiency based on precipitation, crop stage, monitoring of soil moisture water recycling
	Drainage	removal of riparian vegetation, disruption/reduction in diversity of substrate, alteration of creek form/function - impacting fish species diversity siltation, sedimentation downstream	maintenance of riparian buffers fixing/replacing broken tile drains incorporation of natural channel principles
	disposal of organic wastes/mulches	potential for nutrient contamination of water sources	composting, incorporation of mulches into soil bury/burn diseased material
	management of native habitats (hedgerows, field margins, shelterbelts)	potential loss of habitat value and species diversity with spraying of herbicides, mowing, thinning	use of buffers
	conversion of native habitats for increased production	loss of native habitats including wetlands, woodlands, native grasslands, field margins, hedgerows, riparian areas loss of more suitable farmland habitat types (forage crops, tame or seeded pasture) reduced connectivity, decrease in habitat heterogeneity	habitat maintenance – stewardship of existing habitats on the farm maintenance of connectivity/corridors to provide access to resources habitat restoration/enhancement through planting permanent cover crops on cropland, planting trees in shelterbelts, riparian areas, or along woodlot margins, vegetative buffers
	feedlots and winter yards, barns and manure storage facilities	nutrient contamination of surface and ground water sources	planned site locations at recommended distances from water sources proper storage and handling facilities, management of manure and other wastes in barns, feedlots, wintering areas manage milkhouse waste and wash water manage litter waste from poultry operations
Crop Production continued	Livestock disposal	nutrient contamination and disease	plan timing and location (distance from water sources) to reduce risk of contamination
	feed and silage storage	nutrient contamination, high concentrations of nutrients and acids can increase levels of ammonia, iron and nitrate in water	planned site locations at recommended distances from water sources

Table 2: Farm Elements with Potential Impact Biodiversity

Farm Production Type	Farm element with potential to impact biodiversity	Endpoint impacts of agriculture on the environment	Mitigative measures – Best Management Practices to reduce risk
Livestock Production	Livestock grazing	needs of wildlife are variable with respect to grazing intensity overgrazing in large areas can facilitate invasive species establishment, lead to soil erosion, cause compaction competition for range resources nest trampling	rotational grazing, rest rotational grazing
	livestock use of sensitive areas	sedimentation/siltation of streams/wetlands streambank erosion compaction of streambeds, disturbance to aquatic and riparian vegetation nutrient contamination of surface water sources	manage access to sensitive areas, utilize alternate watering sources manage access to riparian areas limiting grazing and manure accumulation manage access to woodlots to ensure maintenance of regeneration/structural diversity maintain or plant buffers
	Livestock disease	transmission of disease between livestock and wildlife	manage interaction between wildlife and livestock in areas of high risk

(based on issues identified in Environmental Farm Plan workbooks from Alberta and Ontario, and available provincial environmental scans)

Elements of biodiversity also impact farm production and management decisions. Positive benefits from biodiversity including pollinator services, pest control, protection of water quantity and quality are recognized by most producers as essential to sustainable production over the long term. Elements of biodiversity can be costly to individual farmers as well, with invasive species, disease, and wildlife damage all contributing directly to reductions in profits for many farmers. This document aims to address some of the key issues relating to both risks and benefits of biodiversity on farms and farm practices on biodiversity.

ANALYSIS

Risk is a function of the ability to cause harm (hazard) and the chance of being in harms way (exposure). With the large degree of scientific uncertainty on many issues related to biodiversity,

and an associated concern over extrapolation of results on populations that are naturally highly variable, the designation of risk requires considerable care and involvement with affected parties. The designation of risk in this assessment is therefore limited and related to the extent and use of practical mitigative measures for reducing exposure to environmental hazards.

The analysis of literature collected for the database has been summarized based on key issues. Literature from peer reviewed journals, federal and provincial government departments, industry and non-government organizations was reviewed for each key issue. In the analysis, the problem is identified, along with direct impacts to biodiversity and agriculture (hazard), followed by an assessment of mitigative measures related to chance of exposure, and an assessment of risk. A general summary of farm impacts, production types currently posing the greatest risk, regions of highest impacts, mitigative actions and the extent of their application, and information gaps is also provided in a table for each issue. The table provides a regional and production-based context derived from information from the literature review and discussion with experts in the field. All of the key issues in this report are inter-related to some degree, and there may be some overlap between chapters, or omissions covered under other issue summaries. Related issues are listed for each key issue indicating the presence of associated information.

Analysis of Farm Risk and/or Benefit to Biodiversity

Native Habitats

Farm Impact on Biodiversity (+ positive, – negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
– conversion of native habitats (habitat quantity)	grain, oilseeds, vegetables, berry crops, vineyard, orchard, other	Fraser River Delta (Pacific Maritime), Okanagan	habitat maintenance, habitat enhancement,	widespread stewardship is often the reason for existence of	threshold levels of native habitat required to sustain

Farm Impact on Biodiversity (+ positive, – negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
	specialty crops, greenhouses	Valley (Montane Cordillera), Peace River Parkland (Boreal Plain), Southern Ontario and St. Lawrence Lowlands in Quebec (Mixed-wood Plain)	habitat restoration, farm environmental stewardship	residual native habitat, however economic barriers exist to maintenance in many regions	biodiversity – ‘how much is enough?’ it is necessary to define baseline information needs/ habitat inventory based on long term objectives for wildlife habitat in Canada
– fragmentation of remaining native habitats (habitat quality), reduced connectivity	grain, oilseeds, vegetables, berry crops, vineyard, orchard, other specialty crops, greenhouses	Okanagan Valley (Montane Cordillera), Boreal Transition (Boreal Plain), grainbelt (Prairies), parkland (Prairies and Boreal Plain), southern Ontario and St. Lawrence Lowlands (Mixed-wood Plain)	habitat maintenance, habitat enhancement, habitat restoration, farm environmental stewardship	widespread stewardship is often the reason for existence of residual native habitat, however economic barriers exist to maintenance in many regions	

Problem definition

The presence of residual patches of native habitat in agricultural landscapes is important for most wildlife species, often supporting critical needs such as breeding habitat (Neave et al. 2000). The availability of these habitats is influenced by both their amount and distribution across the landscape (habitat quantity) and their ability sustain populations over the long term (habitat quality). Farming influences habitat quantity and quality, through direct habitat conversion and use, and indirectly through pollution, disturbance, and fragmentation.

Elements of biodiversity impacted

Species may use different portions of the landscape to acquire their range of resource needs including both native habitats and farmland habitats. The suitability of habitat for species depends on the patchiness of the landscape, access/connectivity of resources, the presence of seasonal needs, and occurrence of predators and disease (Neave et al. 2000). The quality of remaining native habitats for wildlife is impacted by patch size, distribution and surrounding use. All habitat needs must be accessible to a species for it to survive in an area. For example, bees require nesting substrate and blooms which are temporally and patchily distributed. Availability of these habitat needs within their 1-2 km range of movement, along with permeability of surrounding lands all impact bee survival and production (Cane 2001).

Some grassland species have been shown to be sensitive to grassland habitat area, including grasshopper sparrows (*Ammodramus savannarum*), bobolinks (*Dolichonyx oryzivorus*), and savannah sparrows (*Passerculus sandwichensis*) on the prairies (Johnson 1996). Large bodied species including northern harrier (*Circus cyaneus*), short-eared owl (*Asio flammeus*), Wilson's phalarope (*Phalaropus tricolor*), marbled godwit (*Limosa fedoa*) and willit (*Catoptrophorus semipalmatus*) are rarely found in smaller habitat patches (Johnson 1996). The long-billed curlew (*Numenius americanus*), a species of special concern, was found nesting only in larger grassland areas where openings are >250m at their narrowest point in British Columbia (COSEWIC 2002). The amount of grassland cover in the landscape was also related to curlew populations with numbers dropping by half in areas with <50% cover, compared to areas with 50-100% (COSEWIC 2002). Agricultural land use is important to long-billed curlews however, with a preference for moderate to heavy grazing, and often the use of cropland after fledging (COSEWIC 2002).

The size of residual woodland fragments also determines habitat quality for many species in the eastern hardwood forests of the Mixedwood Plain and Atlantic Maritime ecozones. The Acadian flycatcher (*Empidonax vireescens*) and hooded warbler (*Wilsonia citrina*) (both species at risk) are most common in forests greater than 100 ha in size (Friesen and Stabb 2001). Many other species in the region require continuous forest cover, including the Red-shouldered hawk (*Buteo lineatus*), oven bird (*Seiurus aurocapillus*) and wood thrush (*Hylocichla mustelina*). For the red-shouldered hawk, the response is based on competition from other larger raptors at the agricultural/forest interface. The amount of forest cover in an area often influences the use of smaller forest fragments by bird communities, with species responses to woodland patch size changing in areas with high proportions of forest cover (Helferty 2002; Friesen and Stabb 2001; Hobson and Bayne 2000). The configuration of forest fragments has also been shown to be important to species with poor dispersal abilities (Villard et al. 1999). Edge effects, including changes in habitat, microclimate, prey availability, predation and nest parasitism levels have been demonstrated for amphibians, birds and mammals, decreasing habitat quality of small habitat patches (Young and Yahner 2003; Helferty 2002). Abiotic factors such as noise, vibration, traffic and pesticides can also reduce habitat quality in small woodland patches for many amphibian species (Helferty 2002). Lee et al. (2002) demonstrated the variability in the relative importance of within patch characteristics, size, and landscape cover between species, and the associated implications for conservation efforts.

The fragmentation of landscapes can alter many interspecific interactions including pollinator-plant, predator-prey, nest predation, nest parasitism, and the movement of individuals, seeds and pollen (Elsinger 2003). Robinson et al. (1995) showed that many populations of forest birds are population sinks in landscapes dominated by agricultural fields. Nest parasitism and predation

rates were so high in the study, that local reproduction of species such as wood thrushes (*Hylocichla mustelina*), tanagers (*Piranga* spp.), hooded warblers (*Wilsonia citrina*), oven birds (*Seiurus aurocapillus*) and Kentucky warblers (*Oporornis formosus*) was found to be insufficient to compensate for adult mortality (Robinson et al. 1995). Friesen et al. (1999) also linked habitat fragmentation with low pairing success for ovenbird (*Seiurus aurocapillus*), red-eyed vireo (*Vireo olivaceus*) and wood thrush (*Hylocichla mustelina*).

In native grassland, woody vegetation can fragment habitat and reduce quality for some area sensitive species (Johnson 1996). Woody vegetation also provides perches for raptors and cowbirds (*Molothrus ater*), attracts different wildlife communities which may compete for grassland resources, and provides travel corridors and cover for mammalian predators (Johnson 1996). Kirk (2003) suggested that planting trees may have increased predation on endangered burrowing owls (*Athene cunicularia*). Swainson's hawk (*Buteo swainsoni*), however appears to have been positively influenced by cultivation and tree availability (Schmutz et al. 2001). Johnson (1996) cautions that planting trees in areas of native grassland may not have all of the same benefits of adding trees to cropping landscapes for wildlife.

The suitability of the matrix of agricultural land between residual patches of native habitat also affects habitat quality. Roads are often barriers to movement by species such as amphibians (Helferty 2002), and agricultural use of native habitats for grazing, or forage production can reduce habitat quality seasonally (Aldridge 2000). McMaster et al. (2002) found that the proportion of cropland in the landscape increased nest density in haylands, increasing vulnerability of nests and hens to predators. Some crop types act as physical or behavioural barriers for species, and may make the species vulnerable to predation. Corridors of suitable

habitat (which can include certain agricultural crops) may be necessary for movement between resources. A variety of corridors including uplands, pasture, hedgerows, meadow, or riparian habitat are used for dispersal of juvenile upland amphibian species from wetlands (Helferty 2002). Suitability or quality of the corridors is most related to corridor width (a 1:1 or 1:2 ratio of linkage width to distance is suggested) (Helferty 2002). Duchesne and Belanger (1997) suggest a minimum width of 300 m and 200 m for forested and riparian corridors respectively, to mitigate edge effects for amphibians and small and large mammals. Duschene et al. (1998) suggest an even larger edge effect for forest birds, with a minimum corridor size of 900 m to minimize impacts.

Hedgerows and field margins have also been shown to be valuable refuges for native flora and fauna, particularly in the intensive agricultural landscapes of eastern Canada. A study in Quebec demonstrated their importance for a variety of woody and herbaceous plant species, including several rare species (Jobin et al. 1996). Boutin et al. (2002) demonstrated that natural, structurally diverse hedgerows were the most valuable for plant conservation, with planted shelterbelts and field margins supporting more transient plant communities. Physical characteristics of hedgerows, including species richness, structural diversity of trees and shrubs, and size are have also been demonstrated to be important factors influencing bird use (Jobin et al. 2001)

The availability of wetland and riparian habitat is critical to most wildlife species for part of their life cycle. Wetlands are habitat for 1/3 of the species at risk in Canada, with direct habitat loss, degradation from pollutants and surrounding habitat change responsible for the declines (Wiken et al. 2003). Wetland drainage in most regions has focussed on shallow temporary and seasonal wetlands, directly impacting habitat quantity, and influencing habitat quality by isolating

remaining wetlands, and reducing dispersal of aquatic species (Euliss and Mushet 1999). Farm management practices also impact wetland habitat quality, impacting margins, and facilitating pollution by sediment, nutrients, pesticides and pathogens. Farm practices also impact riparian areas, through use by livestock, use for crop and forage production, and contamination from pesticides and nutrients. Riparian areas are important habitats for many species, and provide essential ecological services, controlling erosion and filtering runoff, and regulating temperature of aquatic ecosystems (Maisonneuve and Rioux 2001). Maisonneuve and Rioux (2001) found that the complexity of vegetation structure in riparian areas, influenced the abundance of small mammals and herpetofauna. This has also been demonstrated for birds (Deschenes et al. 2003) and plants (Boutin et al. 2003).

Status and effectiveness of mitigation

Maintaining the base of native habitat in agricultural regions is a critical conservation strategy with impacts for most wildlife species. Farmers bear this stewardship responsibility, and are often the reason why native habitats have been retained. Economic forces also influence land conversion, with prices of grain and cattle often driving conversion of rangeland to crops on the prairies (Baydack et al. 2000). Approximately 21% of native prairie remains in the prairie Ecozone, primarily on land that is limited for crop production by drought frequency or low fertility (Masterman 2003; Hammermeister et al. 2002). Much less remains in some ecoregions (e.g. 6% in aspen parkland, and moist mixed grassland), and local representation can be extremely low across some areas of the prairie landscape (Hammermeister et al. 2002).

Wetland losses are estimated at approximately 65% for coastal marshes in Atlantic Canada, 70% in southern Ontario, 71% on the prairies and 80% in the Fraser River Delta in B.C. (Wiken et al.

2003). Woodland losses have been significant in some regions of Canada including southern Ontario where less than 10% remains in many counties (Neave and Wolthausen 2004). The fragments that remain are often small, and impacted by habitat quality issues related to woodlot management including high grading and single species management (e.g. sugar maple (*Acer saccharum*) for veneer or maple syrup). Best management practices and habitat stewardship programs with the goal of both maintaining the base, and enhancing habitat quality are widespread as is participation by farmers. For example, in Ontario approximately 10,000 woodlot properties with a total of 600,000 ha are currently managed under a Managed Forest Tax Incentive Program plan where landowners develop a woodlot management plan and commit to stewardship (Neave and Wolthausen 2004). The Landowner Habitat Program of the Alberta Conservation Association signed 222 long term agreements with landowners between 1986 and 1997, totaling approximately 21850 ha of habitat including native aspen parkland, native grassland, riparian dense nesting cover and other uplands (Neave and Wolthausen 2004). Landscape level planning involving woodlot owners is also having an impact in areas such as southern Ontario, Quebec, and New Brunswick (Neave and Wolthausen 2004).

Programs integrating riparian management for both wildlife and on-farm soil and water conservation are also widespread across the country, with increasing participation from landowners. The Cows and Fish Program in Alberta works to foster awareness and demonstrate how improvements in riparian and watershed management can enhance landscape health and productivity for the benefit of landowners and others. The program has provided presentations, field days and workshops to over 22000 participants since 1992 (Neave and Wolthausen 2004). A Saskatchewan Wetland Conservation Corporation study of riparian areas in 16 watersheds, investigated indicators of riparian function in agricultural landscapes. While introduced invasive

species were a problem at all sites, other indicators were found less commonly including: area of exposed soil >10% (36% of sites), poor bank conditions from livestock grazing (17% of grazed sites), significant manure deposits (10% of grazed sites), damage from cultivation (13%), significant sedimentation (20%), direct seeding next to riparian areas (1%) (PFRA 2000). Continued support for riparian stewardship programs such as Alberta's Cows and Fish program will increase awareness, and promote further improvements.

Habitat restoration is an expensive option for habitat and species management, but is often used to restore riparian and wetland functions, and occasionally where species populations and habitats have fallen below threshold levels for sustaining biodiversity. On the prairies, conversion of cropland to tame forage through the permanent cover program and the new Green Cover program has been shown to be a cost-effective way to provide quality nesting habitat for upland species while reducing grazing pressure and improving the condition of existing rangelands (Saskatchewan Scan Committee 2004).

For some species loss of wintering habitat may be a more significant contributor to population decline than habitat loss in here in Canada. Burke and Nol (2000), predict that this is the case for veery (*Catharus fuscenscens*) and ovenbird (*Seiurus aurocapillus*) populations. Fragmentation on breeding grounds may still have an impact as well (Burke and Nol 2000).

Assessment of risk

Literature on thresholds of native habitat required to maintain biodiversity have predominantly focussed on woodland habitats. Villard 1999 found that the occurrence of many woodland songbirds increased dramatically when the area of woodland increased to between 10-20% of the landscape. Cadman (1999) found that the number of forest interior bird species in an area of 10

km² continued to increase to approximately 35.5% forest cover. The impact of habitat loss is predicted to be independent of habitat fragmentation when greater than 10-30% of the original habitat remains – fragmentation effects are influential on species below that threshold (Parker and MacNally 2002). Fahrig (1997) also demonstrated through a simulation model that a threshold in breeding habitat cover in the range of 20% may exist where survival is independent of spatial pattern. Villard et al. 1999 found no thresholds however in species response to habitat loss and habitat configuration cautioning against the application of a simple management rule.

In some areas of the country, we are clearly below these thresholds for woodland habitat (e.g. Essex County in southern Ontario with 3% woodland cover). Biodiversity response includes a high incidence of species at risk, sink populations of other species, and threats from invasive species, and predators. Similar responses to habitat loss can be seen in other regions (native grassland, wetlands, riparian areas) and it is likely that in some areas of Canada's agricultural landscapes the unknown threshold levels for some habitats have been reached.

In the Great Lakes region of southern Ontario, Environment Canada (2004c) has developed a framework for decision making with respect to habitat maintenance and protection based on minimum guidelines for maintaining viable populations in wetland, riparian and forest ecosystems in the region. These guidelines, based on science, provide much needed guidance for resource managers with respect to 'how much habitat is enough?'. A regional wildlife habitat needs assessment in the United States with a similar title 'How much is enough' provides comparable guidance on a nation-wide scale for how much habitat is needed to sustain wildlife populations on agricultural lands, with specific goals for grasslands, wetlands, riparian habitat, riparian buffer zones and forest beyond baseline conditions (McKenzie and Riley 1995).

Determining how much habitat we have in Canada (baseline) and setting targets based on scientific thresholds remains a high priority for both the scientific and resource management communities.

Much of the habitat conversion in agricultural landscapes has been done in the past, with further threats primarily from intensification, increases in farm size, and continuously changing economic demands. Farm stewardship must continue to be a key component of biodiversity conservation strategies.

Key Issues with Analysis related to *Native Habitats*

- Grazing
- Agricultural Intensification

Farm Field Management

Farm Impact on Biodiversity (+ positive, – negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
– tillage systems impact on soil ecosystem and facilitating runoff to aquatic ecosystems	grain, oilseeds, vegetables, other specialty crops	Peace River Parkland (Boreal Plain), Prairies, Mixedwood Plains, Atlantic Maritime	conservation tillage techniques, terracing, intercropping	spreading with development of GMO technology however transition is slow as a result of costs and social barriers to change, realization of environmental benefits is delayed	methods to maximize the wildlife benefits of conservation tillage alternatives to no-till where it is not a viable option (e.g. potatoes, intensive horticultural production)
– harvesting practices impacting seasonal habitat use	forage crops	Pacific Maritime, Prairies, Mixedwood Plains, Atlantic Maritime	delayed haying, flushing bar	economic barriers to application with delayed haying impacting forage quality, farmer acceptance/interest is the only barrier to flushing bar use	later maturing alfalfa/legume crops how do cropping practices impact wildlife potential

Problem definition

Mechanical disturbances during planting, tillage, and harvest have implications for species that use cropland as habitat. Conventional tillage causes soil disturbance, with impacts on soil fauna, as well as decreasing infiltration causing runoff to aquatic ecosystems. Residues from previous crops are also integrated into the soil, providing less spring cover and food sources to wildlife. Conservation tillage techniques offer alternatives to conventional tillage, retaining residues and decreasing the potential for soil erosion. Planting, harvest and the application of nutrients and pesticides also impact soil quality, both chemically and mechanically. The timing of all operations on fields has an impact on species utilizing fields particularly during the breeding

season.

Elements of biodiversity impacted

Many species cannot tolerate mechanical disturbance from tillage. Burrowing rodents such as Richardson's ground squirrel (*Spermophilus richardsonii*), pocket gophers and voles require subsurface tunnels for nesting, escape and food gathering and favor conservation tillage practices (Bourne 1997). Impacts on invertebrates are variable depending on their vertical distribution in the soil, mobility and power of dispersal and susceptibility to compaction, chemicals and disturbance (McLaughlin and Mineau 1995). No-till has been shown to increase diversity of surface microarthropods and predatory species such as spiders, mites and carabids (Fawcett and Towery 2002). Earthworms also tend to increase as tillage decreases (Fawcett and Towery 2002). Tillage has less impact on organisms with higher turnover rates such as bacteria, protozoa, nematodes (Fawcett and Towery 2002).

Tillage can also cause direct mortality or injury to some species. Ploughing has recently been shown to impact a Quebec population of wood turtles (*Clemmys insculpta*) (a COSEWIC species of concern) in Quebec with a high incidence of shell injuries and implications for reduced growth and recruitment and increased predation rates for individuals on agricultural lands (Saumure 1997). The degree and timing of tillage also impacts bird populations. Surface tillage implements frequently kill or injure incubating birds and nestlings, as well as damaging eggs (McLaughlin and Mineau 1995; Kirk et al. 1996). Density of nests on untilled land tends to be greater, with higher recruitment rates (McLaughlin and Mineau 1995). Kirk et al. (1996) found that subsurface tillage in wheat stubble saved up to 53% of nests. Lokemoen and Beiser (1997) found that species of special concern, including pintail, grasshopper sparrow (*Ammodramus savannarum*) and lark

bunting (*Calamospiza melanocorys*), preferred to nest in organic fallow and minimum tillage wheat stubble over conventional crop fields although hatching and fledging success did not differ between field types. The recent suggested link between pintail (*Anas acuta*) decline and loss of summerfallow on the prairies is related to the seasonal delay in tillage on summerfallow fields, with disturbance often following the pintail nesting season (Masterman 2003). Winter wheat is now being planted in some areas to allow pintails adequate time to lay eggs and complete incubation without being disturbed by farming activities (Masterman 2003).

Specific types of machinery or activities may also affect bird mortality during the nesting season. Seed drills with narrow disk openers have been shown to destroy fewer nests than drills with wide disk openers (Kirk et al. 1996). Seeding, pesticide application and harvesting also disturb the crop areas, and may be detrimental to birds in the breeding season, regardless of use of conservation tillage systems (Kirk et al. 1996).

Habitat for birds and mammals tends to improve with reduced tillage due to increases in both food (increased invertebrate populations, availability of waste grain), and cover (provided by crop residues) (Fawcett and Towery 2002). Increased food availability is of particular benefit to birds that use cropland during breeding, overwintering and migration (Lokemoen and Beiser 1997), and studies have shown that a higher relative abundance of upland bird species can be found on minimum tillage than conventional farms (Shulter et al. 2000).

The timing and frequency of harvest can also impact nesting birds. Haying and mowing can destroy nests and eggs, as well as ground nesting females reluctant to leave their eggs during incubation. Nests that escape damage from machinery are often left exposed and can be easily located by predators. Haying of grassland has also been shown to impact native plant species due

to the continuous removal of the seed head before the plant reaches maturity. The Western Prairie Fringed Orchid (*Platanthera praeclara*) (endangered) and Western Silvery Aster (*Aster sericeus*) (threatened) both flower late in the season with seed set in late August and September respectively (Manitoba Conservation undated (a) and (b)). Haying is listed as one of the risks from agriculture for these species, along with with over-grazing, herbicide spraying, and habitat loss (Manitoba Conservation undated (a) and (b)).

Status and effectiveness of mitigation

The use of conservation tillage has received increasing interest because of its value for soil conservation and the economic advantage to the farmer (Fawcett and Lowery 2001). The practice also benefits aquatic habitats by reducing erosion of sediment, nutrients and pesticides from fields. In the United States, conservation tillage is now practiced on 36.6% of the total cropland acres (Conservation Technology Information Centre 2002). In Canada, use of conservation tillage in the prairie provinces has increased from 25% of total area seeded in 1991 to 32% in 1996 (Padbury and Stushnoff 2000). An indicator of soil cover by crops and residue showed a national decrease of 20% for average number of bare soil days between 1981 and 1996 (Huffman 2000). This improvement and associated decrease in risk in soil erosion was attributed to conservation tillage, chemical fallow and reduced summerfallow (Huffman 2000). Other mitigative measures have been suggested to reduce impacts of tillage operations on ground nesting birds including: changes in frequency and timing of tillage operations, use of winter wheat, and the use of delayed tillage in fallow (Lokemoen and Beiser 1997).

Damage from haying can be partially mitigated through the use of flushing devices. In a study by Calverly and Sankowski (1995), fields mowed with flushing devices had 42 flushing events with

all females escaping successfully. In fields mowed without the device, 48% of flushing attempts resulted in female duck mortality (Calverly and Sankowski 1995). Delayed haying is another beneficial management practice, with guidelines suggested by conservation interests of waiting until July 15th to ensure species have time to raise their broods. An analysis of over 6900 duck nests on CRP lands in the United States showed activity in 70% of the nests in June 15th, 33% on July 1st, and 11% on July 15th (Krapu et al. 2000). Mowing typically occurs around mid to late June on the prairies, with nutritional quality of alfalfa hay peaking at first flower, and then degrading in quality (Dale et al. 1997). Delaying haying until July 15th can cause considerable losses to farmers (Dale et al. 1997). Where haying is done more than once in a season, delays could also result in a considerable decline in quantity harvested.

The use of warm-season grasses in a portion (20-30%) of pasture and hayfields is another recommended practice in the north-eastern United States (Guiliano and Daves 2002). Warm season grasses typically produce 70% of their biomass after June 1st (as opposed to cool season grasses which produce 60-70% prior to June 1st) (Guiliano and Daves 2002). Grazing and mowing are typically delayed in these fields, resulting in less disturbance and destruction of nests (Guiliano and Daves 2002).

Another recommended practice to reduce mortality of birds during haying is avoiding nighttime mowing which will reduce injuries to birds roosting in fields at night (McGaully 2004). Haying from the inside to the outside of a field is also recommended, as opposed to beginning at the perimeter and mowing towards the centre, as this practice forces animals into a continuously smaller space as they avoid the harvester (Green undated).

Assessment of risk

The risk to biodiversity from tillage appears to be decreasing with continual increases in number of farmers using conservation tillage practices. This is in part the result of the introduction of genetically modified crops, which facilitate weed control without mechanical disturbance. Management changes could further improve wildlife habitat in no-till and should be investigated. Fawcett and Lowery (2002), found that leaving 10-14 inches of stubble when harvesting small grains would improve habitat compared to shorter lengths. Seasonal risks from harvest (particularly haying and mowing) are well documented, and some mitigation is possible. However use of mitigative measures are not widespread due to economic and social constraints and the difficulty in technology transfer to producers. Risk to breeding birds in particular therefore remains high in all regions.

Key Issues with Analysis related to *Farm Field Management*

- Siltation/Sedimentation
- Agricultural Intensification
- Genetically Modified Crops
- Pesticide Contamination
- Nutrient Contamination

Grazing

Farm Impact on Biodiversity (+ positive, -- negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
+ heavy, moderate, light grazing provides preferred habitat for different species + grazing an essential element of grassland management	beef, dairy, natural land for pasture, tame or seeded pasture, woodlots	Montane Cordillera, Prairies, Boreal Plains, northern Mixedwood Plain	rotational grazing, rest rotational grazing	increasing, with some barriers to actions from costs and labour	cow/calf stocking rates are based on forage production, not wildlife needs, rates need to be assessed to look at their effectiveness in achieving biodiversity conservation
– overgrazing of large areas degrading habitat	beef, dairy, natural land for pasture, tame or seeded pasture, woodlots	Montane Cordillera, Prairies, Boreal Plains, northern Mixedwood Plain	rotational grazing, rest rotational grazing	increasing with some barriers to actions from costs and labour	
– livestock damage to sensitive habitat areas (riparian areas, wetlands, streams, woodlots)	beef, dairy	very site specific in: Montane Cordillera, Prairies, Boreal Plains, Mixedwood Plains, Atlantic Maritime	rotational grazing, rest rotational grazing, alternative water sources, fencing of sensitive areas, controlled livestock access	economic barriers to application, some incentive programs exist to cover part of the costs	
– competition for range resources	beef	Montane Cordillera	control stocking rates on critical wildlife areas (crown land)	not applied	degree of competition for range resource between cattle and wildlife is poorly documented

Problem definition

The amount of farmland in pasture has a significant impact on local biodiversity. Pasture can be variable in quality for biodiversity however, depending on the vegetative cover (native or seeded) and the pressures from livestock grazing. Grazing is an essential part of ecological management

of prairie grasslands. Native grassland ecosystems have evolved based on both grazing disturbance and fire. Grazing of woodlots and riparian areas in eastern Canada, has had impacts on regeneration of native forest cover, however pasture provides habitat for many farmland birds in these fragmented landscapes.

Elements of biodiversity impacted

Grazing is an important element of prairie grassland management, and the use and stewardship of natural grasslands by livestock producers is critical for the maintenance of extensive and high quality habitats in some prairie regions. Wildlife species on the prairies are adapted to a range of variation in both grazing intensity and timing (Bradley and Wallis 1996). Some birds and mammals prefer overgrazed sites, including the endangered burrowing owl (*Athene cunicularia*), the mountain plover (*Charadrius montanus*), McCown's longspur (*Calcarius mccownii*), and Richardson's ground squirrel (*Spermophilus richardsonii*) (PFRA 2004; Bradley and Wallis 1996). Species such as western meadowlark (*Sturnella neglecta*), long-billed curlew (*Numenius americanus*), savannah sparrow (*Passerculus sandwichensis*) and vesper sparrow (*Pooecetes gramineus*) prefer moderately grazed sites (PFRA 2004; Bradley and Wallis 1996, Johnson 1996). Others species frequent lightly grazed grasslands with greater litter and vegetative structure, including Baird's sparrow (*Ammodramus bairdii*), sharp-tailed grouse (*Tympanuchus phasianellus*), Sprague's pipit (*Anthus spragueii*) and meadow vole (*Microtus pennsylvanicus*) (PFRA 2004; Roersma 2000; Bradley and Wallis 1996). Livestock grazing is patchy, and with rotational grazing systems, rangeland can provide a wide range of habitats across the landscape for different species (PFRA 2004). While the majority of bird, mammals and plant species are adapted to moderate levels of grazing, light and heavily grazed grasslands must also be represented (Bradley and Wallis 1996).

On the prairies, moderate grazing controls dominant, aggressive and often invasive species (PFRA 2004). Grazing also prevents smothering of healthy plant growth by a thick litter layer (PFRA 2004). Grazing is also used as a strategy to manage encroachment of aspen (*Populus* spp.) into grassland. Aspen stands can be a threat to sharp-tailed grouse (*Tympanuchus phasianellus*), providing perch sites for predators and impacting nest success when nests are within 50 m of perch sites (Alberta NAWMP 2001). Brush encroachment is a major concern in the Boreal transition region, where aspen groves covered 10-30% of the landscape historically, and current estimates of native vegetation are less than 20% (Luciuk et al. 1998).

Pasture lands are also important habitats for many species in eastern Canada as well. For example, pasture is the preferred habitat of the endangered loggerhead shrike (*Lanius ludovicianus*) in Ontario and Quebec (Chabot 2001). Optimal conditions regarding height and heterogeneity of ground cover, and the importance of grazers within loggerhead shrike territories is still under investigation (Chabot et al. 2001).

Pressure on rangeland from overgrazing have serious impacts on biodiversity and native habitats. In eastern Canada, the use of forested pastures has had a large impact on understory plants and stand development. Over-grazing of bluffs and riparian areas on the prairies also impacts woody species, providing less winter browse for large game, compacting soils, and often exposing streambanks in riparian areas (PFRA 2004). Livestock access to riparian areas and watercourses can impact aquatic habitats disturbing streambanks and stream beds and contributing nutrients and sediment. Livestock trampling of nests, burrows and streambank vegetation in the riparian zone is a threat to some species at risk in the south Okanagan/ lower Similkameen regions of B.C. including the tiger salamander (*Ambystoma tigrinum*), great basin spadefoot toad (*Scaphiopus*

intermontanus), and the painted turtle (*Chrysemys picta*) (Government of British Columbia 2001).

A study in the aspen parkland showed direct and indirect impacts of cattle overgrazing on bird productivity. Grazing directly impacted habitat structure and site suitability, and reproductive success was influenced by trampling of nests, disturbance of breeding behavior and vegetation removal making nests vulnerable to predation (Prescott et al. 2000). Locally, overgrazing can also reduce substrate available for nest construction, and habitat for invertebrate prey species (Lapointe et al. 2003). Belanger and Picard (1999) found that birds in the spring flooded prairies of the islands of the St. Lawrence were six times more abundant in ungrazed and moderately grazed pastures than intensively grazed pastures. Nest density for dabbling ducks was 10 times higher in the same habitats (Belanger and Picard 1999).

Competition for resources between livestock and large game species is also a concern in the ranching areas of the mountains in Alberta and BC. A study by Telfer (1994) showed that cervids and livestock overlapped in their use of space, habitat and forage resources particularly in late autumn and early winter. No definite conclusions could be drawn about competition, but at greater stocking densities, competition may be an issue (Telfer 1994).

Status and effectiveness of mitigation

Rest rotational grazing systems allow pastures time to recover from the pressures of livestock grazing. They also facilitate soil protection, and reduce nutrient runoff, and are integral in providing a variety of intensities of grazing (habitat types) both spatially and temporally. In areas of ecologically managed grazing, the growth and seed production of some invasive species not accustomed to grazing may be greatly reduced (Environment Canada 2001).

Deferred grazing around critical wetland habitats to reduce livestock disturbances during the nesting season is a best management practice that can be built into a rotational grazing system. New grazing systems for riparian areas have also been developed with potential for increases in forage productivity (PFRA 2004). Grazing systems that ensure sufficient carryover for spring nesting, increase residual cover and decrease habitat disturbance during the breeding season provide favorable habitat for sharp-tailed grouse (*Tympanuchus phasianellus*), waterfowl, and sage grouse (*Centrocercus urophasianus*) (Aldridge 2000, Alberta NAWMP 2001). Managing livestock access to sensitive sites and providing alternate water sources will also mitigate a variety of impacts on streambanks, riparian areas and wildlife using these habitats.

Restoration of native grassland is an expensive undertaking and where possible habitat maintenance of native grasslands should be the primary goal of conservation programs. Seeding with a few available native species (e.g. northern wheat grass (*Agropyron dasystachyum*), western wheat grass (*Agropyron smithii*), green needlegrass (*Stipa viridula*)) is an option to produce productive pasture and provide good wildlife habitat (Jefferson et al. 1997). Including a fast growing legume species such as alfalfa with the native mix, has been shown to increase cattle gains, and control weeds increasing productivity (Jefferson et al. 1997). Seeding of native or tame grasses and legumes has been shown to provide additional wildlife benefits, especially where it replaces annual cropland.

Assessment of risk

Livestock grazing has the potential to provide a wide range of benefits to biodiversity, from habitat protection and management to control of invasive species and brush encroachment. Over 70% of the community pastures in Alberta and Saskatchewan support endangered species (Luciuk

et al. 1998) and many farmers are active stewards of native grassland.

In a survey of livestock producers known to be using pasture and riparian management in the prairie provinces, most producers reported that the change to rotation grazing from previous systems (primarily continuous grazing) resulted in numerous improvements for livestock and forage production (Chorney and Josephson 2000). Most producers indicated that their primary rationale for changes in management were to improve their pasture condition (96%) and the long term sustainability of their land (92%) (Chorney and Josephson 2000). Fifty percent of the producers indicated that they had some form of restricted access of livestock to waterbodies (Chorney and Josephson 2000). After making their changes, most farmers observed an improvement in cover for waterfowl (71%), improved livestock health (72%), improved cover for upland game (60%) and improved water quality of surface water bodies (68%) (Chorney and Josephson 2000).

The benefits of grazing management to livestock health and forage productivity have been demonstrated. However there are constraints to change, including cost, labour and management and lack of sufficient water supply. Recommended targets exist for stocking rates in natural land for pasture and tame or seeded pasture (provincial guidelines). These targets, while effective in reducing stresses on pastures and forage production from overuse, have not been assessed for their effectiveness in achieving biodiversity conservation.

Key Issues with Analysis related to Grazing

- Native Habitats
- Farm Field Management
- Nutrient Contamination

- Disease
- Invasive Species

Pesticide Contamination

Farm Impact on Biodiversity (+ positive, – negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
<p>– widespread application affecting both target and non-target organisms</p> <p>– runoff from soil to aquatic ecosystems</p> <p>-- application or drift to natural habitats</p> <p>– contamination of aquatic and terrestrial habitats through improper storage/handling and disposal of containers/treated seed</p>	<p>grain, oilseeds, greenhouse, horticulture, orchard, vineyard, vegetables, other specialty crops</p>	<p>Fraser River Delta (Pacific Maritime), Okanagan Valley (Montane Cordillera), Prairies, southern Ontario and St. Lawrence Lowlands of Quebec (Mixedwood Plains), Atlantic Maritime</p>	<p>integrated pest management</p> <p>IPM</p> <p>organic farming</p> <p>resistant crop varieties, GMOs</p> <p>crop rotation</p> <p>mechanical control (tillage)</p> <p>biological control</p> <p>protection of soil and water quality through BMPs including riparian habitat maintenance, and buffers</p>	<p>IPM – cost and time barriers to application</p> <p>organic – barriers to application based on both markets, and cost and time required for certification</p> <p>GMOs are widespread for some crop types</p> <p>crop rotation and tillage widespread</p>	<p>understanding interactive effect of multiple compounds in ecosystems</p> <p>risks from break- down products</p> <p>effects of long term exposure to low levels</p> <p>cumulative effects on aquatic ecosystems</p> <p>impacts of seasonal patterns of pesticide concentrations in aquatic systems</p> <p>research on endocrine disrupting compounds, windows of sensitivity, delayed responses</p> <p>differential sensitivity within species by age, sex, size</p>

Problem definition

Pesticides include herbicides, insecticides, fungicides and vertebrate toxicants used to control

target species of weeds, insects, disease and vertebrate pests. Unintentional impacts on non-target species appear to be inevitable, with impacts on both species that ingest the chemicals, and often secondary impacts on consumers further up the food chain. Impacts are influenced by both the toxicity of the chemical (varies by species), and chance of exposure (amount, timing and method of application). Direct exposure in farm fields and field margins impacts terrestrial species, with contributions from soil erosion, drift, and atmospheric deposition to aquatic habitats.

Elements of biodiversity impacted

The specific effects of pesticides varies by organism. Herbicides and fungicides are generally not toxic to birds but some may adversely impact other non-target organisms including native plants, fish and some invertebrates (Canadian Wildlife Service 2001). Mammals are better at detoxifying cholinesterase-inhibiting organophosphate and carbamate pesticides than birds (Canadian Wildlife Service 2001). Other pesticides such as synthetic pyrethroids are not acutely toxic to birds or mammals, but have impacts on aquatic species and ecosystems (Canadian Wildlife Service 2001). Direct impacts of pesticides on aquatic systems range from direct kills of fish and other organisms, to sub-lethal effects on reproduction, growth and development, and increased vulnerability to environmental stresses (Coote and Gregorich 2000).

Many of the pesticides known to directly harm non-target wildlife species have been removed from the Canadian market in the last 10-20 years. Granular carbofuran, estimated to have killed 200,000 to 1 million birds in Ontario cornfields over 5 years from 1980-1985 (Kirk et al. 1996) was removed from Canadian and American markets in the 1990s. Recent research indicates that the products that have replaced granular carbofuran have much less impact on birds (Kirk et al 1996). This is not the case in other regions of the world where many of these pesticides are still

widely used with limited regulatory standards (Mineau 2004). An example of the effects on Canadian wildlife is evident in the death of a large number of North American Swainson's hawks (*Buteo swainsoni*) overwintering in Argentina attributed to monocrotophos exposure (Mineau 2004). The poisoning of Swainson's hawks by this organophosphate pesticide created enough international pressure for voluntary withdrawal of its use by the Argentinian government in the mid-1990s (Mineau 2004). The evolution of pesticide use in Canada has tended toward decreased persistence and increased specificity toward target pests (Environment Canada 2001). Mineau (2004) however, reports that many insecticides used in North America still kill birds, with scattered losses that are generally undetected.

Indirect impacts of pesticides have been demonstrated for many species. Pesticide contamination of wetlands and resultant reduction of aquatic invertebrates can impact the entire aquatic food chain. Sheehan et al. (1995) showed the implications of this impact for waterfowl, linking low recruitment to inadequate nutrition from reduced food availability for breeding hens and newly hatched ducklings (Sheehan et al. 1995). Granular anticholinesterase insecticides, consumed by wintering waterfowl foraging for seed in agricultural fields, poisoned both waterfowl and many scavenging raptors in the Fraser River Delta between 1991 and 1997 (Environment Canada 2004). Six of the seven insecticides implicated in the raptor poisonings have since been removed from the market, however other granular products are still available that pose similar risks for ingestion (Environment Canada 2004).

Pesticide drift into field margins, hedgerows and forest edges can impact surrounding habitat structure (Boutin et al. 2001; Jobin et al. 1997). Herbicide drift in these areas can impact plant species diversity, by shifting abundance and composition of species, and by creating disturbances

that facilitate the establishment of weedy or invasive species (Boutin et al. 2001; Jobin et al. 1997; Freemark and Boutin 1995). Habitat structure (composition, heterogeneity and interspersed) is also impacted by herbicide use with implications for habitat quality and quantity for beneficial insects and arthropods, and birds (Freemark and Boutin 1995). The drift and intentional spray of insecticides into these habitats for control of arthropod pests has been shown to impact pollinators and predators. Pesticides vary in their toxicity to pollinators, with a range of available alternatives to reduce impacts on bees in particular (B.C. Ministry of Water Land and Air Protection undated). Non-target impacts from insecticides, along with host plant losses from herbicide use have been implicated as reasons for pollinator decline in North America, along with habitat fragmentation and loss of critical nesting habitat (Cane and Tepdino 2000; Pernal 1999; Allen-Wardell et al. 1998).

Generally, herbicides are not acutely toxic to soil organisms but they may affect food and habitat by locally impacting vegetation (Freemark and Boutin 1995). Heavy pesticide use, however has been shown to reduce soil biological complexity impacting microbial activity (USDA 2004a). Impacts are variable depending on the specific pesticide and species, but generally foliar insecticides have less impact on soil organisms than fungicides or fumigants (USDA 2004a).

The long range transport and deposition of pesticides in the atmosphere is also a known source of contamination to aquatic and terrestrial habitats. In an Alberta watershed study investigating water quality in an agricultural area, 5 pesticides were detected during sampling with no record of local application (Alberta Agriculture Food and Rural Development 2002a).

Pesticides can also impact endocrine (hormone) systems involved in growth and development of wildlife species. Pauli (2002) reported that the early hatchling life stages of frogs were

particularly sensitive to some pesticides in agricultural runoff. Endocrine disruption from the substances studied altered hormone levels, sexual development, sperm mobility, male to female ratios, metamorphosis and immune functions (Pauli 2002). Effects on development and reproduction have also been observed in birds and fish exposed to organochlorine insecticides (many off the market) and currently used pesticides such as atrazine, trifluraline and permethrin (Société de la faune et des parcs du Québec 2002; Environment Canada 2001).

Status and effectiveness of mitigation

Application of pesticides within an overall integrated pest management (IPM) system is one option to reduce pesticide use on farms. IPM considers the use of pesticides, plant resistance, mechanical cultivation, crop rotation, inter-cropping, disruption of pest reproduction, and the management of biological processes to build populations of beneficial predators/parasites – combined with monitoring of threshold levels (Hilliard et al. 2002). IPM is simple idea, but is difficult to practice and use by farmers is not widespread, as it requires a large investment of time, knowledge and resources (Hilliard et al. 2002). Elements used in an IPM approach however, such as crop rotation and use of resistant plant varieties, have become widespread contributing to pesticide use reductions for some crop types. Koroluk et al. (2000) reported that over 55% of the crop area in Canada is under rotation systems, with as much as 75% in the Mixedwood Plain ecozone. In British Columbia, a recent survey showed that over 77% of berry, grain, oilseed, tree fruit and vegetable producers have adopted some elements of IPM (MacDonald et al. 2003). Organic farming is another mitigation measure that is slowly increasing in areas of the country with growing demand from consumers.

Although integrated pest management systems and organic farming are the most direct mitigative

actions for pesticide reduction, farm management elements which contribute to soil and water quality such as conservation tillage, buffers, and shelterbelts all contribute to prevention of runoff and erosion, a source of potential pesticide contamination of aquatic habitats. The presence of herbicides in streams in a U.S. National Water Quality Assessment was highest in the most intensively farmed regions of the country, particularly the corn belt (USDA 1999). The assessment found that farm management strategies successful in reducing the potential of runoff, would likely lead to regional scale improvements in water quality (USDA 1999).

Results of a recent survey of pesticide use by Ontario farmers, indicate that total pesticide use (as measured by active ingredient) decreased by 40.7% from 1983 to 1998 (AgCare 2003). This has been linked to both advances in pesticide science and education and changes in farm practices through integrated pest management and the use of biotechnology (AgCare 2003). In the past 5 years alone, overall pesticide use in fruit and vegetable crops has decreased by 20%, with use of insecticide and fungicides reduced by 57% and 54% respectively (AgCare 2003). Similarly, a 51% reduction in insecticide application was reported in the United States from 1979-1991 (Hilliard et al. 2002). While increases in BMPs associated with integrated pest management and crop rotations account for some of this reduction, it should be noted that the decrease in volume is also related to the use of more potent active ingredients which may not reflect a reduction in impact on the environment (Baril A. 2005).

Assessment of risk

Risk of pesticide contamination depends on where the pesticide ends up in the environment, it's toxicity to non-target species, and the timing and mechanism of application. Currently, standards and guidelines for pesticide use are not available for all pesticides (USDA 1999). Standards,

guidelines and most toxicity assessments generally don't account for risks from pesticide mixtures, or breakdown products (USDA 1999). This gap needs to be addressed to provide sufficient information to producers interested in reducing risks. Most producers rely on Health Canada and Agriculture and Agri-Food Canada to make these determinations through pesticide licensing and labeling requirements. Persistence of pesticides in the environment also increases risk that wildlife will be exposed to chemicals. An Alberta watershed study found residues of seven herbicides applied in the previous spring in field runoff the following year (Alberta Agriculture Food and Rural Development 2002).

A study from the University of Guelph (2000) demonstrated a 21% reduction in the risk to the environment from pesticides in Ontario between 1983 and 1993. With continued trends in reduction over the last 10 years, risks should be continuing to decrease. However, the widespread use of pesticides in intensive agriculture systems, and continuing development of new chemicals, will make the study of impacts on biodiversity a continual challenge. The Farm Environmental Management Survey (in 2001) indicated that about 73% of farmers apply pesticides to their crops (Korol 2004). Herbicides account for the largest portion of pesticide use, and impacts in intensively farmed monocultures of corn, soybeans and vegetables such as potatoes can be large. Species using particular crop types such as vegetables and orchards may be particularly at risk because of both the toxicity of chemicals involved and the number of applications per year (Boutin et al. 1999). Possible delayed responses and interactions of endocrine disrupting compounds need further investigation for both terrestrial and aquatic systems.

Key Issues with Analysis related to *Pesticide Contamination*

- Farm Field Management

- Agricultural Intensification
- Genetically Modified Crops

Nutrient Contamination

Farm Impact on Biodiversity (+ positive, – negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
+ nutrient and organic matter additions to soil	benefits to grain, oilseeds, forage crops, vegetables, berry crops, orchards, vineyards, other specialty crops, natural land for pasture, tame or seeded pasture	Pacific Maritime, Montane Cordillera, Prairies, Boreal Plains, Boreal Shield, Mixed-wood Plain, Atlantic Maritime	nutrient management planning		effects of long term nutrient loading on aquatic and terrestrial ecosystems cumulative effects on soil quality & food webs
– nutrient runoff from fields to water courses, nutrient drift from fields into native habitats	grain, oilseeds, vegetables, specialty crops	Fraser River Delta (Pacific Maritime), southern Ontario and St. Lawrence Lowlands in Quebec (Mixed-wood Plain)	nutrient management planning, timing of application, incorporation buffers, healthy riparian areas, conservation tillage, maintenance of tile drains and outlets	recent legislation for nutrient management may have an impact	persistence of endocrine disrupting chemicals in soil /water after manure application
– nutrient runoff from feedlots/ ranching operations	beef, dairy	Montane Cordillera, Prairies, southern Ontario, St. Lawrence Lowlands (Mixed-wood Plain)	managing livestock access to sensitive areas management and location of winter yards and feedlots buffers, healthy riparian areas	financial, labour and time barriers to mitigative actions	
– nutrient contamination from improper manure storage and handling	dairy, pork, poultry	Fraser River Delta (Pacific Maritime), Manitoba (central and Inter	proper manure storage and handling facilities at recommended	financial, labour and time barriers to mitigative actions many producers	

Farm Impact on Biodiversity (+ positive, – negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
facilities in intensive livestock operations		Lakes regions) Alberta (Parkland area) (Prairies), southern ON, St. Lawrence Lowlands QC (Mixedwood Plain)	distances from water course waste treatment where necessary	unaware of BMPs	

Problem definition

Applying nutrients in the form of manure or compost to farm fields is a sustainable agricultural practice, providing a source of both nutrients and organic matter to the soil. Nutrients increase plant production and organic matter improves soil structure. Inorganic fertilizers are also often applied to add nutrients to the soil. With careful planning, manure, compost and fertilizer can be added to farm fields, with a limited impact on the environment. Proper application rates, timing and methods are required to minimize risk of contamination of surface and ground water sources through erosion pathways. Other potential risks for nutrient contamination include runoff from feedlots and wintering areas, livestock access to water bodies, leaks/spills at manure storage and handling facilities, and milkhouse wastewater.

Elements of biodiversity impacted

Nutrients can contaminate surface waters when runoff and erosion from farm fields reach wetlands or streams. Excess phosphorous and nitrogen accelerate the growth of algae and other aquatic plants (eutrophication), and additional plant respiration and decomposition can deplete dissolved oxygen levels in the water with implications for fish and other aquatic organisms

(Alberta Agriculture Food and Rural Development 2002b). With increased emergent plant biomass, plant species diversity tends to decrease, with dominance by a few species (Chambers et al. 2001). Eutrophication creates turbid conditions, smothers many bottom-dwelling organisms, clogs spawning beds and causes shifts in species composition (Coote and Gregorich 2000). Large blue green algae blooms can also produce toxins affecting both wildlife and livestock (Alberta Agriculture Food and Rural Development 2002b).

Fish are particularly sensitive to pollution and impacts of excess nutrients and organic matter can affect reproductive success. Organic matter deposited on eggs can cause the eggs to suffocate or develop abnormally as a result of reduced oxygen levels (Environment Canada 1998). Spawning fish and newly hatched fry are also sensitive to agricultural pollution (Environment Canada 1998). Ammonia is particularly toxic to fish at high levels, impacting their ability to absorb oxygen (Environment Canada 2001b). Accidental manure spills related to aging storage facilities or improper handling of manure often cause fish die-offs (Société de la faune et des parcs du Québec 2003). Sub-lethal exposure to ammonia has also been shown to cause physiological problems in fish and increase susceptibility to disease and parasites (Chambers et al. 2001).

Amphibian decline has been related to long term exposures to nitrates in water, with the highest risks during the egg and tadpole developmental stages (Environment Canada 2001b; Gray and Tuominen 1999). High nitrate concentrations associated with fertilizer have been shown to impact hatchling success and tadpole survivorship for several amphibian species in Ontario (Bishop et al. 1999). Studies indicate that nitrate concentrations ranging from 13-40 ppm will kill 50% of tadpoles, and concentrations from 2-5 ppm result in chronic effects including reduced feeding, movement, and deformities (Canadian Wildlife Service 2004). Water quality data

collected in the Great Lakes states and provinces in the 1990's showed that nitrate levels in this region exceeded 2 ppm in 19.8% of the samples, and exceeded 10 ppm in 3.1% (Canadian Wildlife Service 2004). Bishop et al. (1999) showed that embryos of the northern leopard frog (*Rana pipiens*) were sensitive to ammonia concentrations over 0.27 mg/L, and added that concentrations above 2mg/L were regularly detected in water near agricultural lands.

Amphibian deformities have also been linked to agricultural landscapes, often attributed to pesticide contamination, nutrients and other pollutants such as fuel (Ouellet et al. 2001). A recent study looked at these factors along with ultra violet radiation and parasite infection as potential factors influencing amphibian decline (Blaustein and Johnson 2003). The study found that while all factors may contribute to amphibian decline and deformities, a parasitic trematode (*Ribeiroira ondatrae*) accounts for one of the most prevalent deformities, extra hind legs (Blaustein and Johnson 2001). Nutrient contamination from agriculture has been shown to exacerbate the parasite outbreaks by causing eutrophication which nourishes the snail populations that host the parasitic trematode before it infects the tadpoles (Johnson and Chase 2004; Blaustein and Johnson 2001). Kiesecker (2002) found that stresses from pesticide exposure can impact the ability of the host tadpole to resist parasitic infection, resulting in greater parasite loads and risk of deformities.

Fertilizers and manure are also sources of heavy metals (along with some pesticides and irrigation water) with potential toxic effects on humans, livestock, plants and aquatic life at high concentrations (Alberta Agriculture Food and Rural Development 2002a). Waterborne pathogens and parasites in runoff can impact wildlife in aquatic ecosystems, and can be detrimental to human and livestock health. Mitchell (2002) found that runoff from beef, dairy, and game farmed elk and bison in Alberta, was a significant contributor of parasite loads in a watershed (including

Giardia and Cryptosporidium). Changes in aquatic ecosystems from nutrient enrichment, eutrophication and alteration of water flow have also been linked to changes in density of intermediate hosts and ultimately parasite loads in watersheds (Environment Canada 2001c; Spalding et al. 1993). A general relationship between agricultural intensity and levels of pathogens in water has not been established to date in Canada (PFRA 2000). However, runoff from wintering areas and feedlots, and waste waters from dairy and hog operations are likely to be a significant source and concerns continue to increase with intensification of livestock operations (PFRA 2000). The compression of wildlife populations into smaller habitat areas due to fragmentation can also increase risk of water contamination by wildlife (Environment Canada 2001b).

Large increases in intensive hog production is a concern for both manure management, and the potential release of a range of pharmaceuticals (antibiotics, dewormers, reproductive hormones) into the environment. While most of these products are completely broken down in the pig's body, the potential for environmental contamination is the subject of ongoing research. Pig reproductive hormones have the potential to act as endocrine disruptors in the environment, impacting growth, development and reproduction of fish and wildlife (Alberta Pork 2002). The release of antimicrobial medications into the environment also increases the risk of drug resistance (Alberta Pork 2002). The broad use of endectocidal drugs (such as ivermectin) in cattle has been shown to impact invertebrate communities associated with dung, with reported effects on larval and adult mortality, feeding, reproduction, growth and metamorphosis, and water balance (Herd 1995). The importance of these impacts on invertebrate communities is still under investigation, with potential concern for ecological services such as nutrient cycling, pollination and predation (Herd 1995).

Nutrient drift to surrounding habitats can also impact plant communities, resulting in a decline in species richness (Kleijn and Snoeijs 1997), increases in plant biomass (Kleijn 1996) and dominance by unwanted weeds and introduced species (Boutin and Jobin 1998). Spreading nutrients on native rangeland also impacts plant communities, causing species shifts, increases in weedy species, and reduction in ground cover species in favor of dominant grasses (Alberta Agriculture Food and Rural Development 2003).

Status and effectiveness of mitigation

Nutrient losses are economically significant to the farmer, and pose a risk to water quality. Nutrient management is a large part of environmental farm planning, and best management practices exist to reduce nutrient pathways to water. The risks are variable regionally and locally depending on site conditions (soil type, tillage methods, slope, cover crop, presence of native cover and buffers) and precipitation. Timing of application and concentration of nutrients applied need to be planned based on crop needs and absorption capabilities. The Farm Environmental Management Survey (in 2001) reported that approximately one quarter of manure produced in Canada is from farms with formal manure management plans and/or nutrient management plans either required by government regulation, or developed to reduce environmental risks (Beaulieu 2004). A greater proportion of farms (32.6%) indicated that they had fully implemented beneficial management practices related to manure management, and 15.9% of farms indicated partial implementation (Beaulieu 2004). However, another 41.7% indicated that they were still unfamiliar with beneficial management practices for manure in their region (Beaulieu 2004). The Farm Environmental Management Survey (in 2001) indicates that three quarters of Canadian farmers apply inorganic fertilizers to their fields to provide nutrients to crops (Korol 2004). While only 15% of farms have formal nutrient management plans, approximately 50% of Canadian

farms use annual soil test results to determine application rates (Korol 2004).

The Farm Environmental Management Survey (in 2001) reported that 23.3% of producers with farms with liquid manure storage systems were unfamiliar with the best management practices related to manure management in their region (Statistics Canada 2003). On farms with solid/semi-solid systems 44.4% were unfamiliar with the BMPs. Nationally, 52.5% of respondents with liquid manure storage systems and 26.2% with solid/semi-solid storage systems indicated that they have fully adopted BMPs related to manure management on their farm (Statistics Canada 2003). Recent legislation such as the Agricultural Operations and Practices Act in Alberta, Ontario's Nutrient Management Act and Quebec's Loi sur la qualité de l'environnement, will also have an effect on nutrient management, particularly on intensive operations.

The intensification of the livestock industry across Canada has resulted in large nutrient surpluses in some regions. In the Lower Fraser Valley for example, chicken production increased by 36% over 5 years from 1996 to 2001 (Schreier et al. 2003). The continuous concentration of animals in key agricultural areas, as well as increases in stocking densities on individual farms will result in increasing waste management problems. Producers have responded, reducing nitrogen and phosphorous concentrations in food, and moving manure from surplus to deficit areas, but in some areas of concentrated intensive livestock production, manure waste treatment facilities are required to reduce the impacts of nutrients on the environment (Schreier et al. 2003). The expansion of the livestock industry has been restricted in some regions of the country such as Quebec because of water quality concerns (Harker et al. 2004). Promotion of the concept of environmental certification in the pork industry with standards for wildlife habitat protection, soil

conservation and maintenance of phosphorous levels is ongoing in Quebec (Société de la faune et des parcs du Québec 2003).

On the prairies, nutrient levels in small watersheds have been correlated to agricultural intensity (PFRA 2000). In Alberta, a 5 year water quality study found that moderate and high intensity areas (based on livestock density, fertilizer and herbicide inputs) had the highest risk of water quality degradation (Alberta Agriculture Food and Rural Development 2004). On a regional scale, the significance of nutrients from agriculture on water quality is not clear (PFRA 2000). The 1998 U.S. National Water Quality Inventory showed that nutrients are the 3rd most prevalent pollutant in streams identified as environmentally impaired, after sediment and bacteria (Fawcett and Towery 2002).

Practices such as conservation tillage, retaining or planting buffers, maintenance of healthy riparian habitats and agricultural drains, and crop rotation, all reduce the potential of erosion and pathways of nutrients to water. Managing livestock access to sensitive sites, providing alternate water sources, and developing or upgrading manure storage systems can be extremely costly to the farmer. Stewardship programs, and government loans and grants are available in some cases, bearing part of the cost, but often the cost, labour and time investments can be a barrier to adoption of best management practices. The success of the Cows and Fish program in Alberta, along with many other community based watershed stewardship initiatives, indicates the commitment of producers to water quality protection and improvement.

Assessment of risk

In Canada, household sewage is the largest point source of nitrogen and phosphorous to the environment, and agricultural activities are the largest non-point pollution source. The risk of

water contamination by nitrogen and phosphorous is highest where excess soil moisture is present along with intensive agriculture (e.g. potato farms in Atlantic Canada, Fraser River Delta, southwestern Ontario, St. Lawrence Lowlands Quebec) (MacDonald 2000; Bolinder et al. 2000). As intensity of production increases, risk of contamination tends to increase with higher nutrient demands and inputs for crops such as corn and soybeans (MacDonald 2000; Bolinder et al. 2000). Areas of intensive livestock production also create risks for nitrogen contamination (MacDonald 2000).

Mitigative measures are in place to reduce non-point source pollution on farms, and Environmental Farm Planning and stewardship initiatives are raising awareness, and providing some resources to reduce pollutant pathways. Farmers are very concerned about water quality for both human and livestock health reasons and have shown a greater interest in BMPs related to water quality issues than wildlife habitat issues. Livestock weight gain and health have been shown to increase with improved water quality (Chorney and Josephson 2000). Given the rapid (and projected) increases in intensive livestock operations, the management of nutrient surpluses, and the efficient storage and application of nutrients are going to be important issues for farm environmental management in the future.

Key Issues with Analysis related to Nutrient Contamination

- Farm Field Management
- Agricultural Intensification
- Grazing
- Disease

Siltation/ Sedimentation

Farm Impact on Biodiversity (+ positive, – negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
– soil erosion into aquatic ecosystems from conventional tillage and summerfallow	grain, oilseeds, summerfallow vegetables, other specialty crops	Fraser River Delta (Pacific Maritime), Prairies, southern Ontario and St. Lawrence Lowlands QC (Mixedwood Plain), Atlantic Maritime	conservation tillage techniques, terracing, intercropping, buffers, habitat maintenance of riparian areas,	spreading with development of GMO technology however transition is slow as a result of costs and social barriers to change, realization of environmental benefits is delayed	effects on watersheds significance/ extent of impact relative to other land uses cumulative impacts of all land uses
– degradation of riparian habitats through overgrazing – stream bank trampling, streambed disturbance by livestock	beef, dairy	Montane Cordillera, Prairies, Boreal Plain, southern Ontario and St. Lawrence Lowlands QC (Mixedwood Plain)	managing livestock access to sensitive sites	cost/time/labour barriers to application – some incentive programs exist to assist with cost	

Problem definition

When soil erodes from farm fields, it often becomes a both a pollutant and carrier of pollutants to surface water sources. Sediment loads depend on the use of the surrounding land, and health of riparian areas surrounding wetlands and streams. Conventional tillage and some other cropping practices increases risk of erosion, and intensive livestock use of riparian areas, wetlands and streams can also impact stream banks, stream beds and the condition of riparian areas. Sediments impact aquatic ecosystems causing turbidity, degrading habitat, and often altering the food chain.

Elements of biodiversity impacted

Excess sediments suspended in surface water can decrease visibility for aquatic organisms, disrupting normal foraging, mating and escape behaviour (Coote and Gregorich 2000). Respiration in fish can also be impacted due to gill abrasion (Coote and Gregorich 2000). Increased turbidity can also reduce oxygen availability and may impact aquatic food webs by shading primary producers (Euliss and Mushett 1999). Helferty (2002) found that spring breeding amphibians avoid breeding grounds with high sediment levels. Suspended silt and clay are toxic to some zooplankton and can reduce feeding rates, and required energy for reproduction (Euliss and Mushet 1999; Gleason and Euliss 1998). Suspended sediment can also clog filtering apparatuses of aquatic invertebrates (Euliss and Mushet 1999).

The deposition of sediment on spawning gravel, degrades habitat for fish, often covering incubating eggs which can impact development and reduce survival by suffocating eggs or trapping emerging fry (Coote and Gregorich 2000). Impacts on fish can be significant, with research in Quebec showing a large decline in brook trout (*Salvelinus fontinalis*) egg emergence from over 90% at 0% fine sediment present in gravel, to less than 70% emergence with 10% fine sediment, and only 25% emergence with 30% fine sediment in gravel (Société de la faune et des parcs du Quebec 2002). Sedimentation also buries seed banks and invertebrate egg banks in wetlands (Euliss and Mushet 1999). Substrates critical to the production of periphytic algae and macrophytes may also be covered with sediment, impacting production of a critical element of the food chain (Gleason and Euliss 1998). Aquatic invertebrates may be heavily impacted due to reductions in both food (algae/macrophytes) and cover. The results are impacts on wetland nutrient cycles, and reduced food availability for wetland wildlife (Gleason and Euliss 1998).

Tillage of lands surrounding wetlands causes increases in water level fluctuations, potentially impacting aquatic communities by altering water chemistry and seasonal water levels (Euliss and Mushet 1999). Different crops allow different rates of erosion, with intensive row cropping of wide row crops such as soybeans and corn having greater potential for erosion than narrower row crops such as wheat and oats (Coote and Gregorich 2000). Gleason and Euliss (1998) showed that sedimentation was much greater in wetlands surrounded by cropland, than grassland cover. Intensive livestock use of riparian areas and watercourses can also cause sedimentation, as a result of stream bank trampling and reduced vegetative cover. Alteration of stream bank vegetation through grazing or cultivation can increase water temperatures, potentially influencing the effect of pollutants on aquatic life (PFRA 2000). Higher temperatures impact oxygen availability, solubility of chemicals, and may limit growth, spawning, incubation and migration as most aquatic organisms have a narrow optimum temperature range (PFRA 2000). Land drainage and stream channelization to assist runoff are other major sources of sediment and associated pollutants to surface waters (PFRA 2000).

Status and effectiveness of mitigation

The U.S. National Water Quality Initiative (1998) reported that sediment was the most prevalent pollutant in streams identified as environmentally impaired (Fawcett and Towery 2002). The importance of sedimentation from field runoff on the Canadian Prairies is not clear (PFRA 2000). Beneficial management practices to reduce erosion are practiced by many Canadian farmers, and include planting perennial cover, use of conservation tillage, planting of buffer strips and shelterbelts. Crop rotation of wide row and narrow row crops can also reduce erosion risk (Coote and Gregorich 2000).

Kulshreshtha and Knopf (2003) recently reported on the distribution and use of trees from the Prairie Farm Rehabilitation Centre's Shelterbelt Centre in Indian Head Saskatchewan. The majority (88.6%) of trees distributed from 1981-1996 were distributed to landowners for planting of field and farmstead shelterbelts (Kulshreshtha and Knopf 2003). Over the last century (1901-2002) an estimated 576 million seedlings have been distributed by the centre for planting to benefit soil, water, air and biodiversity (Kulshreshtha and Knopf 2003). Similar programs exist in other provinces (on much smaller scales) particularly for riparian habitat improvements. Stewardship and incentive programs also exist for managing livestock access to water, but often the cost, labour and time investments can be a barrier to adoption of best management practices for producers.

Assessment of risk

Shelton et al. (2000) reported that an indicator of the risk of water erosion (based on land use, tillage practices, and crop types) fell for most provinces including Alberta, Saskatchewan, Manitoba, Ontario and New Brunswick between 1981-1996. Over the same period, the risk remained the same in British Columbia and Prince Edward Island, and increased in Quebec and Nova Scotia (Shelton et al. 2000). The risk of tillage erosion in Canada fell 22% over the same period (King et al. 2000). While the risk of tillage erosion dropped largely due changes in tillage equipment, adoption of conservation tillage and changing crop rotations, some areas of the country showed increasing risk over this period as a result of increased intensification of crop production (King et al. 2000). In the maritime provinces for example, risk of tillage erosion dropped overall, but New Brunswick and Prince Edward Island were identified as areas of continuing high risk associated with potato production on steep slopes (King et al. 2000).

While the adoption of conservation tillage practices and other BMPs, along with the decrease in summerfallow on the prairies is having impact in mitigating risks, it is evident from the U.S. National Water Quality Survey, that sedimentation is still a problem in agro-ecosystems. Individual farmers are also conducting assessments and reducing risks through processes such as the Environmental Farm Plans. This is a critical step to reducing impacts, as variables such as slope, soil type, agricultural production type, tillage practices, cropping patterns and amount of residual natural cover make management solutions different on every farm.

Key Issues with Analysis related to *Siltation/Sedimentation*

- Farm Field Management
- Grazing
- Agricultural Intensification
- Pesticide Contamination
- Nutrient Contamination

Genetically Modified Crops

Farm Impact on Biodiversity (+ positive, – negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
– recent and extensive use of GM varieties with potential direct and indirect impacts on non-target species – increased herbicide use -- change in farm practices with intensification + increased use of conservation tillage systems + reduced pesticide use + reduced fertilizer use	grain oilseeds vegetables	Prairies Mixedwood Plain Atlantic Maritime	extensive field trials to monitor impacts	ongoing in industry, government and research communities	impact of insecticidal residues on soil and aquatic organisms long term and cumulative effects on biodiversity impacts on organisms at higher trophic levels determining what is a significant effect, and what are good bio-indicator species what will be the impacts of multiply-engineered traits or gene stacking?

Problem definition

Genetically modified (GM) crops were approved in 1996 for use in Canada. Concern for biodiversity and risk to the environment has arisen due to expansion of crops quickly over a large area, and a number of questions about long term impacts. These potential impacts have been outlined by a number of sources (Conway 2000; Marshall 2003; Peterson et al. 2000; Pimental 2000; Walker 2000) and include:

- gene transfer and potential risk for creating plants with increased weediness or herbicide

resistance, or new viral strains with undesirable traits;

- development of resistance to Bt, a toxin from the bacterium *Bacillus thurengiensis*;
- increased herbicide use;
- impacts on non-target species, trophic interactions and ecological services; and,
- loss of biodiversity from changes in farm practices.

Potential environmental benefits are also outlined by the same authors including reduced pesticide use, reduced fertilizer use, increased opportunities for reduced tillage systems, development of perennial grains and slowing erosion using perennial crops.

Elements of biodiversity impacted

Herbicide-tolerant soybeans, cereals and canola were the first GM crops to be used on a large scale. These crops are resistant to glyphosate ('Round-up') and have simplified weed control for farmers. Benefits of this technology to both farmers and the environment include: facilitating continued expansion of reduced tillage and no-till, prevention of soil erosion, and the use of more benign herbicides. 'Weeds' in crops and surrounding field margins can be important for other organisms including insects and associated mammal and bird assemblages (Marshall 2003; Peterson et al. 2000). There is concern that the use of round-up ready GM crops may eliminate weeds 'too' efficiently, simplifying the vegetative structure of agro-ecosystems or causing weed community shifts (Conner et al. 2003; Marshall 2003). Glyphosate, however, is not completely effective, leaving on average 2% of weeds in crop fields (Felsot 2001). A Farm Scale Evaluation of the impact of genetically modified herbicide tolerant (GMHT) crops in comparison to conventional crop management on native flora and fauna was conducted in the United Kingdom. Results showed that impacts on weed communities and seed banks were variable depending on

the crop studied (Heard et al. 2003). Invertebrates at all trophic levels were sensitive to local impacts from changes in weed management related to shifts in resource availability (Hawes et al. 2003).

Concern also exists over increased use of herbicides with the potential for pollution of agricultural and aquatic ecosystems (Pimental 2000). Increased use of glyphosate by producers in Canada and the U.S. as a result of the expansion into 'round up ready' crop varieties has lead to concern over its toxicity to non-target species. A study of glyphosate tolerant spring wheat addressed some of these concerns over the risk of replacement of traditional crop varieties and their associated herbicides (Peterson and Hulting 2004). In a comparison of risk (both hazard and exposure) of 16 active herbicide ingredients on: acute dietary risk for birds and mammals; acute risk for aquatic invertebrates, vertebrates and plants; and seedling emergence and vigour of non-target terrestrial plants, glyphosate was found to have the least risk for aquatic plants including duckweed (*Lemna minor*) and green algae, as well as non target seedling emergence and ground water (Peterson and Hulting 2004). While all herbicides were below tolerable risk levels for the ecological variables in the study, when glyphosate was applied in Round up, 10 of 15 had lower risk quotients for aquatic vertebrates, and 11 had lower risk quotients for aquatic invertebrates (Peterson and Hulting 2004). The formulation surfactant in Roundup, is significantly more toxic to aquatic organisms than the active ingredient (glyphosate), but because of its low concentrations in the mix, risk from chronic toxicity remains low (Felsot 2001).

The use of pest resistant crops, such as Bt corn can reduce pesticide use significantly with benefits to non-target fauna (Marshall 2003). The controversy over Bt corn and Monarch butterflies (*Danaus plexippus*) however, has brought public attention to some of the potential

risks associated with genetically modified crops. The Bt toxin in genetically modified corn is expressed in pollen and concern for Monarch butterflies and other non-target species arose from the potential for ingesting pollen falling on host plants. Most of the controversy is based on research on event 176 Bt corn which was demonstrated to have effects on first instar monarch butterflies (*Danaus plexippus*) and black swallowtails (*Papilio polyxenes asterius*) (Stanley-Horn et al. 2001; Shelton and Sears 2001). Other events (Mon 810 and Bt11) have no significant impact on these non-target species (Shelton and Sears 2001). Event 176 Bt corn expressed the highest level of Bt toxin, and has been removed from the market since 2001 based on resistance concerns. Coordinated research on other varieties in Maryland, Iowa and Ontario have now shown that the dose of Bt pollen that monarchs are exposed to under field conditions does not significantly affect monarch larval mortality and development (Shelton and Sears 2001).

Although herbicide-tolerant soybeans have been shown to have lower insect populations than conventional cultivars, studies in rape seed have indicated that there is no difference in insect pollinator number or behaviour associated with crop flowers (Marshall 2003). Direct toxicity to honey bees (*Apis mellifera*) is extremely rare with no current evidence of changes in colony performance due to widely grown GM crops (Conner et al. 2003).

Some predators and parasitoids in genetically modified crops have been shown to be influenced by prey quality, with effects on weight gain and time to maturity (Conner et al. 2003). Impacts have been generally attributed to quality and quantity of prey, and not the toxins in the transgenic plants (Conner et al. 2003). Other studies have shown an increase in native beneficial invertebrates in GM crops due to reductions in pesticide use (Conner et al. 2003). Riddick et al. (2000) found that heteropteran predators and spiders were significantly more abundant in

transgenic potatoes than regular crop varieties, and no significant difference was found for carabid and coccinelid predators.

Effects of GM crops on soil organisms in agro-ecosystems have also been studied, however research is ongoing and long term impacts remain unknown. Soil organisms are heavily exposed to genetically modified plant material in leaf litter, root exudates and during decomposition (Conner et al. 2003). A study on soil organisms in plant litter from genetically engineered tobacco with proteinase inhibitor 1, a protein with insecticidal activity, showed that the protein was persistent in buried plant litter for close to 2 months (Donegan et al 1997). The transgenic litter altered nematode community trophic structure, and had significantly lower Collembola populations (Donegan et al. 1997). Cowgill et al. (2002) showed that both the use of nematicides in traditional varieties and GM nematode resistant plants affected components of the soil microbial community. The changes however, did not alter soil functioning represented by litter decomposition rates (Cowgill et al. 2002). Plant structural changes related to amount of lignin in GM corn varieties have also been shown to influence communities of soil organisms by changing the structure of food resources (USDA 2004). Most studies have shown similar changes in communities of bacteria, fungi and soil invertebrate populations, but direct toxicity effects have not been demonstrated (Conner et al. 2003).

Status and effectiveness of mitigation

Research into GM crops is ongoing with respect to both environmental issues, and the development of crop types with new traits. The Canadian Food Inspection Agency (CFIA) is responsible for assessment of risk in Canada and monitors all field trials of GMO crop varieties to ensure that trials comply with a thorough checklist for environmental safety (Crop Protection

Institute of Canada 2001). Environment Canada carries the responsibility of providing guidelines for testing effects on the environment (Crop Protection Institute of Canada 2001). In the US, the Environmental Protection Agency (EPA) has a similar role. Prior to registration of Bt corn in the United States, the EPA conducted a series of risk assessments on the potential effects of Bt endotoxins on a wide range of organisms including birds, aquatic invertebrates, honey bees (*Apis mellifera*), ladybugs (Coccinellidae), earthworms (Lumbricidae), springtails (Collembola), other non-target organisms and endangered species (Shelton and Sears 2001). The outcome of these assessments indicated that they could ‘foresee no unreasonable adverse threats to humans, non-target organisms or the environment’ (Shelton and Sears 2001).

Use of genetically modified crops in Canada has steadily increased since their approval in 1996. In Ontario it is estimated that 50-55% of soybeans and corn, and over 90% of canola acres are GM varieties (AgCare 2003). No-till crop acres in the U.S. have increased 35% since 1996, with 63% of soybean farmers citing herbicide-tolerant technology as the key factor in their decision (Fawcett and Towery 2002).

The use of Bt crops in the U.S., has resulted in an estimated annual reduction of over 7.7 million acre treatments of synthetic insecticides (Shelton and Sears 2001). This successful reduction in pesticide use may be overshadowed however, by the continued increase in glyphosate use due to developing weed resistance associated with heavy reliance on this single herbicide (Benbrook 2004). Marshall (2003) reports that the use of herbicide resistant crops has resulted in a 72% increase in the use of glyphosate in the United States.

Assessment of risk

It appears that genetically modified crops have the potential to both positively and negatively

impact biodiversity and the functioning of ecosystems. There is still considerable debate in the conservation and scientific community about their use, risks and benefits. The risks associated with each different GM crop still need to be assessed independently, avoiding the rush to release them into the farm environment. Peterson et al. (2000) suggest that risk depends on the complex interaction of genetic modification, the organism's natural history and the properties of the ecosystem it is introduced into. It also remains critical under any assessment of risk to define an appropriate baseline for comparison and decision (Conner et al. 2003). In this case, any risk assessment of the ecological impacts of GM crops, needs to involve a comparison of both the perceived benefits and potential threats of the crops they are replacing (Conner et al. 2003). An assessment of potential for collateral damage is also necessary (Maguire 2001).

Changes in farm practices associated with the use of GM crops, including increases in conservation tillage, reductions in pesticide use, and the development of perennial crops, have far reaching implications for soil and water quality, and biodiversity. Other changes in farm practices including field size expansion, intensification into monoculture crops, and the potential for development of characteristics such as drought tolerance facilitating the expansion of crops into marginal lands, will also create future challenges for biodiversity conservation.

Key Issues with Analysis related to *Genetically Modified Crops*

- Farm Field Management
- Pesticide Contamination
- Agricultural Intensification

Agricultural Intensification

Farm Impact on Biodiversity (+ positive, – negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
– changes in farm production type resulting in decreased habitat heterogeneity	grain, oilseeds, greenhouse, orchard, vineyard, vegetables, other specialty crops	Fraser River Delta (Pacific Maritime), Okanagan Valley (Montane Cordillera), Prairies, southern Ontario and St. Lawrence Lowlands QC (Mixedwood Plain), potato production areas of the Atlantic Maritime	conservation tillage, crop rotation, integrated pest management, habitat maintenance	intensification is driven by economic cycles and market demands, barriers to application from associated market losses, and socio-economic trends in farming practices to larger farms, fields and machinery	determining thresholds where farmland habitats become wildlife population sinks
– excess nutrients from intensive livestock production and potential for over application and contamination of terrestrial and aquatic ecosystems	beef, dairy, pork, poultry	Fraser River Delta (Pacific Maritime), Manitoba (Central and Inter Lakes regions) and Alberta (Parkland area) (Prairies), southern Ontario and St. Lawrence Lowlands QC (Mixedwood Plain)	proper manure storage and handling facilities at recommended distances from water course waste treatment where necessary nutrient management planning	financial, labour and time barriers to mitigative actions many producers unaware of BMPs recent legislation for NMP may have impact	effects of long term nutrient loading on aquatic and terrestrial ecosystems

Farm Impact on Biodiversity (+ positive, – negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
impacts on water quality and quantity from water use for livestock watering and irrigation	beef, hogs, poultry, dairy, grain, oilseeds, forage crops, vegetables, berry crops, orchard, vineyard, other specialty crops	southern Alberta and Saskatchewan (Prairies), Okanagan Valley (Montane Cordillera), southern Ontario and Quebec (Mixedwood Plain)	permits for water use, water saving BMPs, pivot sprinklers, micro-irrigation, mulches	use by permit is widespread, and irrigation efficiency has improved considerably	how much water must be left in high-demand areas to retain the integrity of the surface and ground water (what is a sustainable level of use to protect water quantity and quality over the long term and are these levels the same as those required to sustain biodiversity over the long term)

Problem definition

Agricultural intensification refers to the increase in intensity in farm production types (woodlot<pasture<forage<cropland<specialty crops) and the associated increase in tillage and inputs. The intensification of agriculture has been ongoing for the last century and will continue with developments in biotechnology, precision farming and irrigation technologies. With these developments, along with increases in the size of farms, machinery and fields there has been a general decrease in diversity of cover types over large areas, and often the removal of natural habitats (woodlots, hedgerows, wetlands) for ease of production. Specialization in intensively managed crops, often requiring more inputs of fertilizer, pesticides and irrigation now cover areas that once supported a more heterogeneous farming lifestyle often including livestock, forages, crops and woodlands. On the prairies, this trend has been towards grain and oilseeds. Corn and

specialty crops dominate large areas of Ontario and Quebec.

Elements of biodiversity impacted

All agricultural land provides habitat for some species, but for many species, cropland provides lower quality habitat (Neave et al. 2000). These species are often dependent on the remnants of natural or semi-natural habitats remaining in the agricultural landscape. Intensity of production and landscape distribution of cover types impacts both quantity and quality of these remaining habitats.

Some species have responded favorably to agricultural lands, but generally wildlife prefer agricultural production types with less intensive cropping practices. Pasture and tame perennial cover provide habitat for more species than cropland, as they maintain a well developed herbaceous layer for insect prey and protective cover (Jobin et al. 1996). McMaster (2000) recorded 9 of 10 prairie grassland bird species more frequently in permanent cover program fields than in cropland. Waterfowl including gadwall (*Anas strepera*), mallards (*Anas platyrhynchos*), and blue-winged teal (*Anas discors*) have also been shown to prefer tame hay to cropland for nesting (McMaster et al. 2002). Pintails (*Anas acuta*) have been shown to be 10 times more productive in hayland than spring seeded croplands hatching one nest for every 142 and 1332 acres respectively (Masterman 2003). Fall seeded cereal crops have also proved to be very productive for pintails at one nest per 72 acres (Masterman 2003). The use of winter wheat has been shown to reduce disturbance to wildlife especially during the nesting season (Fowler 2002; McGauly 2004). Practices such as green manure and relay cropping systems may also be beneficial for birds, but little is known of their effects (Kirk et al. 1996)

Markets often are the basis of shifts in agricultural practices. On the prairies, the prices of grain

and cattle drive many landuse decisions (Baydack et al. 2000). When the price of grain is high, pasture may be converted to grain, decreasing habitat availability for many species, when grain prices drop, production no longer makes sense on marginal lands, and the area is re-seeded. When cattle prices are high, pastures may be more heavily grazed, again diminishing habitat quality for some species (Baydack et al. 2000).

The use of large machinery and the amalgamation of farms across Canada has resulted in a decrease in local diversity of farm habitats including cropland. Jobin et al (1996) showed this trend in Quebec and linked declines in populations of farmland birds with decreased heterogeneity of farm livelihoods. Smith (2003) also linked farmland diversity with increased diversity of bird life. Anuran populations have also been impacted by reductions in habitat heterogeneity following agricultural intensification in southern Quebec (Bonin et al. 1997). On the prairies, Swainson's hawk (*Buteo swainsoni*) has shown a preference for a mix of native habitats and a diversity of crops over large areas of intensive monoculture (Schumtz et al. 2001). Habitats such as field margins, hedgerows and woodlots adjacent to intensively farmed fields are also impacted by intensive management of farm fields. These habitats are often removed for ease of operations in intensively farmed fields, and where they remain they may be dominated by weedy species as a result of disturbance from cropping practices (McLaughlin and Mineau 1995). A study of hedgerows in eastern Canada by Boutin et al. (2001) showed that field size has doubled over the last 40 years in the region, at the expense of hedgerows and other native habitats. Large scale studies in Great Britain have looked at the impacts of agricultural intensification on populations of farmland birds over the past 30-40 years. A group of interrelated factors including: reductions in spring sowing of cereals, simplification of crop rotation, increased pesticide and inorganic fertilizer use and intensive grassland management were linked

to population decline and range reductions for a large number of farmland bird species in these studies (Robinson and Sutherland 2002; Chamberlain et al. 2000; Fuller et al. 1995).

The pressures of intensification in Canada are particularly obvious in highly productive areas. In British Columbia's Fraser River Delta for example, the expansion of the greenhouse industry is putting pressure on farmland which provides critical migratory and wintering habitat for millions of waterfowl, shorebirds and raptors (Canadian Wildlife Service 2003). The low elevation grasslands and particularly the endangered antelope-brush plant community of the south Okanagan / lower Similkameen have been subject to both urban development pressure and a rapidly expanding wine industry (Government of British Columbia 2001). Demand for other specialty crops such as ginseng and fruits and vegetables, and the expansion of livestock farms, is also impacting biodiversity in the region. The intensification of livestock farming has increased rapidly in other regions of the country as well with implications for manure management and water quality. Improvements in forage crops and range management have also increased stocking rates on many farms (Lapointe et al. 2003).

The hydrology of a region depends on the composition of the landscape, with the proportion of annual cover and crop type impacting absorption and flows (Harker et al. 2004). Expanded road networks associated with intensification have implications for invasive species spread, habitat fragmentation, and have created an elaborate drainage network which impacts water quality and quantity (Baydack et al. 2000). Water use for irrigation of specialty crops and livestock watering may alter flow regimes, cause fluctuations in water levels, or impact water quality with resultant implications for fish habitat (Sentar Consultants Ltd. 1995). Effects include direct blockage of fish movement, loss of habitat, sedimentation of spawning beds (Sentar Consultants Ltd. 1995).

Irrigation may also create salinity and associated drainage problems (Sentar Consultants Ltd. 1995). For most of the past 100 years, irrigation provided substantial habitat for wildlife due to seepage along canals. With the lining of canals, and improvements in efficiency little water is now left for habitat.

Status and effectiveness of mitigation

Commodity prices will continue to influence farm management decisions with respect to agricultural intensification. However, many of the practices that benefit wildlife habitat and biodiversity have direct economic benefits to producers. The use of conservation tillage systems, crop rotation, and integrated pest management systems, have all been shown to reduce the impacts of crop production on soil, water and biodiversity. Buffers protect aquatic wildlife and provide reservoirs of habitat for beneficial insects, while protecting water quality for farm use and irrigation, as well as reducing weed interaction between crop and non-crop habitats. Management of manure from intensive livestock operations will continue to be an important issue in some regions of the country.

Improvements in irrigation efficiency and water use in livestock operations are ongoing with new developments subject to land classification /planning and water use licensing. Most water withdrawals occur on the Prairies (75%) (Harker et al. 2004) where BMP's and regulatory improvements have lead to great increases in efficiency of water use. The change from flood irrigation to pivot sprinklers in Alberta increased irrigation efficiencies by 40% (Harker et al. 2004). Use of mulches on in horticultural crops also decreases losses and watering requirements. While these trends are positive for water conservation, an assessment is needed to determine whether current irrigation policy is compatible with a sustainable water resource and biodiversity

conservation over the long term.

Assessment of risk

The risk to biodiversity from agricultural intensification stems from the change in cover type (from more suitable farm habitat to less suitable farm habitat), from the decrease in heterogeneity in the farm landscape, and from the loss of marginal land habitats which are critical to biodiversity including pasture, wetlands, woodlands, shelterbelts, hedgerows, and field margins. The importance of habitat maintenance through private stewardship will remain critical in all agricultural landscapes as agricultural intensification increases. The most effective approach to habitat maintenance through stewardship may differ as intensification increases and the area of native cover decreases. Wildlife Habitat Canada (2001) proposed a framework based on theoretical thresholds of native cover required for various species. Stewardship programming in areas of high native cover (approximately 50-100%) should be based on voluntary landowner recognition and education. As the habitat base decreases, landowner recognition efforts can be enhanced with financial incentive programs, technical support and extension. Where native habitats represent only a small portion of the landscape, land acquisition, conservation easements and protected areas can play an important role (Wildlife Habitat Canada 2001).

The risk to biodiversity from intensification is greatest in regions where cash cropping (monocultures) and intensive livestock production are continuing to increase. Total economic activity by region can be generally correlated with impacts on biodiversity (Environmental Scan Team 2004). Intensive cropping areas include: corn, soybeans, vegetables and fruit production in southern Ontario and the St. Lawrence valley in Quebec; potatoes in the river valleys of New Brunswick and Nova Scotia, on Prince Edward Island, and in Manitoba; the irrigated areas of

southern Alberta and Saskatchewan; fruit and specialty crops in the Okanagan Valley in B.C., and the greenhouse, fruit crop and specialty crop industry in the Fraser River Delta/Georgia Basin. Intensive livestock production is also concentrated regionally, with poultry, dairy and hogs concentrated in the Fraser River Delta, intensive hog production concentrated in Manitoba, Ontario and Quebec, and intensive dairy production in southern Ontario and Quebec. Feedlot production intensity is greatest on the prairies, particularly in Alberta.

Regions where the full agricultural potential has not yet been attained due to lack of seed varieties adapted to local conditions may also be at risk over the long term. The development of short season varieties of corn has resulted in an expansion of its range of production in the last 10 years, often at the expense of lower input crops and land uses.

Key Issues with Analysis related to *Agricultural Intensification*

- Native Habitats
- Farm Field Management
- Pesticide Contamination
- Nutrient Contamination
- Disease

Invasive Species

Farm Impact on Biodiversity (+ positive, – negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
<ul style="list-style-type: none"> – exotic plants introduced for crops/forage replacing native flora – habitat disturbance and farm practices can facilitate spread of invasive species – importation of nursery stock responsible for many introductions 	grain, oilseeds, forage crops, horticulture, orchard, vineyard, vegetables, specialty crops, apiary	Pacific Maritime, Montane Cordillera, Prairies, Mixedwood Plain, Atlantic Maritime	<ul style="list-style-type: none"> regulation of imported goods direct control through use of pesticides, integrated pest management and biocontrol indirectly through ecological management of farm habitats, reduced tillage systems 	<ul style="list-style-type: none"> the ability of inspectors to reduce entry of invasive species is severely limited by scientific knowledge of threats, manpower and costs control is widespread for some species, however costs are often high 	<ul style="list-style-type: none"> lack of sufficient knowledge of the distribution, abundance, and biology of both native and invasive species lack of expertise for proper identification of invasive and native species what mechanisms trigger dormant invasive species populations to explode and become pests, what elements of habitat change cause these population explosions need identification techniques for lay people research on controls of established pests and effectiveness of eradication and control methods impacts of invasive forage crop species on native upland and wetland habitats
Invasive species Impact on Agriculture (+ positive, – negative)	Agricultural production types currently at greatest risk	Current regions of highest impact	Mitigative Action	Extent mitigative measures are applied	
<ul style="list-style-type: none"> + introduction of useful invasive species e.g. earthworms, honey bees – crop and forage losses due to invasive species – impacts of invasive species on livestock health and market devaluation 	beef, tame or seeded pasture, natural land for pasture, woodlot, orchard, vineyard, apiary	Pacific Maritime, Montane Cordillera, Prairies, Mixedwood Plain, Atlantic Maritime	<ul style="list-style-type: none"> regulation of imported goods direct control through use of pesticides, integrated pest management and biocontrol indirectly through ecological management of farm habitats, reduced tillage systems 	<ul style="list-style-type: none"> the ability of inspectors to reduce entry of invasive species is severely limited by scientific knowledge of threats, manpower and costs control is widespread for some species, however costs are often high 	

Problem definition

Invasive species refer to species that are not indigenous to an area (exotic) and whose introduction is likely to cause ecological or economic harm. Some species have been deliberately introduced into Canada, such as crop plants, livestock, and garden plants, while many others have been introduced accidentally, arriving in ballast, packaging, and associated with goods such as food and horticultural products. It is estimated that between 20-30% of these species are pest species, however relatively few have become serious pests for biodiversity and agriculture (Pimental et al. 2000). The lack of natural enemies and parasites, and the availability of disturbed habitats in agricultural systems provides suitable conditions for these species to establish.

Elements of biodiversity impacted

The impacts of invasive species are second only to habitat loss as a cause of biodiversity loss (Parrault et al. 2003). In the United States, competition with and predation by invasive species is the primary reason that almost half (400 of 958) of the threatened and endangered species are considered at risk (Pimental et al. 2001). Approximately 90 species considered to be at risk in Canada may be threatened by invasive species (Government of Canada 2004). Many declining cavity nesting bird species have been impacted from competition with European starlings (*Sturnus vulgaris*). Garry oak (*Quercus garryana*) ecosystems in British Columbia are threatened by invasion of scotch broom (*Cylisus scoparius*) and other exotic shrubs, as well as exotic perennial grasses seeded for livestock forage and erosion control (Fuchs 2001). It is estimated that up to 82% of the herbaceous cover in the remaining garry oak sites is composed of invasive species (Fuchs 2001). The residual forest fragments of southern Ontario are also threatened by invasive species. Garlic mustard (*Alliaria officinalis*), is able to aggressively spread and dominate in shaded habitats, particularly forested riverbanks and moist woodlots and is implicated in the

decline of populations of the white wood aster (*Aster divaricatus*) (Environment Canada 2003) woodland poppy (*Callirhoe papaver*), and American ginseng (*Panax quinquefolius*), all species at risk in southern Ontario.

Invasive species tend to be capable of spreading quickly and are often found in agro-ecosystems, dominating residual habitat fragments. Purple loosestrife (*Lythrum salicaria*) is capable of spreading at a rate of 115000 ha/year, and quickly changes wetland structure by crowding out other species (Pimental et al. 2000). Changes in species composition and nutrient cycles in purple loosestrife dominated wetlands, alter species composition, choke out fish spawning habitats, and reduce wetland habitat quality for food and nesting for many wildlife species (Alberta Agriculture Food and Rural Development 2002c). Ecosystem functions such as natural pest control, water filtration by wetlands, nutrient cycling, absorption and energy flow may also be impacted by invasive species in terrestrial and aquatic systems (Government of Canada 2004).

Genetic diversity can also be impacted through the introduction of invasive species. The spread of white mulberry (*Morus alba*), a plant introduced for cultivation in southern Ontario, is a threat to the native red mulberry (*Morus rubra*) because the two species hybridize and the abundant white mulberry could potentially genetically swamp and eliminate the red mulberry (White et al. 1993). The intentional introduction of species for agricultural use, can also have this impact, as is the case with native reed canary grass (*Phalaris arundinacea*), and a related introduced Eurasian cultivar. The spread of the cultivar in this case, has the potential to genetically swamp the native genotype (White et al. 1993).

While most introductions occur at the borders as the result of international trade, agriculture has had a role in influencing the establishment, spread and movement of invasive species. In the

United States, 128 crop species that have escaped from cultivation, have become serious weeds (Pimental et al. 2000). The movement of harvested produce, livestock and vehicles across the landscape facilitates spread, and invasive species seeds may contaminate seed mixes for forage or crops. Edges between cultivated areas and native habitats supply prime areas for the introduction and spread of invasive plants (Saskatchewan Scan Committee 2004). Nurseries importing horticultural species and propagative material are also responsible for many introductions in Canada and the United States. Approximately 85% of the 235 invasive woody plants in the United States were intentionally introduced for landscaping purposes (Fraser Basin Council 2004). Imported nursery stock is responsible for the accidental introduction of some serious forest pests in North America including: chestnut blight (*Cryphonectria parasitica*), white pine blister rust (*Cronartium ribicola*), balsam wooly adelgid (*Adelges piceae*), beech scale (*Cryptococcus fagisuga*), dogwood anthracnose (*Discula destructiva*), Port Orford cedar root disease (*Phytophthora lateralis*) and butternut canker (*Sirococcus clavigigneti-juglandacearum*) (Parrault et al. 2003). More recently, the plum pox virus (Plum Pox Potyvirus), a disease of stone fruit trees, has been introduced in nursery stock to Ontario and Nova Scotia, with potential implications for fruit production (Parrault et al. 2003), and sudden oak death (*Phytophthora ramorum*), has been distributed to a large number of states and British Columbia through mail order Camellias from a single nursery in California.

Boutin and Jobin (1998) found that noxious weeds (often invasive) prevail in field types associated with more intensive farming practices. Natural habitats adjoining fields with increased tillage and pesticide drift, are often more open and disturbed providing suitable conditions for weeds to establish (Boutin and Jobin 1998). The use of buffers to protect the integrity of residual natural habitats, can mitigate these problems and improve habitat quality for pollinators and

natural enemies of crop pests (Boutin and Jobin 1998). Overgrazing by livestock or wildlife can also provide suitable disturbance areas for invasive species establishment (Fraser Basin Council 2004). Rotational grazing can be effective in controlling dominance of some invasive species, with moderate grazing able to reduce growth and seed production of invasive species not accustomed to being grazed (Environment Canada 2001a; PFRA 2004).

Elements of Agriculture Impacted

Most of Canada's food and feed production comes from introduced agricultural species with obvious benefits to agriculture. The common earthworm (*Lubricus terrestris*), is an accidentally introduced invasive species, that has proven to be beneficial maintaining soil structure, and increasing the rate of breakdown of plant residues. Honey bees (*Apis mellifera*) and alfalfa leaf cutting bees (*Megachile rotundata*) are also introduced species, managed for their pollinating services for a variety of crops. Many introduced invasive species however, have proven to be extremely detrimental to agriculture, often threatening crop production and livestock health, with costs for control and potential devaluation and market losses from commodity contamination (Government of Canada 2004).

Some serious threats exist across the country. Hound's tongue (*Cynoglossum officinale*) for example is a problem in the B.C. interior, and in southern Alberta's foothills. The invasive weed impacts forage establishment, is toxic to livestock with potential to cause cumulative liver damage, and its burrs (seeds) can irritate eyes and ears of livestock and wildlife (Fraser Basin Council 2004). The burrs can also reduce cattle market value, and reduce thermal insulation in wild ungulates (Fraser Basin Council 2004). Leafy spurge (*Euphorbia esula*), another invasive found across western Canada, causes stomach irritations and lesions to cattle. Control of leafy

spurge in Saskatchewan is estimated to cost \$7 million per year (Parrault et al. 2004). In Manitoba, the net economic impact is estimated to be \$16 million per year, with an additional loss of \$5 million in producer income and production expenditure, and \$11 million in secondary impacts on other sectors (Parrault et al. 2003). The risk of spread of the Asian longhorn beetle (*Anoplophora glabripennis*) in eastern Canada has implications both for forestry and agriculture with estimated losses of \$480 million in hardwood production and \$130 million annually in farm maple syrup revenues (Parrault et al. 2003).

The Fraser Basin Council (2004) provides a conservative estimate for the economic impact of invasive species on Canadian agriculture at over \$1 billion annually. However estimates from the United States, predict that impacts are much higher. Pimental et al. (2000) estimates that losses in U.S. crop systems (including forages) due to weeds are valued at \$32 billion U.S. annually with a 12% reduction in crop yields. Invasive species represent 73% of these weeds (Pimental et al. 2000). In U.S. pastures, 45% of weeds are invasive exotics and are responsible for losses of \$1 billion U.S. per year in food, and \$5 billion U.S. in control (Pimental et al. 2000). Reductions of 13% annually in U.S. crop production (\$34.7 billion U.S.) are due to pest insects and mites – 40% are these are invasive exotic species (Pimental et al. 2000). Crop losses from plant pathogens amount to about \$33 billion U.S., with an additional \$720 million spent by farmers on control – 65% of these species are invasive exotics (Pimental et al. 2000). An estimated 9 billion per year is estimated in livestock losses to introduced microbes and parasites (Pimental et al. 2000). A recent estimate of the impacts of invasive plant pests on agriculture and forestry in Canada is \$7.5 billion annually (Government of Canada 2004).

Status and effectiveness of mitigation of impacts on biodiversity and agriculture

The introduction and spread of invasive species is a large problem in Canada, especially with the continuing expansion of international trade. The problems are difficult to stop at the border, with inspections by Canadian agencies averaging only 1-2% of shipments (Parrault et al. 2003). Risk analysis for intentional introductions have been conducted for a variety of species (GM crops are a good example). However garden and landscaping species coming into nurseries are seldom assessed for their invasive potential (Parrault et al 2003). Canada has recently developed an invasive alien species strategy, which should coordinate priority actions of prevention, early detection, rapid response, and management of established and spreading invasive species (Government of Canada 2004).

Risk assessment for recently established species has been effective in some cases at slowing and eliminating the spread of invasives. The enormity of the risk from species such as the Emerald Ash Borer (*Agrilus planipennis*) to farm forests, and the forest industry in Canada has resulted in decisive action involving quarantine on movement of wood products in the Windsor/Essex area of southern Ontario, and a planned removal of all ash trees in a larger exclusion zone (Neave P. 2004).

Many control methods exist for invasive species, ranging from physical removal, pesticides, and prescribed burning, to the use of biological agents and ecological or integrated pest management (White et al. 1993). These methods are costly to landowners (as demonstrated by Pimental et al. 2000 and Parrault et al. 2003). Disturbance from tillage, grazing, and pesticide use can make natural areas more susceptible to invading species. It is possible that restoring natural conditions (through grazing management, woodlot management and use of buffers) might be a more

effective method of control for some species over the long term than continued removal (White et al. 1993).

Assessment of risk

Invasive species are a considerable risk to biodiversity, impacting ecological function of native habitats, causing species population declines, and impacting genetic diversity of some species. Agriculture is also significantly affected by invasive species, with impacts on crop, pasture and livestock productivity, farm management costs and time requirements, and ecological services.

Key Issues with Analysis related to *Invasive Species*

- Disease
- Native Habitats
- Farm Field Management
- Grazing

Diseases

Farm Impact on Biodiversity (+ positive, – negative)	Agricultural production types currently posing greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
– transport of infected livestock between farms, regions – transmission of disease at the wildlife/farm interface	game farm, beef, poultry, sheep	Fraser River Delta (Pacific Maritime), Prairies, Boreal Plains	cull of infected livestock, management of wildlife/livestock interactions ensuring transplanted animals are disease free	limited, with delayed action following outbreaks	need for ongoing testing/monitoring programs effects of diseases are often less well known for wild species (e.g. CWD) what causes endemic wildlife diseases and introduced diseases to become virulent
Biodiversity impact on agriculture	Agricultural production types currently at greatest risk	Current regions of highest impact	Mitigative Actions	Extent mitigative measures are applied	
– transmission of disease at the wildlife/farm interface	game farm, beef, poultry, sheep	Fraser River Delta (Pacific Maritime), Prairies, Boreal Plains	wildlife management, increased hunting or cull of infected herds eliminate game farming in areas of high risk	barriers to action including knowledge of impacts on species, costs	

Problem definition

The risk of disease transmission between livestock, humans and wildlife has increasingly become a concern, associated with an increase in:

- the intensity of livestock production in some regions;
- livestock contact with wildlife and wildlife habitat;
- the potential for contamination of water from runoff;
- domestication of wildlife; and,
- global trade resulting in accidental introductions of new diseases.

Diseases, whether endemic to an area or introduced, often affect both wildlife and livestock with transmission occurring at the interface between wildlife habitat and farmland. Many diseases such as chronic wasting disease, bovine tuberculosis and brucellosis have become established in Canada, with implications for biodiversity conservation and agricultural production.

Elements of biodiversity and agriculture impacted

Disease transmission at the interface between wildlife and livestock has become a significant problem in Canada. Endemic wildlife diseases, multi species diseases and introduced diseases can be passed between wildlife and livestock through direct or indirect contact, or contamination of shared resources including rangeland and water (Bengis et al. 2002).

Chronic wasting disease is transmitted between animals sharing range and water resources, potentially through saliva or contamination of soil from excreta (Williams et al. 2002). It has been a problem in captive herds of deer (*Odocoileus* spp.) and elk (*Cervus elaplus*), but also infects wild populations in several states and Saskatchewan. The spread of the disease was probably facilitated through movement of animals in the game farming industry (Bunk 2004). While all infected captive herds (40 in Saskatchewan and 3 in Alberta) have been culled in Canada, ongoing hunter cooperative studies indicate a that proportion of the free-ranging populations of deer and elk have the disease in Saskatchewan (Williams et al. 2002; Bollinger et al. 2004). Environmental contamination of infected premises continues to pose a threat to wild cervids in these areas, and infected wild animals are a potential source of infection for healthy farmed cervids in the region (Bollinger et al. 2004).

Until recently, bovine tuberculosis was assumed not to be self-sustaining in wildlife. However elk (*Cervus elaplus*) and white-tailed deer (*Odocoileus virginianus*) in the Riding Mountain National

Park area were found with the disease after an outbreak of bovine tuberculosis in cattle in the area (Bergeson et al. 2003). The use of shared resources on pasture, and in crops and forage has been linked to disease transmission between elk and livestock in other studies (USDA 2004).

Brucellosis persists in bison (*Bos bison*) and caribou (*Rangifer tarandus*) populations in northern Canada, with infections resulting in abortion, weak calves, infertility, chronic arthritis and lameness, and potential human health risks (Alberta Sustainable Resource Development 2004a). While domestic cattle and captive bison are considered brucellosis free, a large risk exists to the expansion of livestock into the infected area (particularly Wood Buffalo National Park) (Alberta Sustainable Resource Development 2004a).

West Nile Virus has recently expanded across much of Canada with implications for the health of some wild and domestic species. While wild birds carry the disease (transmitted through mosquitoes), the impacts appear to be most severe on only a few wildlife species including corvids and some raptors (Ollis 2004). Livestock that appear to be severely impacted include domestic geese, horses, mules, and donkeys (Ollis 2004). West Nile Virus has also recently been flagged as a potential threat to the endangered sage grouse (*Centrocercus urophasianus*), after being linked to the deaths of 18 grouse in Alberta, Montana and Wyoming (Alberta Sustainable Resource Development 2004b).

There is a suggested link between wild waterfowl (a natural reservoir of the avian influenza virus) and the outbreak of highly pathogenic avian influenza in the B.C. Fraser Valley in 2004, although there is no definitive epidemiological evidence (Canadian Food Inspection Agency 2004). It is likely that the farm to farm movement of people, birds, and equipment, along with airborne transmission through dust and feathers facilitated the quick spread in the region (Canadian Food

Inspection Agency 2004).

Status and effectiveness of mitigation of impacts on biodiversity and agriculture

The government of Canada recently drafted a National Wildlife Disease Strategy, providing a policy framework to minimize effects of wild animal diseases focussing on prevention, early detection, and effective disease management (Canadian Wildlife Service 2004b). The Canadian Food Inspection Agency is responsible for regulations limiting entry of infected livestock into Canada, a difficult task with constantly emerging issues and research needs. It is critical that both wildlife and livestock interests be fully integrated into disease management in Canadian agricultural landscapes (Leighton 2002).

For diseases that appear to be well established in wild populations (such as brucellosis in Wood Buffalo National Park) the management of wildlife populations where possible, and reduction or elimination of interactions between wildlife and livestock are key strategies to reduce impacts. The recent infection of wild cervids with chronic wasting disease in regions of Saskatchewan may warrant more aggressive management measures and research to prevent further spread (Bollinger et al. 2004). Prevention of the establishment of new foci of the disease is critical, with no movement of infected animals or materials to new areas (Bollinger et al. 2004). The eradication of chronic wasting disease from farms in Alberta and Saskatchewan has cost \$30-40 million (Canadian Wildlife Service 2004; Williams et al. 2002). Trade sanctions against the Canadian Cervid Industry have also been significant (Canadian Wildlife Service 2004). The implications for wild populations of deer and elk may be even greater, with eradication unlikely once the disease has been established (Bunk 2004).

Assessment of risk (and existing targets/thresholds)

Agricultural landscapes provide resources for a variety of wildlife and livestock with implication for disease management. Diseases often establish in disturbed environments, and new patterns of disease also may develop in disturbed conditions (Canadian Wildlife Service 2004). The movement of livestock or wildlife for release programs also carries the risk of releasing diseases into new areas (Canadian Wildlife Service 2004). Once a disease is established in the area, susceptible wildlife may act as reservoirs or sources of new infections for livestock, complicating eradication and control, and prolonging economic and management impacts for producers (Leighton 2002).

Key Issues with Analysis related to Diseases

- Invasive Species
- Nutrient Contamination
- Agricultural Intensification

Wildlife Damage

Biodiversity Impact on Agriculture (+ positive, -- negative)	Agricultural production types currently at greatest risk	Current regions of highest impact	Mitigative actions	Extent mitigative measures are applied	Areas for further research
– damage to stacked hay and crops by wildlife	grain, oilseeds, forage crops, orchard, vineyard, berry crops, vegetables, apiary	Pacific Maritime – Fraser Delta as staging/wintering grounds (Pacific Flyway), Prairies – Saskatchewan, Mixedwood Plain – Quebec St. Lawrence Lowlands	scarecrows, scare cannons, alternate or lure crops, hunting, trapping, poisoning, habitat management, barriers	some compensation programs require prevention, costs of prevention must be economically viable	research on mitigation measures has been extensive limited impact assessment linking positive habitat conservation activities to damage
– livestock predation by wildlife	beef, sheep	Montane Cordillera – B.C. Interior and Alberta foothills	hunting, trapping, poisoning, barriers, movement of herds, guard animals	some compensation programs require prevention, costs of prevention must be economically viable	
– farm structure damage by wildlife	dugouts, ditches, irrigation systems, dykelands	Montane Cordillera, Prairies, Atlantic Maritime	trapping, hunting, barriers	widespread	

Problem definition

Farm crops and livestock are often an attractive food source for wildlife species. These crops have become an important source of food for many species of birds, particularly during the spring and fall migration. Most farmers will accept some losses, but often species populations become unbalanced, and prevention and/or compensation for damages is necessary (OSCIA 2002). Wildlife damage to agriculture occurs when wildlife feed on crops and stacked or stored hay, predators kill or injure livestock, or wildlife damages farm structures and buildings. Dabbling ducks, Canada geese, snow geese, deer, elk, raccoons, blackbirds, and coyotes are the most common species implicated in wildlife damage to crops and livestock in Canada. Losses tend to

be patchy, with a small proportion of farmers suffering large losses, and the majority incurring very little (Rollins et al. 2004).

Elements of agriculture impacted

The annual cost to farmers for reported wildlife damage to crops and livestock is estimated at \$22.6 million nationally, within a range of \$9.9 to \$52.6 million (CFA and WHC 1998). Table 3 gives an indication of these losses regionally.

Waterfowl cause the most extensive damage to agricultural crops across Canada. On the prairies, duck and geese damage from feeding and trampling of crops far exceeds \$20 million in years with delayed combining due to prolonged wet weather. It should be recognized that only a small portion of farmers who have both loss of yield and extensive damage actually claim for compensation (Neave D. 2004). In recent years there has been a growing level of damage on winter wheat during migratory bird spring migrations and bird depredation on specialty crops. In both cases this is primarily due to changes in crop selection and farming practices (Neave D. 2004).

Table 3: 1997 Estimated Value of Wildlife Damage (\$000) (Canadian Federation of Agriculture and Wildlife Habitat Canada 1998)

Area	Crop	Livestock	Total	Lower Limit	Upper Limit
NF	15	10	25	10	66
PEI	60	-	60	28	14
NS	498	56	554	339	897
NB	170	15	185	110	3317
QC	1,160	196	1,356	1,005	1,774
ON	4,427	728	5,155	2,806	11,431
MB	1,312	40	1,352	600	2,136
SK	6,598	1,200	7,798	2,132	12,765
AB	1,808	100	1,908	677	10,386
BC	2,807	1,398	4,205	2,144	12,671

Table 3: 1997 Estimated Value of Wildlife Damage (\$000) (Canadian Federation of Agriculture and Wildlife Habitat Canada 1998)

Area	Crop	Livestock	Total	Lower Limit	Upper Limit
Canada	18,885	3,743	22,598	9,850	52,585

** these values are best estimates based on variable data (some based on claims, others on questionnaires to farmers)*

Wildlife damage to crops and livestock is a serious problem for farmers in Canada. In a recent survey of landowners across Canada, 57% of landowners reported that wildlife had caused damage to their operations, particularly deer and geese (Environics Research Group 2000). Forty-three percent of the landowners interviewed felt crop damage was a serious problem (Environics Research Group 2000). A 1998 Wildlife Impact Assessment in Ontario found that deer (*Odocoileus virginianus*) induced losses affected nearly half of field crop producers and a third of fruit and vegetable growers (OSCIA 2002). Most farmers will tolerate some wildlife damage because they enjoy having wildlife on their land for recreation or aesthetic reasons or because they feel they have a responsibility to provide habitat in their stewardship role (Rollins et al. 2004). Tolerance of wildlife varies depending on farm characteristics, wildlife species, overall wildlife populations and production value (Rollins et al. 2004).

Losses to production from wildlife damage can be substantial in some regions. A Wildlife Impact Assessment in 1998 indicated that in Ontario alone, wildlife damage topped \$41 million and is continuing to increase (OSCIA 2002). In the late 1990s, Quebec farmers were suffering losses of nearly \$1 million a year from greater snow geese (*Chen caerulescens*) as they migrated north each spring (Environment Canada 2000). The development of a spring conservation hunt, and permits for lure crops, baiting and electronic calls by conservation interests have reduced both economic losses and acres impacted (Environment Canada 2000). In the United States, birds cause more than \$100 million in losses per year to corn, sunflower, wheat, sorghum, rice and fruit

crops (Level 2004). Introduced species such as starlings (*Sturnus vulgaris*) and house sparrows (*Passer domesticus*) cause a large proportion of this damage, however native species such as robins (*Turdus migratorius*) and cedar waxwings (*Bombycilla cedrorum*) impact fruit crops such as grapes, cherries and blueberries (Level 2004). Losses to individual farmers are often significant, however nationwide damages from birds are estimated at 1-2% of yield (Kirk et al. 1996). The number of livestock killed by predators reached close to half a million in 2002 in the U.S., primarily lambs and calves (Level 2004).

Status and effectiveness of mitigation

Management practices to prevent losses have been designed to deal with wildlife through lethal and non-lethal methods. Frightening devices such as scarecrows and scare cannons may be erected in areas of concentrated wildlife use. Farm management practices can also be altered to reduce risk of damage including timing of harvest, barriers to access, hay storage techniques, and lure crops. Barriers to access and guard animals can also be used to reduce habitat use by wildlife species. Trapping, hunting, and chemical toxicants and repellants are also control options. The cost of prevention can be high, and must be weighted against losses. Fencing costs are generally not economically viable, and the cost of netting to reduce bird losses in blueberries is estimated at approximately \$10000 per acre (OSCIA 2002).

Compensation programs exist for producers whose unharvested crops, stacked or stored hay or livestock are impacted by wildlife. Compensation rates vary among the provinces ranging from zero to 100%, and are dependent on wildlife species and type of damage (Gray and Sulewski 1997). Government cost shared programs also exist to lure feeding waterfowl away from susceptible areas (Girt 1995). Prevention and compensation policies are generally not well

coordinated in Canada (Gray and Sulewski 1997).

With the decline in waterfowl hunters and increase in waterfowl population densities, prevention programs have been shown to be cost effective in conjunction with compensation. Compensation and prevention programs have helped maintain wildlife populations within intensively managed farmland (e.g. Fraser Delta, parkland region, and the St. Lawrence lowlands) with lure crops and dispersal mechanisms minimizing heavy site-specific (spot) losses to farmers. Similar programs that prevent elk (*Cervus elaplus*) and deer (*Odocoileus* spp.) damage to hayfields, bear (*Ursus* spp.) damage to apiaries and bird populations effecting berry crops have also been found to be cost effective and with no reported deleterious impact to wildlife.

From 1992-93 through 1996-97, federal and provincial compensation program expenditures ranged from a low of \$4.6 million to a high of \$17.2 million (CFA and WHC 1998). During that period, current federal and provincial prevention spending accounted for a combined total of approximately \$1.2 million annually (CFA and WHC 1998). Based on two analyses of the effectiveness of linking prevention and compensation (Gray et al. 1995, Gray et al 1997), and an examination of linkages to current habitat programs (Girt and Neave 1994), a proposal was prepared to the Ministers of Agriculture in 1998. This proposal titled 'Proposal for a National Agricultural Stewardship Program: A Wildlife Damage Prevention and Compensation Program for Farmers' (CFA and WHC 1998) has not yet been addressed.

Assessment of risk

Wildlife damage to crops, livestock and farm structures such as dugouts and buildings will continue to be an issue in Canada with abundant populations of some wildlife species using agricultural land to fulfil their habitat needs. Losses to individual farmers can be very high, and

an appropriate mix of best management practices, and incentives for prevention needs to be balanced with compensation measures to reduce individual losses. Most importantly, these programs help recognize the value of farm stewards in providing wildlife and habitat on their properties and through their support of surrounding habitat rehabilitation measures.

Key Issues with Analysis related to *Wildlife Damage*

- Native Habitats

Ecological Services

Biodiversity impact on agriculture (+ positive, – negative)	Agricultural production types receiving most benefit	Current regions of highest impact	Agricultural impacts on ecological services	Extent of impact	Areas for further research
+ pollination	forage crops, greenhouse, orchard, vineyard, vegetables, berry crops, other specialty crops	Pacific Maritime, Montane Cordillera, Prairies, Boreal Plain, Mixedwood Plain, Boreal Shield, Atlantic Maritime	pesticide impacts on non-target species agricultural intensification habitat loss	research is ongoing into decline, loss of habitat is widespread	extent of decline of different pollinators, impact of invasive species need a greater understanding of the extent of economic values of these services what are the threshold levels of these services required to sustain agricultural and ecosystem productivity need to communicate the critical connection between these services and the retention of farmland habitat and biodiversity use of constructed wetlands for
+ nutrient cycling	grain, oilseeds, forage crops, tame or seeded pasture, natural land for pasture, woodlot, orchard, vineyard, vegetables, berry crops, other specialty crops	Pacific Maritime, Montane Cordillera, Prairies, Boreal Plain, Mixedwood Plain, Boreal Shield, Atlantic Maritime	tillage, nutrient contamination, erosion impact soil chemical, physical and biological properties	widespread, impacts are variable depending on disturbance, soil, and species	
+ pest control	grain, oilseed, forage crops, orchard, vegetables, other specialty crops	Pacific Maritime, Montane Cordillera, Prairies, Boreal Plain, Mixedwood Plain, Boreal	pesticide impacts on non-target species agricultural intensification habitat loss (field margins,	loss of habitat is widespread impacts of increased field size on marginal habitats widespread	

Biodiversity impact on agriculture (+ positive, – negative)	Agricultural production types receiving most benefit	Current regions of highest impact	Agricultural impacts on ecological services	Extent of impact	Areas for further research
		Shield, Atlantic Maritime	woodlands, wetlands, riparian areas, hedgerows)		livestock waste water treatment systems in intensive livestock management areas
+ water purification	beef, dairy, pork, poultry	Pacific Maritime, Montane Cordillera, Prairies, Boreal Plain, Mixedwood Plain, Boreal Shield, Atlantic Maritime	habitat loss (wetland and riparian habitats)	widespread	
+ water retention and flood control	grain, oilseeds, forage crops, tame or seeded pasture, natural land for pasture, woodlot, orchard, vineyard, vegetables, berry crops, other specialty crops	Pacific Maritime, Montane Cordillera, Prairies, Boreal Plain, Mixedwood Plain, Boreal Shield, Atlantic Maritime	habitat loss (wetland, woodland, native grassland and riparian habitats)	widespread	

Problem definition

Biodiversity provides a range of ecological services to agriculture including pollination, nutrient cycling, water retention and purification, flood and erosion control, soil building and maintenance processes and forage for livestock. Many of these services are essential to agricultural production, and they are often influenced by farm management practices.

Elements of agriculture benefited

Approximately 80% of all agricultural plant species are dependent on pollination by animals, predominantly insects (Pernal 1999). Of the insects, bees are the most important, including native and introduced pollinators (such as honey bees (*Apis mellifera*) and leaf cutting bees (*Megachile*

rotundata)). Agriculture and Agri-Food Canada (2001a) estimated the economic value of honey bees as crop pollinators at \$782 million, with an additional \$75 million value for honey and wax in Canada. Pernal (1999) suggests the direct value added to crops by pollinators is \$500 million, with even larger indirect values for production of forages such as alfalfa at \$800 million. Large numbers of bees are required to effectively pollinate crops. In New Brunswick, bees average 10,000 to 15,000 per ha on wild blueberry land, including native bees (62%) and honey bees and alfalfa leaf cutting bees (Agriculture and Agri-Food Canada 2001b). Native bees have been found to be more efficient pollinators than other bees, pollinating up to 4 times faster (Government of New Brunswick 2003).

Soil organisms also play a very important functional role in agro-ecosystems. They are involved in nutrient cycling, through decomposition and transformation of organic residues, and are important in formation of soil structure (Fox and MacDonald 2003). Soil organisms also play a role in the uptake of nutrients by plants, and are important for biological control of human pathogens and agricultural pests (Fox and MacDonald 2003).

Parasites and predators in natural ecosystems provide between 5 and 10 times the amount of pest control as pesticides in natural ecosystems (Pimental et al. 1992). Tremblay et al. 2001 found that cutworm (Noctuidae) and weevil (Curculionidae) populations were reduced in cornfields by birds, with similar trends for aphids (Aphididae) and European corn borer (*Ostrinia nubilalis*). In woodlands, the control of insect outbreaks by songbirds has been estimated to be as much as \$5000 per year for each square mile of forest land (Robinson 1997).

Natural habitats in the landscape have been shown to provide a range of ecological services for agriculture. Livestock grazing on native rangelands have a greater selection of food species,

allowing them to select for the most palatable and nutritious species over the grazing season (PFRA 2000). In addition, native rangeland offers better productivity under drought conditions (PFRA 2000). Riparian areas also benefit livestock, producing a considerably larger quantity of forage than regular pasture, and filtering contaminants in runoff (PFRA 2000). Effective pasture and riparian management has been shown to increase average weight gains, and overall net returns (Chorney and Josephson 2000).

Wetlands are essential for water retention, recharging ground water, and reducing severity of floods. Woodlands, riparian areas and shelterbelts also store water and trap snow, contributing to local water tables. Wetlands filter and purify water in natural ecosystems, and constructed wetlands can provide a similar role in purifying livestock wastes on the farm. A study of subsurface flow wetland treatment of dairy farm stormwater in B.C. indicated that up to 99% of source faecal coliforms were removed, while nutrients and TSS reductions ranged from 25-95% (Bruce 2003). The wetland treatments utilized aerobic and anaerobic bacteria on plant roots and in the soil matrix, to actively purify water (Bruce 2003).

Shelterbelts are generally planted for their benefits in controlling soil erosion, but also have benefits as wildlife habitat. A recent study from the Prairie Farm Rehabilitation Administration's Shelterbelt Centre estimated the benefits from reduced soil erosion from trees distributed by the centre were between \$8 and \$12 million. Additional ecological services included reductions in greenhouse gas emissions estimated to be between \$56 and \$417 million (Kulshreshtha and Knopf 2003).

There are secondary benefits from non-agricultural habitats such as woodlands, wetlands, shelterbelts, hedgerows, and riparian areas, interspersed among cropfields in providing critical

habitat for many beneficial insect predators, and pollinators, unable to overwinter in cropfields (Boutin and Jobin 1998). These habitats are also home to a variety of insectivorous birds and mammals.

Status of ecological services

Farming activities can impact these ecological services, creating problems both for biodiversity and agriculture. Pollinator decline has been linked to a number of causes including introduced mites and disease, pesticide impacts on non-target species, habitat loss, and agricultural intensification (Cane and Tepedino 2001; Pernal 1999). Intensive cash cropping of large monocultures of corn and wheat, are incapable of sustaining pollinator populations (Cane and Tepedino 2001). Crops such as apples and berries often provide only brief bursts of flowers, with pollen and nectar available for a few weeks only, and scarce resources available to support all life cycles (AAFC 2001b; Cane and Tepedino 2001). Loss of marginal habitats such as hedgerows and field margins under intensive farming systems, may reduces the diversity of flowering plants and impact pollinators (AAFC 2001b).

Soil organisms are also impacted by farming operations, particularly tillage operations and pesticide application. Crop rotations, residue management, extent of removal of crop materials and the addition of organic matter and nutrients all modify nutrient cycles (Fox and MacDonald 2002).

The relationship between ecological services and the maintenance of natural habitats demonstrates the importance of these areas for soil and water conservation. Farmers have been shown to value soil and water conservation more than abstract concepts of habitat, biodiversity and ecological integrity. Often the conservation and management of natural areas can positively

impact their bottom line, and many stewardship programs are attempting to identify these benefits with the long term goal of benefiting soil and water conservation and biodiversity.

Key Issues with Analysis related to *Ecological Services*

- Native Habitats
- Farm Field Management
- Pesticide Contamination
- Nutrient Contamination
- Agricultural Intensification

OBSERVATIONS AND CONCLUSIONS

The agriculture chapter of the 1994 Biodiversity Science Assessment (Mineau et al. 1994) supports the basis of this assessment on the risk and benefits of biodiversity on farms and equally farm practices on biodiversity. As stated in the summary of the 1994 report:

- Canadian agriculture has a significant influence on biodiversity because of its prevalence over such a large portion of landscapes in southern biomes;
- It is possible for agricultural lands to play a positive role in the maintenance of biodiversity.

There are many different agricultural landscapes across Canada. They vary in degree of intensity of agricultural practices on a variety of grassland and forested ecosystems. It is therefore very difficult and hazardous to generalize on biodiversity/ agriculture interactions and their impacts over time. Soil, climate, tradition and market forces have very different effects on the prairies, Canada's largest farmland region (80%), than in the specialty orchard areas of British Columbia or the dairy industry along the Saint Lawrence River valley. Effects of practices at the local farm scale are also variable depending on site conditions, farm management practices and use of best management practices.

In addition, current assessments are often subjective as they are based on published biodiversity research that remains focused on specific species and scattered agricultural sites across Canada. There is still a limited research focus to provide qualitative and quantitative information on the impact of current and modified agricultural practices in addressing biodiversity issues at the landscape level. In the absence of empirical evidence linked to effective modeling programs,

conservation interests can only continue to identify potential hazards and/or benefits and advocate the precautionary principle. To advance biodiversity conservation through the establishment of guidelines to minimize or mitigate the impacts of agricultural practices, it is critical that responsible agencies are prepared to assess the anticipated impacts relative to habitat goals with measurable targets and thresholds within a landscape context. These goals are slowly being developed, independently across the different farmland regions.

Assessing the impacts of different agricultural practices is also difficult as collectively they often have cumulative and/or compensatory effects on elements of biodiversity. In some cases there can be a net benefit to biodiversity conservation. In other cases, two or more agricultural practices have a synergistic and detrimental impact on biodiversity. Some examples are obvious, such as the impact of drainage of wetlands on the level of ground water. Others are more subtle, such as the increase in herbicide use with the conversion to minimum tillage practices, a potential benefit to soil invertebrates but not for pollinators. And others are poorly understood, including the environmental and economic benefits of genetically modified organisms. In many cases, farmers rely on government agencies to mitigate risks to the environment (e.g. through approval of pesticides and GM crops, and protection from introductions of invasive species). In these cases, farmers may be following government regulations and guidelines and still have a major impact on the environment.

Any assessment also has to recognize that the ongoing changes on farm landscapes are primarily a function of changes in commodity prices (demand) and corresponding agricultural policy initiatives. Environmental incentives to farmers are one of the key exemptions from free trade limitations. However Canada appears to have not effectively used this strategy to help farmers

build sustainable agricultural programs that recognize the underlying importance of retaining the natural integrity of their land. Voluntary adoption of environmental farm plans and broad adoption of conservation “stewardship” programs have stalled due to the lack of a positive policy framework. Without this same framework, instituting guidelines that will be perceived as a regulatory measure will likewise have limited acceptance at the farm gate.

There are other, often larger influences shaping specific agricultural landscapes in Canada. The impact of industrial development and urbanization is recognized as a serious threat to biodiversity in many regions of southern Canada. These impacts are often additive to those of agricultural activities, and can easily offset any mitigative measures on the farm.

Recognizing all of these constraints, the development of national agri-environmental standards to provide direction on the conservation of biodiversity is overdue. Acceptance of these guidelines within the agricultural and conservation communities should allow for strategic risk reduction for some of the issues identified in this report and database, and the 1994 Science Assessment.

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APPENDICES

Appendix A: Database Structure

The following headings provide a template for information in the database of literature collected for this report. Each reference has been entered using this template, to facilitate follow-up to information discussed in the report, and to allow the user to search for more specific information. Queries can be made in the database by author, year, species, species guild, ecosystem type, ecozone, farm risk to biodiversity, biodiversity impacts on agriculture, risk to biodiversity, and risk to agriculture. Species, species guild and ecosystem type can also be queried in combination with ecozone. Briefly, each database entry includes:

Reference

Full bibliography reference with Author, Date, Title, Journal/other reference, # pages.

Publication Type

This entry records the scientific basis for the literature cited. A list of choices were provided including:

- Peer reviewed journal
- Trade journal
- Bulletin
- Government Report
- Factsheet
- Book/Chapter

- Best Management Practice Guide
- NGO Report

Content Description

This entry identifies the specific content of the document. A list of choices were provided including:

- Research Results
- Basic Data
- Analysis/Recommendations
- Programs

Flagship Document

This entry allows the user to quickly identify the most useful documents to start with when searching for information on a topic. These types of documents would provide the best synthesis of the issues, a good example would be the Biodiversity Science Assessment from 1994.

Targets/Thresholds/Standards

This entry is another simple yes or no question with the purpose of flagging the documents which have defined standards for biodiversity, that might be directly useful for the National Agri-environmental Standards Initiative.

Summary

A brief summary of the document is provided to give an overview of the content, along with information relevant to the report.

Biodiversity Element

This entry identifies whether the document relates to landscape, ecosystem, species or genetic diversity. A list of choices were provided including:

- Landscape
- Ecosystem
- Species
- Genetic
- All
- Landscape and Ecosystem
- Landscape Ecosystem and Species
- Ecosystem and Species
- Species and Genetic

Species Guild

This entry identifies the guild of species described in the paper. An entry into the box was optional. A standard list of entries for searching includes:

- birds, farmland birds, forest interior birds, grassland songbirds, waterfowl, shorebirds, raptors, upland nesting birds, forest birds, game birds
- mammals, ungulates, carnivores, small mammals
- amphibians
- fish
- reptiles
- invertebrates, soil organisms, pollinators, aquatic macroinvertebrates, grassland butterflies, predatory arthropods, parasites, parasitoids
- plants, woody, herbaceous, weeds, native grasses, aquatic plants
- invasive species

Species

This entry provided the opportunity to enter the name of the specific species discussed in the paper. An entry in the box was optional. Records in the database can be searched by species

(common name).

Species at Risk

This simple yes or no entry flags documents with information on SAR and agriculture.

Ecosystem

This entry provided the opportunity to enter the type of ecosystem involved. A list of choices were provided including:

- Wetland
- Riparian
- Aquatic
- Riparian, Wetland, Aquatic
- Upland – Cropland
- Upland – Pasture
- Upland – Forages
- Upland – Woodland
- Other Uplands (e.g. hedgerows, field margins)
- Upland – ALL
- ALL

Entry into this box was optional.

Spatial Scope – Ecozone

This entry identifies which Ecozone the record falls into. Information in the database to be sorted by Ecozone. A list of choices were provided including the 7 ecozones with agriculture in Canada, and a number of common combinations including::

- Pacific Maritime
- Montane Cordillera
- Pacific Maritime and Montane Cordillera (B.C.)

- Boreal Plains
- Prairies
- Prairies and Boreal Plains (many wildlife issues span both of these ecozones)
- Boreal Shield
- Mixedwood Plain
- Atlantic Maritime
- All
- International

Spatial Scope – Regional

This entry allowed for a more specific identification of the location of the study (e.g. province, region, or watershed). Entry into this box was optional.

Farm Production Type

This entry identified the type of farm production systems discussed in the reference. More than one farm type could be added to each entry. A list of choices were provided including:

- beef
- dairy
- pork
- poultry
- sheep

- game farm
- other livestock
- grain
- oilseeds
- summerfallow
- forage crops
- tame or seeded pasture
- natural land for pasture
- woodlot
- greenhouse
- horticulture
- orchard
- vineyard
- vegetables
- berry crops
- other specialty crops
- bees
- all

Farm Risk to Biodiversity

This entry identified causes and endpoint impacts of agriculture on the environment. A list of choices were provided including:

- land conversion
- agricultural intensification
- soil erosion
- soil compaction
- soil degradation (includes salinization)
- nutrient contamination
- pathogen contamination
- siltation/sedimentation
- grazing damage
- tillage
- harvest
- timing of operations
- pesticide contamination
- invasive species introduction
- invasive species spread
- GMO

- disease
- endocrine disrupting substances
- water withdrawal
- irrigation
- drainage
- salinization

Mitigative Actions

This entry identified common mitigative measures/ BMP's that reduce the risk to biodiversity referred to in the reference. A list of choices were provided including:

- nutrient management planning
- managing livestock access to water
- manure management (including compost piles, feedlots, wintering sites)
- grazing management
- habitat restoration
- habitat enhancement
- habitat maintenance
- no-till/ reduced tillage
- crop rotation
- residue management

- shelterbelt
- riparian or upland buffer strips
- fall seeding
- modified haying/ harvest
- irrigation management
- organic farming
- integrated pest management
- farm waste management
- permanent cover
- wildlife management
- land use planning
- woodlot management planning
- invasive species control

Key Biodiversity Issues

This entry identified the elements of biodiversity impacted by farming practices. A list of choices were provided including::

- habitat quantity (habitat loss/removal)
- habitat quality – habitat degradation, habitat heterogeneity, fragmentation, connectivity
- species reduced vigour or health

- mortality of individuals
- population stability
- effect on reproductive success
- species diversity
- genetic diversity
- ecosystem function
- reduced food availability/quality

Biodiversity Impacts on Agriculture

This entry identified impacts (+ve or –ve) of biodiversity on agriculture. Entries were selected from a list of choices as follows:

- crop damage
- livestock predation
- wildlife damage to farm structures
- disease
- ecological services (e.g. pollination, pest control, nutrient cycling, etc)
- invasive species

Risk to Biodiversity

This entry identified the severity of the risk to biodiversity discussed in the paper. Risks were categorized as:

- Potential for Extensive Damage (associated with SAR impacts, activities causing

mortality to a high proportion of the population or impacting sustainability of population over the long term, permanent destruction of habitat)

- Mitigated at a Cost (impact can be mitigated at a high cost to the landowner)
- Manageable (manageable within the context of farming operations)
- Unknown (more information/ research is required to determine risk to biodiversity)
- N/A
- neutral (impact is neither positive or negative)

Agricultural activities shown to positively influence biodiversity were identified as:

- ‘positive influence’ (agriculture is shown to have a positive influence on species/habitats of concern)

Risk to Agriculture

This entry identified the severity of the risk to agriculture discussed in the paper. Risks were categorized as:

- **Potential for Extensive Damage** (associated with large losses to farm income and productivity)
- **Mitigated at a Cost** (impact can be mitigated at a high cost to the landowner)
- **Manageable** (manageable within the context of farming operations)
- **Unknown** (more information/ research is required to determine risk to agriculture)
- N/A

- neutral (impact is neither positive or negative)

Elements of biodiversity shown to positively influence agriculture were identified as:

- **‘positive influence’** (elements that contribute to ecological services such as pest control, pollination, nutrient cycling).