Environment Canada   Environnement Canada

National Agri-Environmental Standards Initiative (NAESI)

Report No. 4-21

Achievable Standards Modeling - Beneficial Management Practices Efficacy

Technical Series 2008

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
Prairie smoke and bee: Emily Wallace, Prairie Northern Region, Environment Canada

This report can be cited as follows:

Tchigio, I. 2008. Achievable Standards Modeling - Beneficial Management Practices Efficacy. National Agri-Environmental Standards Initiative Technical Series Report No. 4-21. 160 p.

Prepared and published by
Environment Canada
Gatineau, QC

March 2008

NATIONAL AGRI-ENVIRONMENTAL STANDARDS INITIATIVE TECHNICAL SERIES

ACHIEVABLE STANDARDS MODELING - BENEFICIAL MANAGEMENT PRACTICES EFFICACY

REPORT NO. 4-21

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 Innocent Tchigio, independent consultant. 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:

Environment Canada
National Agri-Environmental Standards
Initiative Secretariat
351 St. Joseph Blvd. 8th floor
Gatineau, QC
K1A 0H3
Phone: (819) 997-1029
Fax: (819) 953-0461

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 Innocent Tchigio, consultant privé. 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 :

Secrétariat de l’Initiative nationale	351, boul. St-Joseph, 8eétage
d’élaboration de normes	Gatineau (Québec) K1A 0H3
agroenvironnementales	Téléphone : (819) 997-1029
Environnement Canada	Télécopieur : (819) 953-0461

TABLE OF CONTENTS

LIST OF TABLES

1 INTRODUCTION

The National Agri-Environmental Standards Initiative (NAESI) has been developed by Environment Canada, and is aimed at setting performance standards for agriculture. Environmental themes - air, water, biodiversity and soil - identified under the National Agricultural Policy Framework, are addressed. A NAESI Biodiversity report assesses the effects of agricultural Beneficial Management Practices (BMPs) on conservation and restoration of biodiversity in agricultural regions (ERIN Consulting Ltd., 2006).

This study examines the efficacy of BMPs (from the national and provincial lists and ERIN Conulsting Ltd. (2006) in terms of documented quantitative and/or qualitative effects on biodiversity elements, as well as addressing possible weaknesses and gaps. The scope of this work is to develop a report and database, based on the NAESI-Biodiversity reports, available review reports, and literature. Results will be used as support for developing Tier 3 habitat-based achievable biodiversity standards. Achievable performance standards specify the level of environmental quality that can be achieved using recommended, best available processes, practices, sciences and technologies.

1.1 Objectives

- To address weaknesses and fill gaps in a report and database on the quantitative and/or qualitative evidence for efficacy of agricultural Beneficial Management Practices (BMPs) in contribution to biodiversity conservation.

1.2 Tasks

- Review background materials for NAESI Biodiversity and in particular the habitat based biodiversity standards decision support process.
- Review the report and supporting database on Efficacy of BMPs for biodiversity

conservation.

- Complete a literature search and synthesis, supplemented by expert consultation, to confirm report results, and address identified weaknesses and gaps.
- Address the appropriate application of efficacy information to the range of ecozones where agriculture occurs across Canada.
- Prepare a complete, but concise, synthesis report of Efficacy of BMPs for the Conservation of Biodiversity.
- Update the database with any new material located during the search.

The impacts of agriculture on biodiversity have been outlined in a previous NAESI Biodiversity report (ERIN Consulting Ltd., 2006), which defines and describes Beneficial Management Practices (BMPs) that are believed to contribute to the conservation and restoration of biodiversity in agricultural regions. Building from there, this document provides quantitative and qualitative evidence for the efficacy of these agricultural BMPs in this contribution to biodiversity.

2 AGRICULTURAL BENEFICIAL MANAGEMENT PRACTICES (BMPS)

For the purposes of the National Farm Stewardship Program (NFSP), Beneficial Management Practices (BMPs) are farm management practices that:

1. Minimize and mitigate impacts and risks to the environment, by maintaining or improving the quality of soil, water, air and biodiversity;
2. Ensure the long term integrity and sustainability of natural resources used for agricultural production; and,

3. Support the long-term economic and environmental viability of the agriculture industry.

A list of 30 national BMP categories and 70 associated practices has been developed to identify those BMPs eligible for assistance under the program (Table 1). Province-specific lists identify those that are eligible for financial and technical assistance within each province.

Under NAESI, ERIN Consulting Ltd., 2006) assessed BMPs from national and provincial lists, and other agricultural guidelines, which are believed to have positive impacts on biodiversity. These BMPs were classified into 6 categories (permanent cover and grassland management, woodlot management, soil management, riparian areas and water management, nutrient management, and species management) including 48 specifics or subcategories (Table 2). A review of these agricultural Beneficial Management Practices has outlined some weaknesses and gaps. The primary areas of concern include:

- Benefits (direct versus indirect) of BMPs to biodiversity;
- Lack of quantitative and qualitative measures;
- Absence of thresholds, such as minimum/optimum percentage of land, patch or area size, or strip width;
- Limitations related to landscape type (e.g., grassland, woody vegetation), climate (dry, rainy), and ecoregions.

Table 1: National and provincial BMPs (from the National Farm Stewardship Program, AAFC, 2008a).

Category code	BMP Category	Practice code	Type of Practice	Province-specific										
				YT	BC	AB	SK	MB	ON	QC[1]	NB	NS	PE	NL
01	Improved Manure Storage and Handling	0101	increased storage to meet winter spreading restrictions (including satellite storage)	--	X	X	X	X	X		X	X	X	X
		0102	improved features to prevent risks of water contamination (leaks, spills)	--	X	X	X	X	X		X	X	X	X
		0103	slurry storage covers to reduce odours and GHG emissions and liquid volume	--	X	X	X	X	X		X	X	X	X
		0104	containment systems for solid manure (includes covers)	X	X	X	X	X	X		X	X	X	X
		0105	assessment and monitoring of existing manure storage infrastructure	--	X	X	X	X	X		X	X	--	X
		0106	engineering design work	--	X	X	X	X	X		X	X	X	--
02	Manure Treatment	0201	dewatering systems, nutrient recovery systems	--	X	X	X	X	X		X	X		X
		0202	composting of manure	X	X	X	X	X	X		X	X	X	X
		0203	anaerobic digesters	--	X	X	X	X	X		X	X	X	--

Table 1: National and provincial BMPs (from the National Farm Stewardship Program, AAFC, 2008a).

Category code	BMP Category	Practice code	Type of Practice	Province-specific										
				YT	BC	AB	SK	MB	ON	QC[1]	NB	NS	PE	NL
		0204	engineering design work	X	X	X	X	X	X		X	X	X	--
03	Manure Land Application	0301	specialized modifications to equipment for improved manure application	X	X	X	X	X	X		X	X	X	X
04	In Barn Improvements	0401	more efficient livestock watering devices and cleanout systems to reduce water use and decrease manure volumes	X	X	--	X	X	X		X	X	X	X
		0402	engineering design work	--	X	--	X	X	X		X	X	X	--
05	Farmyard and Horticultural Facilities Runoff Control	0501	upstream diversion around existing farmyards, greenhouse and container nursery operations (includes downstream protection, e.g., catch basins, storage for runoff, constructed wetlands)	--	X	X	X	X	X		X	X	X	X
		0502	construction of an impermeable base and roof for minimizing runoff from livestock pen areas and confinement areas	X	X	X	X	X	X		X	X	X	--
		0503	engineering design work	--	X	X	X	X	X		X	X	X	--

Table 1: National and provincial BMPs (from the National Farm Stewardship Program, AAFC, 2008a).

Category code	BMP Category	Practice code	Type of Practice	Province-specific										
				YT	BC	AB	SK	MB	ON	QC[1]	NB	NS	PE	NL
06	Relocation of Livestock Confinement and Horticultural Facilities from Riparian Areas	0601	relocation of livestock facilities such as barns, corrals, paddocks and wintering sites away from riparian and other very environmentally sensitive areas	X	X	X	X	X	X		--	X	X	X
		0602	relocation of horticultural facilities such as greenhouses and container nurseries from riparian and other very environmentally sensitive areas	--	X	X	X	X	X		--	X	--	X
		0603	engineering design work	--	X	X	X	X	X		--	X	X	--
07	Wintering Site Pasture Management	0701	shelterbelt establishment	X	X	X	X	X	X		--	X	--	X
		0702	portable shelters and windbreaks	X	X	X	X	X	X		--	X	--	X
		0703	alternative watering systems (e.g., solar, wind, grid lines, waterline from well)	X	X	X	X	X	X		--	X	--	X
		0704	field access improvements: alleyway/access lane upgrades	X	X	X	X	X	X		--	X	--	X
		0705	fence modifications	X	X	X	X	X	X		--	X	--	X

Table 1: National and provincial BMPs (from the National Farm Stewardship Program, AAFC, 2008a).

Category code	BMP Category	Practice code	Type of Practice	Province-specific										
				YT	BC	AB	SK	MB	ON	QC[1]	NB	NS	PE	NL
08	Product & Waste Management	0801	improved on-farm storage and handling of agricultural products (e.g., fertilizer, petroleum products, and pesticides)	X	X	X	X	X	X		X	X	X	X
		0802	improved on-farm storage, handling, and disposal of agricultural waste (e.g., livestock mortalities, fruit and vegetable cull piles, wood waste)	X	X	X	X	X	X		X	X	X	X
		0803	composting of agricultural waste (e.g., fruit, vegetable, wood, straw residue, dead livestock)	X	X	X	X	X	X		X	X	X	X
		0804	engineering design work	--	X	X	X	X	X		X	X	X	--
09	Water Well Management	0901	sealing and capping old water wells	--	X	X	X	X	X		X	X		X
		0902	protecting existing water wells from surface contamination	--	X	X	X	X	X		X	X	X	X
10	Riparian Area Management	1001	alternative watering systems to manage livestock: gravity fed, solar, wind or grid power, pump and waterline systems	X	X	X	X	X	X		X	X	X	X

Table 1: National and provincial BMPs (from the National Farm Stewardship Program, AAFC, 2008a).

Category code	BMP Category	Practice code	Type of Practice	Province-specific										
				YT	BC	AB	SK	MB	ON	QC[1]	NB	NS	PE	NL
		1002	buffer establishment: forbs shrubs, trees; includes planting and weed control; tile effluent treatment systems	X	X	X	X	X	X		X	X	X	X
		1003	fencing to manage grazing and improve riparian condition/function	X	X	X	X	X	X		X	X	X	X
		1004	native rangeland restoration or establishment: native species of forbs, shrubs, and trees	--	X	X	X	X	X		X	X	--	X
		1005	grazing management in surrounding uplands: alternative watering systems and cross fencing	--	X	X	X	X	X		X	X	--	X
		1006	improved stream crossings for livestock or equipment	--	X	X	X	X	X		X	X	X	X
11	Erosion Control Structures (Riparian)	1101	constructed works in riparian areas: contour terraces, gully stabilization, bank stabilization, drop inlets, enhanced infiltration systems, in-channel control, and water and sediment control basins (WASCoBs)	--	X	X	X	X	X		X	X	X	X

Table 1: National and provincial BMPs (from the National Farm Stewardship Program, AAFC, 2008a).

Category code	BMP Category	Practice code	Type of Practice	Province-specific										
				YT	BC	AB	SK	MB	ON	QC[1]	NB	NS	PE	NL
		1102	engineering design work	--	X	X	X	X	X		X	X	--	--
12	Erosion Control Structures (Non Riparian)	1201	constructed works in non riparian areas: contour terraces, gully stabilization, drop inlet systems and enhanced infiltration systems, WASCoBs and constructed wind screens	--	X	X	X	X	X		X	X	--	X
		1202	engineering design work	--	X	X	X	X	X		X	X	--	--
13	Land Management for Soils at Risk	1301	forage or annual barrier establishment for soils at risk (e.g., strip cropping, grassed waterways, perennial forages on severely erodible or saline soils)	--	X	X	X	X	X		--	X	--	X
		1302	straw mulching to assist in permanent forage establishment	--	X	X	X	X	X		--	X	--	X
		1303	grazing management in critical erosion areas not associated with riparian zones: alternative watering systems, cross fencing	--	X	X	X	X	X		--	X	--	X

Table 1: National and provincial BMPs (from the National Farm Stewardship Program, AAFC, 2008a).

Category code	BMP Category	Practice code	Type of Practice	Province-specific										
				YT	BC	AB	SK	MB	ON	QC[1]	NB	NS	PE	NL
14	Improved Cropping Systems	1401	equipment modification on: pre-seeding implements for restricted zone tillage for row crops, seeding and post-seeding implements for low disturbance placement of seed and fertilizer	--	X	X	X	X	X		X	X	X	X
		1402	chaff collectors and chaff spreaders installed onto combines	--	X	X	X	X	X		X	X	X	X
		1403	precision farming applications: GPS information collection, GPS guidance, manual and variable rate controllers for fertilizer application	X	X	X	X	X	X		X	X	X	X
15	Cover Crops	1501	establishment of non-harvested, non-grazed cover crops	X	X	--	X	X	X		X	X	--	X
		1502	equipment modification for inter-row seeding of cover crops (e.g., relay crops)	X	X	--	X	X	X		X	X	X	X
16	Improved Pest Management	1601	equipment modification for improved application	--	X	X	X	X	X		X	X	X	X
		1602	information collection and monitoring	--	X	X	X	X	X		X	X	X	X
		1603	biological control agents	X	X	X	X	X	X		X	X	X	X

Table 1: National and provincial BMPs (from the National Farm Stewardship Program, AAFC, 2008a).

Category code	BMP Category	Practice code	Type of Practice	Province-specific										
				YT	BC	AB	SK	MB	ON	QC[1]	NB	NS	PE	NL
		1604	cultural control practices	--	X	X	X	X	X		X	X	X	X
		1605	mobile water tanks for sprayer filling	--	X	X	X	X	X		X	X	--	--
17	Nutrient Recovery from Waste Water	1701	recycling of wastewater streams from milk houses, fruit and vegetable washing facilities, and greenhouses, to recover nutrients	--	X	X	X	X	X		X	X	X	X
		1702	engineering design work	--	X	X	X	X	X		X	X	X	--
18	Irrigation Management	1801	irrigation equipment modification/improvement to increase water efficiency or nutrient use efficiency	X	X	X	X	X	X		X	X	X	X
		1802	equipment to prevent backflow of altered irrigation water into water sources	X	X	X	X	X	X		X	X	--	X
		1803	improved infiltration galleries and irrigation intake systems	--	X	X	X	X	X		X	X	--	X
19	Shelterbelt Establishment	1901	establishment of shelterbelts/windbreaks for farmyard, field, livestock facilities, snowtrap and wildlife habitat enhancement	--	X	X	X	X	X		X	X	X	X

Table 1: National and provincial BMPs (from the National Farm Stewardship Program, AAFC, 2008a).

Category code	BMP Category	Practice code	Type of Practice	Province-specific										
				YT	BC	AB	SK	MB	ON	QC[1]	NB	NS	PE	NL
		1902	tree materials required for shelterbelt/windbreak establishment	--	X	X	X	X	X		X	X	--	X
20	Invasive Alien Plant Species Control	2001	integrated approaches (cultural, mechanical, and biological) for control of invasive and alien plant species (e.g., leafy spurge, purple loosestrife, scentless chamomile)	X	X	--	X	X	X		--	X	X	X
21	Enhancing Wildlife Habitat & Biodiversity	2101	buffer strips: native vegetation	--	X	X	X	X	X		X	X	--	X
		2102	alternative watering systems	--	X	X	X	X	X		X	X	--	X
		2103	improved grazing systems: cross fencing, restriction of livestock from woodlands	--	X	X	X	X	X		X	X	--	X
		2104	wildlife shelterbelt establishment	--	X	X	X	X	X		X	X	--	X
		2105	improved stream crossings	--	X	X	X	X	X		X	X	--	X
		2106	hayland management to enhance wildlife survival	--	X	X	X	X	X		X	X	--	X
		2107	wetland restoration	--	X	X	X	X	X		X	X	X	--
22	Species at Risk	2201	alternative watering systems	--	X	X	X	X	X		X	X	--	X
		2202	improved grazing systems: cross fencing	--	X	X	X	X	X		X	X	--	X

Table 1: National and provincial BMPs (from the National Farm Stewardship Program, AAFC, 2008a).

Category code	BMP Category	Practice code	Type of Practice	Province-specific										
				YT	BC	AB	SK	MB	ON	QC[1]	NB	NS	PE	NL
		2203	plant species establishment	--	X	X	X	X	X		X	X	--	X
		2204	infrastructure development and relocation	--	X	X	X	X	X		X	X	--	X
23	Preventing Wildlife Damage	2301	forage buffer strips	X	X	--	X	X	X		X	X	--	X
		2302	fencing or netting to protect: stored feed, concentrated livestock, high value crops, drip irrigation systems, and other agricultural activities	X	X	--	X	X	X		X	X	X	X
		2303	scaring and repellent systems and devices	--	X	--	X	X	X		X	X	X	X
24	Nutrient Management Planning	2401	consultative services to develop nutrient management plans; planning and decision support tools	X	X	X	X	X	X		X	X	X	X
25	Integrated Pest Management Planning	2501	consultative services to develop integrated pest management plans; planning and decision support tools	--	X	X	X	X	X		X	X	X	X
26	Grazing Management Planning	2601	consultative services to develop range and grazing management plans; planning and decision support tools	--	X	X	X	X	X		--	X	--	X

Table 1: National and provincial BMPs (from the National Farm Stewardship Program, AAFC, 2008a).

Category code	BMP Category	Practice code	Type of Practice	Province-specific										
				YT	BC	AB	SK	MB	ON	QC[1]	NB	NS	PE	NL
27	Soil Erosion & Salinity Control Planning	2701	consultative services to develop soil erosion and salinity control plans; planning and decision support tools	--	X	X	X	X	X		X	X	--	X
28	Biodiversity Enhancement Planning	2801	consultative services to plan habitat enhancement, wetland restoration, stewardship for species at risk and/or wildlife damage prevention within agricultural land base; planning and decision support tools	--	X	X	X	X	X		X	X	x	X
29	Irrigation Management Planning	2901	consultative services for planning improved water use efficiency and reduced environmental risk of existing irrigation systems; planning and decision support tools	X	X	X	X	X	X		X	X	--	X
30	Riparian Health Assessment	3001	consultative services for assessing riparian health; planning and decision support tools	--	--	X	X	X	X			X	--	X

1 : low-level boom application of manure; limiting the access of livestock to watercourses; establishing buffer strips for protecting watercourses; planting shelterbelts in fields or near livestock buildings; practicing soil conservation; and using integrated pest management.

X: Available in the province.

--: Not offered in the province.

Table 2: Agricultural BMPs from the NAESI Biodiversity report (ERIN Consulting Ltd., 2006).

Categories	Subcategories
Permanent cover and grassland management	Permanent cover and conservation reserve plantings
	Perennial energy crops
	Short rotation forestry
	Grassland management / Hayland management
	Pasture and range management / Grazing regimes
	Grazing timing
	Pasture plants
Woodlot management	Conservation of large wooded blocks
	Retention of connectivity
Soil management	Shelterbelt establishment
	Conservation tillage
	Strip cropping
	Crop rotations
	Cover crops
	Grassed waterways
	Vegetative filter strips
	Wooded fencerows
	Salinity control
	Manure land application
Riparian areas and water management	Filter vegetation strips
Nutrient management	Manure management and improved storage and handling
	Proper treatment of manure
	Relocation of livestock facilities
	Wintering site management
	Pesticide and herbicide storage and handling
	Management of agricultural wastes
	Minimizing chemical inputs to soils
	Optimized nutrients in animals feed
Species management	Integrated pest management / improved pest management
	Chemical use reduction
	Tillage timing and frequency
	Crop rotation
	Cover crops
	Ecological integrated pest management
	Invasive alien plant species control: ecological integrated pest management
	Invasive alien plant species control: physical control

Table 2: Agricultural BMPs from the NAESI Biodiversity report (ERIN Consulting Ltd., 2006).

Categories	Subcategories
	Invasive alien plant species control: biological control
	Invasive alien plant species control: burning
	Invasive alien plant species control: herbicide control
	Preventing wildlife damage: hunting and trapping
	Preventing wildlife damage: habitat modification and management
	Preventing wildlife damage: fencing / barriers
	Preventing wildlife damage: netting
	Preventing wildlife damage: repellants and deterrents
	Preventing wildlife damage: scare tactics
	Species at risk: promote conservation and stewardships
	Species at risk: preserve and maintain specific species at risk habitat
	Grassland management

3 ASSESSMENT OF AGRICULTURAL BMP CONTRIBUTION TO BIODIVERSITY

The 1992 Rio Convention on Biological Diversity defines biodiversity, or biological diversity, as: "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." According to the Canadian Biodiversity Strategy (1995), it refers to "the variety of species and ecosystems on Earth and the ecological processes of which they are a part". Similarly, the definition adopted by Environment Canada (2007) states: “Biodiversity refers to the variability among living organisms - within species (genetic diversity), between species (species diversity), and in ecosystems (ecosystem diversity)”.

Biodiversity is generally assessed using species richness (number of different species in a particular area), Simpson’s diversity index (takes into account the number of species present, as well as the relative abundance of each species) and the Shannon Weiner index (takes into account the number of species and the evenness of the species). \Species diversity is characterized by alpha-diversity or within-habitat diversity (number of species within a given area), beta-diversity or between-habitat diversity (comparing the number of species unique to each ecosystem) and gamma-diversity or geographical diversity (a measure of the overall diversity for different ecosystems within a region).

The efficacy of agricultural BMP's in attaining biodiversity conservation goals was assessed based on existing studies, researche and reports. Several studies have documented the effect of agricultural practices on birds, small and medium-sized mammals, terrestrial invertebrates (insects, butterflies), soil fauna (invertebrates: earthworms and arthropods), herpetofauna (amphibians and reptiles), fishes and plants. Birds (mainly grassland birds, since they are declining faster than any other group of birds in North America) and small mammals are the most highly studied taxa. They provide broader insight into the efficacy of agricultural BMPs in the contribution to biodiversity and were selected as indicator organism.

Quantitative evidence for the efficacy of each specific agricultural BMP, or group of BMPs, was assessed based on evidence of the following:

- High population abundance, density, species richness
- Large numbers of breeding species
- High nest density, nesting success
- A reduction in population mortality and/or nest loss
- High occurrence of species of conservation concern, unique species, endemic or native species

The following measures were considered as qualitative evidence for the efficacy of a specific agricultural BMP or group of BMPs:

- High quality availability of /potential for resources and desirable habitat characteristics (cover, nesting site, food, refuge, travel corridor, landscape diversity, micro-climate).
- Improvement of ecological function (e.g., soil fertility, soil microorganism activities, food chain, micro-habitat).

4 QUANTITATIVE AND QUALITATIVE EVIDENCE FOR EFFICACY OF AGRICULTURAL BMPS

BMPs from the national and provincial lists and from ERIN Consulting Ltd. (2006) were reviewed. Wetland restoration was added to the ERIN Consulting Ltd. (2006) Biodiversity BMPs list. In total, 33 BMPs were assessed. BMPs identified under more than one category in ERIN Consulting Ltd. (2006) were combined. Quantitative evidence for the efficacy of a BMP (or grouip of BMPs) in contribution to biodiversity, is summarized in a table at the end of each section.

4.1 Permanent cover and conservation reserve programs:

- Provide cover, nesting sites, food and refuge for birds and small mammals (voles, mice) in grasslands. Reptiles and invertebrates (insects, butterflies) have also been shown to use Conservation Reserave Program (CRP) grass plantings.
- The Canadian Permanent Cover Program included 521,998 ha of marginal land (15,009 contracts) within four provinces - Manitoba, Saskatchewan, Alberta and British Columbia (PFRA, quoted by AAFC, 2008b).

4.1.1 Birds

Evidence of high avian abundance, density, species richness and increases relative to alternative habitats (e.g., rowcrop):

- Ryan *et al*. (1998) listed 92 species of birds, including 53 songbirds, that had been observed using CRP plantings in the central United States. In the most extensive study of songbird use of CRP in the Midwest, Best *et al*. (1997) observed over 60 species of birds using CRP habitats during the breeding season. Similarly, Best *et al*. (1998) recorded over 40 bird species using CRP grasslands as winter feeding or roosting habitat.
- Best *et al*. (1997) compared avian abundance in paired CRP and rowcrop habitats in six US Midwestern states. They detected from 1.4 to 10.5 times more birds in CRP grasslands than rowcrop fields during the breeding season. The red-winged blackbird, *Agelaius phoeniceus* (3.92 vs. 0.92 individuals/transect); dickcissel, *Spiza Americana* (3.06 vs. 0.08 individuals/transect); song sparrow, *Melospiza melodia* (1.38 vs. 0.10 individuals/transect); grasshopper sparrow, *A. savannarum* (1.28 vs. 0.02 individuals/transect) and field sparrow, *Spizella pusilla* (1.13 vs. 0.07 individuals/transect) were most frequently observed in CRP fields. Best *et al*., 1997 further reported 19 species that were unique to CRP habitats, or more abundant than in nearby rowcrop fields, where only 5 species were unique or substantially more abundant.
- Johnson and Schwartz (1993) evaluated bird use of CRP fields in the northern Great Plains (eastern Montana, North Dakota, South Dakota, and Western Minnesota). They recorded 73 species and a total density of 123.6 pairs/100ha, in CRP fields. They found 16 species to have 7 times the median density, compared to crop sites. The lark bunting, *Calamospiza melanocorys* (22.4 vs. 4.2 individuals/100ha); grasshopper sparrow, *A. savannarum* (21.2 vs. 0.5 individuals/100ha) and red-winged blackbird, *Agelaius phoeniceus* (16.4 vs. 1.1 individuals/100ha) were most frequently observed in CRP fields.

- McMaster and Davis (2001) evaluated the Canadian Permanent Cover Program (PCP) in the Prairie Ecozone of Alberta, Saskatchewan and Manitoba. They recorded totals of 43 and 37 bird species on PCP and cropland, respectively. Ten (10) species were common to PCP sites, whereas only three species were common to cropland sites. Nine (9) of the 10 species were detected significantly more frequently at PCP sites than cropland, whereas only 1 species occurred significantly more frequently in cropland.
- In North Dakota, of 18 breeding species that were common in CRP or crop fields or both, 12 were more abundant in CRP habitats (Johnson and Igl, 1995).
- In southeast Nebraska, King and Savidge (1995) reported a larger number (2.43 vs. 1.71 individuals/station in the first year and 1.75 vs. 1.35 individuals/station in the second year) of ring-necked pheasant (*Phasianus colchicus*) in areas with approximately 20% of the cropland in the CRP program than in areas with <5%.
- Giuliano and Daves (2002) found that, compared with cool-season grass fields, warm-season grass fields supported a greater avian abundance and species richness (both were 1.6 times greater than in cool-season fields).

Evidence of high nest density and nesting success relative to alternative habitats (e.g., rowcrop):

- Apparent success for 1,526 nests monitored in CRP habitats by Best *et al*. (1997) was 40%, versus 36% for 113 nests monitored in rowcrop fields. Nests of red-winged blackbirds, dickcissels and grasshopper sparrows were most frequently encountered. Using a subset of the data from Best *et al*. (1997), Patterson and Best (1996) reported apparent nest success of 38% in CRP habitat and 32% in rowcrop fields in Iowa. CRP fields produced ≥15 times more young birds than rowcrop fields (Best *et al*., 1997).

- Patterson and Best (1996) observed 10 times more nests in CRP fields than cropland in Iowa (Midwest US).
- Best *et al*. (1997) reported that CRP supported 3 times more nesting species and 13.5 times the total number of nests as rowcrop in six US Midwestern states.
- In northwest Texas, Berthelsen *et al*. (1990) found approximately six pheasant nests per 10 acres of CRP grassland, but no nests in cornfields.
- Giuliano and Daves (2002) reported that fledge rates were 1.8 times higher in warm- than cool-season fields where nests were destroyed 10 times more frequently.

Evidence of high occurrence of avian species of concern and unique species in CRP habitats:

- Three [Henslow's sparrow, *Ammodramus henslowii* (0.06 individuals/km of transect); bobolink, *Dolichonyx oryzivorus* (0.79 individuals/km of transect); and sedge wren, *Cistothorus platensis* (0.31 individuals/km of transect)] of the 11 species of conservation concern in the Midwest occurred only in CRP fields (Best *et al*., 1997). Further, the chipping sparrow (*Spizella passerina*) and northern flicker (*Colaptes auratus*) were unique to CRP fields (0.08 and 0.04 individuals/transect, respectively). Additionally, Best *et al*. (1997) reported that 8 (dickcissel, *Spiza americana*, grasshopper sparrow *A. savannarum*; field sparrow, *Spizella pusilla*; bobolink, *D. oryzivorus*; sedge wren, *C. platensis*; ring-necked peasant, *Phasianus colchicus*; northern bobwhite, *Colinus virginianus*; and Henslow's sparrow, *A. henslowii*) of the 19 bird species they most frequently observed in CRP have been undergoing significant population declines (Herkert *et al.*, 1996 quoted by Best *et al.*, 1997).
- Of the 5 species unique to or substantially more abundant in rowcrops than in CRP fields

(Best *et al*., 1997), only one, the lark sparrow (*Chondestes grammacus*), is of moderate conservation concern (Herkert *et al*., 1996 quoted by Ryan, 2000).

- In the Prairies Ecozone, McMaster and Davis (2001) observed 2 of 10 common species on PCP sites only (11.9% of sites for grasshopper sparrow, *A. savannarum* and 8.4 % of sites for Le Conte's sparrow, *A. leconteii*). Sauer *et al*. (1999; as cited by McMaster and Davis, 2001) indicated that 7 of the 10 common species in the CRP fields have undergone significant population declines either in the Prairies Ecozone or within Canada.
- In the northern Great Plains, 5 species [clay-colored sparrow, *S. pallida* (4.0 - 4.5 pairs/100ha) common yellowthroat, *Geothlypis trichas* (2.1 - 3.5 pairs/100ha) sedge wren, *C. platensis* (1.5 - 2.6 pairs/100ha); Baird's sparrow, *A. bairdii* (1.4 - 1.6 pairs/100ha); and dickcissel, *S. americana* (0.1 pairs/100ha)] were observed only in CRP habitats (Johnson and Schwartz, 1993; Johnson and Igl, 1995).
- Reynolds *et al*. (1994) reported that 4 of 9 migratory grassland species in North Dakota that had negative population trends before CRP, had positive population trends in the CRP period.
- Johnson and Igl (1995) noted that 6 of the 12 species (lark bunting, *C. melanocorys*; grasshopper sparrow, *A. savannarum*; bobolink, *D. oryzivorus*; clay-colored sparrow, *S. pallida*; Baird's sparrow, *A. bairdii*; dickcissel, *S. americana*) occurring more abundantly in CRP habitats than in crop fields had suffered significant population declines in North Dakota. In contrast, none of the six species that were more common in cropland than in CRP fields had declined significantly.
- Johnson and Igl (1995) estimated that CRP fields composed only about 7% of the land in North Dakota but supported more than 20% of the statewide populations of many breeding

species. They projected declines in the populations of 15 grassland bird species breeding in North Dakota CRP if those grass fields were reverted back to cropland. Population declines were estimated at 25.8% for sedge wren (*C. platensis*), 20.5% for grasshopper sparrow (*A. savannarum*), 18.8% for savannah sparrow (*P. sandwichensis*), 17.1% for dickcissel (*S. americana*), 17.0% for lark bunting (*C. melanocorys*) and 11.9% for red-winged blackbird (*A. phoeniceus*).

- Based on the Breeding Bird Survey data from Illinois, Herkert (1997) demonstrated a significant positive relationship between the population trend for Henslow's sparrow (*A. henslowii*) and the percent of CRP habitat in a county. Also from the Illinois Spring Bird Count, Herkert (2007) showed that Henslow's sparrow populations have increased substantially over the last 10 years, and that this population increase strongly coincides with the CRP establishment of >400,000 ha of grasslands within Illinois. The increase in Henslow's sparrows was greatest in counties with > 3.2% of their land area enrolled in the Conservation Reserve Program, with populations increasing in these counties at a rate of 0.73 birds per 100 party hours per year. This increase was almost 5 times the rate of increase for counties with < 1.5% of their land area enrolled in the program (0.15 birds/100 party hr/yr).

4.1.2 Small mammals

Evidence of high abundance and species richness of small mammals in CRP habitats:

- In an inventory's study comparing different habitats in the tallgrass prairie preserve in Oklahoma Payne and Caire (1999) found more species of small mammal (13 versus 9), higher abundance (376 vs. 81 individuals) and greater mean species diversity index (0.456 vs. 0.312) in the prairie grass habitat than disturbed areas. Species such as the prairie vole (*Microtus ochrogaster*) and hispid cotton rat (*Sigmodon hispidus*) preferred prairie-grass habitat where respectively 92% and 71% of individuals were captured. Five (5) species (Elliot's short-tailed shrew *Blarina hylophaga*, eastern harvest mouse *Reithrodontomys humulis*, western harvest mouse *R. megalotis*, plains harvest mouse *R. montanus* and woodland vole *M. pinetorum*) were captured only in the prairie-grass habitat.

- Farrand and Ryan (2005) reported 8 species of small mammals captured on CRP fields in Michigan. Hall and Willig (1994) captured 10 rodent species on CRP in Northwest Texas.
- Six (6) mid-sized and large mammals were recorded in CRP fields in the Midwest (Farrand and Ryan, 2005).

Table 3: Summary of the quantitative evidence of the efficacy of permanent cover and conservation reserve plantings.

Quantitative measure	Study area/ Country	CRP / PCP fields[a]	Cropland[b]	Source
Birds				
Number of species	Central US	92	--	Ryan *et al.*, 1998
	Great Plains, US	73	--	Johnson and Schwartz, 1993
	Prairie Ecozone, Canada	43	37	McMaster and Davis, 2001
Number of songbirds	Central US	53	--	Ryan *et al.*, 1998
	Midwest, US	54	54	Best *et al*., 1997
Number of nesting species	Midwest, US	33	10	Best *et al*., 1997
	Midwest (Iowa), US	16	2	Patterson and Best, 1996
	Midwest (Nebraska), US	16	2	King, 1991 quoted by Johnson and Igl, 1995
Number of common species	Prairie Ecozone, Canada	9	1	McMaster and Davis, 2001
Number of species of concern	Midwest (North Dakota), US	6	0	Johnson and Igl, 1995
	Midwest, US	8	1	Best *et al*., 1997
Mean species richness	Prairie Ecozone, Canada	2.50 ± 0.06	1.34 ± 0.05	McMaster and Davis, 2001
Total density (pairs/100ha)	Great Plains, US	123.6	--	Johnson and Schwartz, 1993
Mean abundance (/km of transect)	Midwest, US	16.02	4.90	Best *et al*., 1997

Table 3: Summary of the quantitative evidence of the efficacy of permanent cover and conservation reserve plantings.

Quantitative measure	Study area/ Country	CRP / PCP fields[a]	Cropland[b]	Source
Total number of nests (/habitat)	Midwest, US	1,638	114	Best *et al*., 1997
Number of nests (/10 acres)	Texas, south central US	6[α]	0[α]	Berthelsen *et al*., 1990
Apparent nest success (%)	Midwest, US	40	36	Best *et al*., 1997
	Midwest (Iowa), US	38	32	Patterson and Best, 1996
Nest loss (%)	Midwest (Iowa), US	52	65	Patterson and Best, 1996
Small mammals				
Number of species	Prairie Preserve, Oklahoma, US	13[a]	9[b]	Payne and Caire, 1999
Abundance (ind./habitat)	Prairie Preserve, Oklahoma, US	376[a]	81[b]	Payne and Caire, 1999

PCP: Permanent Cover Program (Canada). CRP: Conservation Reserve Program (US).

[a] : Prairie-grass habitat. *[α]: Ring-necked pheasant nests.*

[b] : Disturbed areas (ranch houses, corrals, oil production sites and roads).

4.1.3 Limitations/weaknesses:

- Due to the small size of CRP, no positive impacts were recorded for large area-sensitive grassland birds.

4.2 Perennial energy crops:

- Provide wildlife benefits of CRP plantings in agricultural zones.
- Create suitable habitat for birds (grassland birds, large game birds: ducks, pheasants) and small mammals (rodents), and harbor invertebrates (ground beetles, butterflies).

4.2.1 Birds

Evidence of high avian species richness in perennial energy crops:

- Semere and Slater (2004) recorded 35 bird species using biomass crop fields in western

England.

Evidence of high occurrence of avian species of concern in perennial energy crops:

- Murray *et al*. (2003) studied the regional effects of converting rowcrop and CRP switchgrass fields to biomass production in the Rathbun Lake Watershed in southern Iowa. They estimated a 6% mean increase in the abundance of 5 species of management priority (bobolink *D. oryzivorus*; dickcissel *S. americana*; field sparrow, *Spizella pusilla*; grasshopper sparrow, *A. savannarum*; and sedge wren, *Cistothorus platensis*) in the total-harvest biomass fields as compared to the prior land use. Also, the number of ring-necked pheasants (*Phasianus colchicus*) and red-winged blackbirds (*Agelaius phoeniceus*) in the watershed increased by 19% and 10% in the strip-harvest biomass fields. A larger number of common yellowthroat (*Geothlypis trichas*) was noted in the total-harvest biomass fields than in the prior land use (33.7 vs. 10.9 x1000 individuals).

Table 4: Summary of the quantitative evidence of the efficacy of the perennial energy crops.

Quantitative measure	Study area/ Country	Perennial energy crops	Arable crops/ cropland	Source
Birds				
Species richness	Western England	35	--	Semere and Slater, 2004
Abundance (x1000)	Southern Iowa, US	180.9*	176.0*	Murray *et al*., 2003
		270.6**	242.4**	Murray *et al*., 2003

**: Five (5) species of management priority (bobolink, dickcissel, field sparrow, grasshopper sparrow, and sedge wren).*

***: Eight (8) other species (brown-headed cowbird, common yellowthroat, horned lark, killdeer, meadowlark, red-winged blackbird, ring-necked pheasant, and vesper sparrow).*

4.2.2 Limitations/weaknesses:

- Murray *et al*. (2003) observed that horned lark (*Eremophila alpestris*) and killdeer (*Charadrius vociferous*) were more abundant in the existing land use than in the biomass fields. They predicted that conversion of fields from rowcrop to biomass production could be detrimental to these species.

4.3 Short Rotation Forestry (SRF):

- Provide cover, understorey vegetation, nesting sites, travel corridors, landscape diversity and micro-climate for birds, small and mid-sized mammals (vole, shrew, mouse, and squirrel) and large mammals. Harbors terrestrial and soil invertebrates (insects, arthropods, worms) (Hardcastle *et al*., 2006).
- Create favorable habitat for bats, migrant and forest birds, and mammals, in agricultural landscape (Christian, 1997; Christian *et al*., 1997).

4.3.1 Birds

Evidence of high avian abundance, density, species richness and increase in short rotation forestry:

- In Minnesota Wisconsin and Dakota, Christian *et al*. (1997) reported higher avian diversity on hybrid poplar plantations (9.74 and 5.07 species/habitat in agricultural and forested landscapes, respectively) than in rowcrop (1.61 and 1.74 species/habitat in agricultural and forested landscapes, respectively) and in Pasture/hayfield (5.18 and 3.01 species/habitat in agricultural and forested landscapes, respectively) during breeding season. They observed a larger number of birds on hybrid poplar plantations (3.41 and 0.93 birds/ha in agricultural and forested landscapes, respectively) than in rowcrop (0.21 and 0.23 bird/ha in agricultural and forested landscapes, respectively) and in pasture/hayfield (0.91 and 0.52 bird/ha in agricultural and forested landscapes, respectively) during breeding season. Both short- and long-distance migrants have been more abundant in plantations than in croplands and pasture/hayfields (Table 5).

Table 5: Number of birds observed on hybrid poplar plantations, wooded wildland and rowcrop fields in forest and agricultural landscape in north central US during breeding season and fall migration (adapted from Christian *et al*., 1997).

Parameters	Land use type (forested landscape)			Land use type (agricultural landscape)		
	Plantation	Wooded wildland	Row crop	Plantation	Wooded wildland	Row crop
Breeding season						
Number of species*	5.07 ± 0.71	6.37 ± 0.34	1.74 ± 0.22	9.74 ± 0.97	15.03± 5.09	1.61 ± 0.30
Total individuals (/ha)	0.93 ± 0.13	1.15 ± 0.10	0.23 ± 0.00	3.41 ± 1.34	5.17 ± 1.07	0.21 ± 0.04
Long-distance migrants (/ha)	0.22 ± 0.05	0.53 ± 0.01	0.04 ± 0.01	0.40 ± 0.03	1.12 ± 0.61	0.02 ± 0.00
Short-distance migrants (/ha)	0.59 ± 0.11	0.45 ± 0.08	0.19 ± 0.00	2.13 ± 0.66	3.52 ± 0.16	0.17 ± 0.03
Permanent resident (/ha)	0.06 ± 0.03	0.13 ± 0.02	0	0.87 ± 0.79	0.46 ± 0.23	0.02 ± 0.01
Fall migration						
Number of species*	3.18 ± 0.40	5.09 ± 0.88	1.58 ± 0.29	4.15 ± 0.67	7.05 ± 1.22	1.00 ± 0.00
Total individuals (/ha)	0.69 ± 0.08	1.18 ± 0.35	0.43 ± 0.03	1.66 ± 0.80	2.64 ± 0.13	0.08 ± 0.01
Long-distance migrants (/ha)	0.11 ± 0.02	0.18 ± 0.03	0.00 ± 0.00	0.14 ± 0.01	0.32 ± 0.03	0.03 ± 0.00
Short-distance migrants (/ha)	0.35 ± 0.06	0.53 ± 0.26	0.16 ± 0.12	0.44 ± 0.14	1.46 ± 0.49	0.03 ± 0.00
Permanent resident (/ha)	0.11 ± 0.03	0.34 ± 0.08	0.00 ± 0.00	0.83 ± 0.57	0.73 ± 052	0.01 ± 0.01

**: Number expected to be counted in an area the same size as the plantation.*

- Hanowski *et al*. (1998) observed greater avian richness and abundance on hybrid poplar plantations (5.60 species/habitat and 12.80 individuals/ha, respectively) than on rowcrop (2.72 species/habitat and 3.21 individuals/ha, respectively) and hay/pasture fields (4.37 species/habitat and 8.40 individuals/ha, respectively) in Minnesota, Wisconsin and South Dakota. Further, they reported more long- and short-distance migrants on hybrid poplar plantations (0.19 and 0.70 individuals/ha, respectively) than on rowcrop (0.01 and 0.29 individual/ha, respectively) and hay/pasture fields (0.12 and 0.39 individual/ha, respectively). They observed a greater abundance of American robin (*Turdus migratorius*), song sparrow (*Melospiza melodia*), clay-colored sparrow (*Spizella pallida*), brown-headed cowbird (*Molothrus ater*), mourning dove (*Zenaida macroura*), common yellowthroat (*Geothlypis trichas*) and Americain golgfinch (*Carduelis tristis*) on plantations than rowcrop or hay/pasture fields.

- Sage *et al*. (2006) recorded 47 species using Short Rotation Coppice (SRC) plots during winter in England. They found that SRC plots exhibited more birds (3.1 birds/ha) than the arable and grassland controls (0.8 and 1.63 birds/ha, respectively). They observed more species per plot per visit in the SRC plots (6.57) than in grass and arable fields controls (4.85 and 2.15, respectively). Of the 37 species observed in spring, 11 were recorded for the SRC plots every year while only 2 and 5 species were recorded from the arable and grassland plots respectively.

Evidence of high occurrence of species of concern and grassland species in short rotation forestry:

- In Minnesota, Wisconsin and Dakota, Christian *et al*. (1997) recorded generalists (mourning dove, *Zenaida macroura*; black-capped chickadee, *Parus atricapillus*; song sparrow, *Melospiza melodia*; and brown-headed cowbird, *Molothrus ater*) and grassland or open area species that used trees on plantation edges as song perches or were seen in areas of clonal failure, including eastern kingbird (*Tyrannus tyrannus*), clay-colored sparrow (*Spizella pallida*), field sparrow (*S. pusilla*), savannah sparrow (*Passerculus sandwichensis*), and western meadowlark (*Sturnella neglecta*). The 3 sparrows have declining population or are of conservation concern.

- Christian (1997) reported abundant tracks of ring-necked pheasant (*Phasianus colchicus*) in hybrid poplar plantations in Minnesota, Wisconsin and South Dakota.

4.3.2 Small mammals

Evidence of high abundance of small mammals:

- Christian *et al*. (1997) observed a similar number of small mammal species on poplar hybrid plantations as on rowcrop fields in Minnesota, Wisconsin and Dakota (Table 6). However, a greater number of individuals (all rodents) were observed on poplar hybrid plantations in agricultural landscape (7.3 vs. 5.8 individuals/50-traps). The prairie deer mouse (*Peromyscus maniculatus bairdii*) and white-footed mouse (*P. leucopus*) were the most abundant species (5.3 and 0.3 individuals/50-traps, respectively). No white-footed mouse (*P. leucopus*) was observed in rowcrop and pasture/hayfield.

Table 6: Small mammal capture (mean number of species or individuals/50-traps units and SE) in hybrid poplar plantations, wooded wildland and rowcrop fields in forest and agricultural landscapes in north central US (adapted from Christian *et al*., 1997).

Parameters	Land use type (forested landscape)			Land use type (agricultural landscape)		
	Plantation	Wooded wildland	Row crop	Plantation	Wooded wildland	Row crop
Number of species	1.7 ± 0.2	3.8 ± 0.4	2.0 ± 0.6	1.8 ± 0.4	6	1.4 ± 0.4
Number of individuals	2.8 ± 0.6	12.1 ± 0.9	3.7 ± 0.7	7.3 ± 3.7	30	5.8 ± 1.6
Number of shrews	0.7 ±0.3	4.6 ±0.9	0.7 ±0.3	0	11	0
Number of rodents	2.1 ±0.5	7.5 ±1.0	3.0 ±0.6	7.3 ± 3.7	19	5.8 ±1.6

- Moser *et al*. (2002) recorded 6 rodent and 1 insectivore species on hybrid poplar plantations in the Columbia River basin, Oregon. The prairie deermouse, *P. maniculatus* was the most captured species (77.5% of total observations). Other species included the great basin pocket mouse, *Perognathus parvus* (9.07% of observations); house mouse, *Mus musculus* (6.1%); Merriam's shrew, *Sorex merriami* (4.1% of observations); montane vole, *Microtus montanus* (1.6% observations); western harvest mouse, *Reithrodontomys megalotis* (1 .1% of observations); and ord's kangaroo rat, *Dipodomys ordii* (0.7% observations).

4.3.3 Mid-sized and large mammals

Evidence of high abundance of mid-sized and large mammals:

- Christian (1997) studied wintertime use of hybrid poplar plantations in Minnesota, Wisconsin and South Dakota. Across agricultural landscapes, he counted more white-tailed deer (*odocoileus virginiatus*) tracks in hybrid poplar plantations (mean count of 31 tracks) than in other land use types (1 track in rowcrop, 4 tracks in wooded wildland and 4 tracks in hayfield/pasture field). In the forested zone, deer use of plantations (12 tracks) was similar to that of wooded wildland habitat (13 tracks). The mean deer track count was slightly higher for plantations than for rowcrop (8 tracks) and hay/pasture fields (1 track) in the forested zone.
- In the forested zone, there was evidence of only slight use of hybrid poplar plantations by forest-associated mammals such as tree squirrels (i.e., the North American red squirrel, *Tamiasciurus hudsonicus*; and the eastern gray squirrel, *Sciurus carolinensis* and fox squirrel, *S. niger*) (Christian, 1997).

Table 7: Summary of the quantitative evidence of the efficacy of the short rotation forestry.

Quantitative measures	**Study area/ Country**	**SRF[a]**	**Pasture/ hayfield[b]**	**Rowcrop[c]**	**Source**
Birds					
Number of species	Eggborough, England	47 (37)*[a]	24 (16)*[b]	39 (21)*[c]	Sage *et al.*, 2006
Species richness	North central[1] US	9.74 ± 0.97	5.18 ± 0.09	1.61 ±0.30	Christian *et al.*, 1997

Table 7: Summary of the quantitative evidence of the efficacy of the short rotation forestry.

Quantitative measures	Study area/ Country	SRF[a]	Pasture/ hayfield[b]	Rowcrop[c]	Source
(/habitat)	North central US	5.60 ± 0.70	4.37 ± 1.20	2.72 ± 0.70	Hanowski *et al.*, 1998
Number of species per plot per visit	Eggborough, England	6.57 ± 0.27[a]	4.85 ± 0.30[b]	2.15 ± 0.25[c]	Sage *et al.*, 2006
Density (/ha)	Eggborough, England	3.1 ± 0.2[a]	1.63 ± 0.02[b]	0.8 ± 0.03[c]	Sage *et al.*, 2006
	North central[1] US	3.41 ± 1.34	0.91 ±0.02	0.21 ±0.04	Christian *et al.*, 1997
	North central US	12.80 ± 4.10	8.40 ± 3.0	3.21 ±1.10	Hanowski *et al.*, 1998
Small mammals					
Number of species	North central[1] US	10	--	--	Christian *et al.*, 1997
	Oregon, US	7	--	--	Moser *et al.*, 2002
Number of species (/50-traps)	North central[1] US	1.8 ± 0.4	3.7 ± 1.2	1.4 ± 0.4	Christian *et al.,* 1997
Number of individuals (/50-traps)	North central[1] US	7.3 ± 3.7	8.7 ± 1.8	5.8 ± 1.6	Christian et al., 1997
Large mammal					
Number of deer tracks (/habitat)	Midwest[1], US	31	4	1	Christian, 1997

**: Spring values; in parenthesis are winter values.* [1] *: Agricultural landscape.*

[a] *: Short Rotation Coppice.* [b] *: Grassland.* [c]*: Arable fields.*

4.3.4 Limitations/weaknesses:

- Plantations favor more habitat generalist bird and mammal species (Schiller and Tolbert, 1998). Christian *et al*. (1997) observed several species in wooded wildlands adjacent to hybrid poplar plantations that were not present on the plantations during breeding season. Similarly, several grassland species were observed in habitats adjacent to plantations but not within plantations.

- No positive impacts on characteristic forest-dwelling mammals. Christian (1997) reported the extremely limited use of plantations during winter by mid-sized mammals typically associated with forests. No shrews were captured on plantations in the agricultural zone in the north central US (Christian *et al*., 1997, 1998).
- Small mammal and bird diversities and abundances are lower on plantations than in natural forest (Christian *et al*., 1997; Hanowski *et al*., 1998).
- Establishment of large plantations may threaten rare bird species adapted to open habitat (Christian *et al*., 1998; Hardcastle *et al*., 2006).
- Hardcastle *et al*. (2006) reported that red-listed species such as the dormouse and red squirrel are unlikely to find suitable habitat in SRF due to the absence of mature trees required for nesting sites.

4.4 Grassland management / Hayland management:

- Properly managed hayland provides cover, food, micro-climate, and suitable habitat for grassland birds, waterfowl, large game birds, prairie mammals and invertebrates (butterflies).

4.4.1 Birds

Evidence of high avian species richness and abundance in hayland:

- Dale *et al.* (1997) assessed the impacts of hay management regimes on endemic grassland birds in the mixed grass prairie ecoregion in Saskatchewan. They reported more species occurring in idle native habitat (3 - 5 species/100-m-radius) than annual hayed (3 - 4 species/100-m-radius) and periodical hayed (2 - 4 species/100-m-radius) fields. The number of species was higher on moved (4 species/100-m-radius) than unmoved (3 species/100-m-radius) plots of annual hayed habitat. Sprague's pipit (*Anthus spragueii*), Baird's sparrow

(*Ammodramus bairdii*) and Savannah sparrow (*Passerculus sandwichensis*) were the most commonly occurring species (up to 100% of census plots) in all habitat types. Further, horned lark, *Eremophila alpestris* (17 - 67 vs. 0 - 17% of census plots); western meadowlark, *Sturnella neglecta* (8 - 42 vs. 0 – 30% of census plots); grasshopper sparrow, *A. savannarum* (0 - 29 vs. 0% of census plots); and chestnut-collared longspur, *Calcarius ornatus* (4 - 25 vs. 0% of census plots) occurred more on annual hayed than periodic hayed fields.

Evidence of high avian nesting species, nest density and nesting success in properly managed hayland:

- In southern Saskatchewan, McMaster *et al*. (2005) located 1,420 nests of 26 species of grassland nesting birds in haylands, primarily waterfowl (69.8% of all nests) and vesper sparrows, *Pooecetes gramineus* (19.0% of all nests). Five [gadwall, *Anas strepera* (29% of all waterfowl nests); mallard, *A.*, *platyrhynchos* (18.5% of all waterfowl nests); blue-winged teal, *A. discors* (19.2% of all waterfowl nests); northern shoveler, *A. clypeata* (15.9% of all waterfowl nests); and northern pintail, *A. acuta* (13.5% of all waterfowl nests)] of the 7 waterfowl species that nested regularly in haylands were most abundant.
- McMaster *et al*. (2005) observed higher Mayfield nest success for all waterfowl (13 - 20%) compared to duck nest success in cropland (2% and 7%, reported by Greenwood *et al*., 1995; Klett *et al*., 1988 respectively). Further, vesper sparrow nest success in haylands (33 - 39%) was relatively higher than that of vesper sparrows breeding in cropland, where nests are vulnerable to tillage operations (13% reported by Rodenhouse and Best, 1983), and to that of other grassland songbird species breeding in native pasture in a more fragmented landscape (7 - 30% for 8 species reported by Davis and Sealy, 2000).

- In Nova Scotia, Nocera *et al*. (2005) observed that delaying hay harvesting by 1.5 weeks (to 1 July) secured an increase in the rate of fledgling from 0 to 20% for bobolink (*D. oryzivorus*), 56% for savannah sparrow (*P. sandwichensis*), and 44% for Nelson's sharp-tailed sparrow (*Ammodramus nelsoni*), the three most common birds breeding regionally in hayfields. Postponing cut by 1 more week (to a minimum of 7 July) allowed maximum fledging rates for all species.
- In Saskatchewan mixed grass prairie, Dale *et al*. (1997) noted that delayed mowing, carried out in the third week of July (until July 15), had a reduced impact on songbird productivity. By this date almost 70% of nests had produced fledged young, so offspring were less susceptible to destruction by mowing.
- Calverley and Sankowski (1995) reported that the use of a flushing device reduced nesting duck mortality in Alberta by enabling successful escape of 100% of female ducks. Observed female duck mortality was 48% in fields mowed without the use of a flushing device.

Evidence of high occurrence of avian species of concern and unique species:

- McMaster *et al*. (2005) recorded 13 species of high management concern occurring in hayland (northern pintail, *Anas acuta*; sharp-tailed grouse, *Tympanuchus phasianellus*; northern harrier, *Circus cyaneus*; short-eared owl *Asio flammeus*; willet, *Catoptrophorus semipalmatus*; upland sandpiper, *Bartramia longicauda*; marbled godwit, *Limosa fedoa*; Wilson's phalarope, *Phalaropus tricolor*; clay-colored sparrow, *Spizella pallida*; Baird's sparrow, *Ammodramus bairdii*; Le Conte's sparrow, *A. leconteii*; chestnut-collared longspur, *Calcarius ornatus*; and bobolink, *D. oryzivorus*). They observed a relatively high total number of nests (39; upland-nesting shorebirds often nest at low densities) for 4 high-priority shorebird species (willet, *C. semipalmatus*; upland sandpiper, *B. longicauda*; marbled godwit, *L. fedoa*; and Wilson's phalarope, *P. tricolor*).

- McMaster *et al*. (2005) noted that estimated waterfowl nest success in hayland is generally within the range necessary to sustain waterfowl populations (15 - 20%, Cowardin *et al*., 1985; Klett *et al*., 1988).
- Dale *et al*. (1997) observed a high abundance of Baird's sparrow (*A. bairdii*) and Sprague's pipit (*Anthus spragueii*), two primary species of conservation concern, in hayland in south-central Saskatchewan.

4.4.2 Small mammals

Evidence of high abundance and increase of small mammals:

- Lemen and Clausen (1984) demonstrated a positive relationship between vegetative cover and the number of rodents in US prairie. They predicted an average decrease of 50%, or increase of 500%, when cover is below, or above, a critical value (around 150 g/m^2) respectively.

Table 8: Summary of quantitative evidence for the efficacy of grassland management / hayland management.

Quantitative measure	Study area/ Country	Annual hayed habitat[ab]	Periodic hayed habitat[ab]	Native unhayed habitat	Crop-land	Source
Birds						
Number of nesting species	Saskatche-wan, Canada	26	--	--	--	McMaster *et al*., 2005
Species richness (/100-m-radius)	Saskatche-wan, Canada	3 -5	3 - 4	2 - 4	--	Dale *et al.*, 1997
		3[b] / 4[a]	3[a] / 3[b]	--	--	Dale *et al.*, 1997
Relative nest abundance	Saskatche-wan,	$0.432 \pm 0.052^{\alpha}$	--	--	--	McMaster *et al*., 2005

Table 8: Summary of quantitative evidence for the efficacy of grassland management / hayland management.

Quantitative measure	Study area/ Country	Annual hayed habitat[ab]	Periodic hayed habitat[ab]	Native unhayed habitat	Crop-land	Source
(/ha)	Canada	0.524±0.075[β]	--	--	--	McMaster *et al*., 2005
Nest success (%)	Saskatche-wan, Canada	33 - 39[α]	--	--	13[α]	McMaster *et al*., 2005
		13 - 20[β]	--	--	2 - 7[β]	McMaster *et al*., 2005

[a] : Moved plots. *[b] : Unmoved plots.*

[α] : Vesper sparrow (Pooecetes gramineus). *[β] : Waterfowl.*

4.4.3 Limitations/weaknesses:

- McMaster *et al*. (2005) reported that, of 11 songbird species (with Partners in Flight scores >20) whose range distributions and habitat preferences were seemingly appropriate for nesting in haylands of the Missouri Coteau, only 5 species nested in haylands (clay-colored sparrow, *Spizella pallida*; Baird's sparrow *Ammodramus bairdii*; Le Conte's sparrow, *A. leconteii*; chestnut-collared longspur, *Calcarius ornatus*; and bobolink, *Dolichonyx oryzivorus*), all with 10 nests or less.
- Diversity of obligate grassland species (e.g., Sprague's pipit, *Anthus sprageuii*) is at risk on large scale hayland.

4.5 Pasture and range management / Grazing regimes / Grazing timing:

- Properly managed grazing improves cover (high visual obstruction), food, and suitable habitat for grassland birds, waterfowl and prairie chickens. Also harbors some prairie mammals and invertebrates (butterflies).
- Contributes to habitat mosaic. Low intensity late season grazing increases species (ERIN Consulting Ltd., 2006).

4.5.1 Birds

Evidence of high avian species richness, abundance and increase in extensively grazed pasture and rangeland:

- Bélanger and Picard (1999) observed a greater number of bird species on ungrazed and moderately grazed prairies (10 and 11 species, respectively) than intensively grazed prairie (2 species) along the St. Lawrence River in Québec. They reported that ungrazed and moderately grazed prairies contained 6 times more birds than intensively grazed prairie (10.4 birds/ha and 11.7 birds/ha vs. 1.6 birds/ha). Of all birds counted in moderately grazed prairie, the swamp sparrow (*Melospiza Georgiana*), savannah sparrow (*Passerculus sandwichensis*), bobolink (*Dolichonyx oryzivorus*) and red-winged blackbird (*Agelaius phoeniceus*) were the 4 most abundant species, accounting for 31.92%, 24.14%, 15.82% and 14.83%., respectively.
- Bélanger and Picard (1999) recorded 6 waterfowl species on ungrazed and moderately grazed prairies while only 1 species was observed on intensively grazed prairie. Three species dominated this landscape (northern pintail, *Anas acuta*; gadwall, *A. strepera*; and mallard, *A. platyrhynchos*).
- In England, Calladine *et al*. (2002) observed that the number of displaying black grouse males increased by an average 4.6% per year at reduced grazing sites, compared with a concurrent average annual decline of 1.7% at normally grazed reference sites.

Evidence of high nest density and nesting success in extensively grazed pasture and rangeland:

- In Québec, Bélanger and Picard (1999) reported that moderately grazed and ungrazed prairies exhibited a waterfowl nest density almost 10 times greater than that of intensively grazed prairie (0.50 and 0.30 nest/ha versus 0.05 nest/ha).

- In a rotational grazing along the St. Lawrence River in southern Québec, Lapointe *et al*. (2000) found densities of 2.8 and 7.0 duck nests/ha, with 69% and 82% Mayfield nest success in the idle and DNC fields, respectively. They observed higher density and Mayfield nest success under unimproved pastures without cattle than in improved pastures (seeding of forage plants) with cattle (2.4 vs. 1.1 nests/ha and 68 vs. 15%, respectively).
- In Alberta's Aspen Parkland, Stavne *et al*. (2003) reported that blackbird nest density was reduced at heavy grazing intensities (0.62 nest/ha) compared to idle/low (1.51 nests/ha) and moderate (1.63 nests/ha) categories. Shorebird nest densities were higher on moderately grazed sites (0.22 nest/ha) compared to idle/ lightly grazed (0.13 nest/ha) or heavily grazed pastures (0.14 nest/ha). Waterbirds had higher apparent nest success at moderately grazed sites (58%) than in idle/ lightly grazed (41%) or heavily grazed (29%) sites.
- In northern England, Calladine *et al*. (2002) reported that a significantly greater proportion of the black grouse females had broods at reduced grazing sites than on normally grazed reference sites (54% vs. 32%). The number of chicks per female was also higher at reduced grazing sites (1.41) relative to reference sites (0.82 chicks/female).
- In mountain grasslands of the Czech Republic, Pavel (2004) observed 72 and 13 bird nests in low and continuously grazed prairies respectively,. Nest loss was higher in continuously grazed (77%) than in low grazed (60%) pastures.
- Carroll *et al*. (2007) observed that dabbling duck (*Anas spp*.) nests were 1.6 to 3.7 times more abundant in rotational grazed than in ungrazed fields in California.
- Bowen and Kruse (1993) found that fields with autumn grazing had greater nest density (18.5 nests/100ha) of upland sandpiper (*Bartramia longicauda*) than fields with spring or season-long grazing (7.5 or 8.5 nests/100ha) in south central North Dakota. In the control (ungrazed)

and autumn & spring fields, nest densities were 15.9 and 11.6 nests/100ha, respectively (Table 9).

Table 9: Mean values of annual nest density (nests per 100ha) and nest success of upland sandpipers in south-central North Dakota, relative to grazing period (adapted from Bowen and Kruse, 1993).

Parameter	Control (ungrazed)	Autumn graze	Autumn - &- spring	Spring graze	Season-long
Nest density (/100ha)	15.9	18.5	11.6	7.5	8.5
Mayfield nest success (%)	81.8	58.8	37.0	63.5	27.7

Evidence of high occurrence of avian species of concern in pasture and rangeland:

- In Québec, Bélanger and Picard (1999) reported species of management concern, such as the sharp-tailed sparrow (*Ammodramus caudacutus*) and brown-headed cowbird (*Molothrus ater*) on moderately grazed prairie only, while the sedge wren (*Cistothorus platensis*) was observed only on ungrazed prairie. They observed a higher relative abundance of bobolink (*D. oryzivorus*) on moderately grazed (89% of observations) than on ungrazed (11% of observations) prairie, while the relative abundance of song sparrows (*Melospiza melodia*) was higher on ungrazed (84% of observations) than moderately grazed (16% of observations) prairie. No bobolink or song sparrows were observed on intensively grazed prairie. The relative abundance of savannah sparrows (*P. sandwichensis*) was higher on moderately grazed (78% of observations) than ungrazed (16% of observations) and intensively grazed (5% of observations) prairie (Bélanger and Picard, 1999).
- Also, Bélanger and Picard (1999) recorded the Northern pintail (*A. acuta*), a waterfowl of management concern, abundantly (26% of observations of the 6 species recorded) on moderately and ungrazed prairie.

Table 10: Summary of quantitative evidence of the efficacy of the pasture and range management/ grazing regimes/ grazing timing.

Quanti-tative measures	Study area/ Country	Idle/ low grazing	Moderate grazing	Intensive grazing	Rotational grazing	Source
Birds						
Species richness	North Dakota	27	26	22	--	Kantrud, 1981
	Québec, Canada	10	11	2	--	Bélanger and Picard, 1999
	Québec, Canada	6^{α}	6^{α}	1^{α}	--	Bélanger and Picard, 1999
Density (birds/ha)	Québec, Canada	10.4	11.7	1.6	--	Bélanger and Picard, 1999
Nest density (nest/ha)	Québec, Canada	$0.30 \pm 0.01^{\alpha}$	$0.50 \pm 0.01^{\alpha}$	$0.05 \pm 0.01^{\alpha}$	--	Bélanger and Picard, 1999
	Alberta, Canada	1.51^{β}	1.63^{β}	0.62^{β}	--	Stavne *et al.*, 2003
	Alberta, Canada	0.13^{μ}	0.22^{μ}	0.14^{μ}	--	Stavne *et al.*, 2003
	California, US	$0.59 \pm 0.34^{\lambda}$ $(0.39 \pm 0.32)^{a}$	--	--	$2.18 \pm 0.34^{\lambda}$ $(0.65 \pm 0.32)^{a}$	Carroll *et al.*, 2007
Number of nests	Czech Republic	72	--	13	--	Pavel, 2004
Mayfield nest success (%)	California, US	2.9^{λ}	--	--	5.3^{λ}	Carroll *et al.*, 2007
	Alberta, Canada	41^{π}	58^{π}	29^{π}	--	Stavne *et al.*, 2003
Nests loss (%)	Czech Republic	60	--	77	--	Pavel, 2004
	Czech Republic	$1,4^{b}$	--	$46,1^{b}$	--	Pavel, 2004

α : Waterfowl. β : Blackbird. μ : Shorebird . λ : Dabbling duck (Anas spp.).π : Waterbird.

a : In parenthesis are values from second year. b : Nest loss due to animal trampling.

4.5.2 Limitations/weaknesses:

- Extensive grazing has no positive impact on the diversity of small mammals. Schmidt *et al.* (2005) reported 5, 6 and 5 species/field respectively in no, low and high sheep grazing in Danish wet meadows.

4.6 Pasture plants:

- Fields with a high proportion of legumes are beneficial for biodiversity (for example, use by wildlife species).

4.7 Conservation of large wooded blocks:

- Provides cover, food, diversity, landscape heterogeneity and micro-climate for wildlife. Important for enhancing species richness for birds (including forest-dependent species, long-distance migrants, forest-interior species, endemic species and species at risk) and small mammals.

4.7.1 Birds

Evidence of high avian species richness in large wooded blocks:

- In a study of the effect of forest size on avian diversity in oak forest patches in rural New Jersey, Forman *et al*. (1976) reported that one large woodlot had more species than the same area subdivided into smaller woodlots (Table 11). They noted that a single 24 ha island contained slightly more species (24) than two 12 ha islands (~ 22) and more species than three 8 ha islands (~ 20). In the New Jersey Piedmont, the most valuable forests would be larger than 40 ha. Thirty-five percent of the species encountered in the forest islands were found only in forests of at least 3 ha, and 22% were only in forests of at least 8 ha.

Table 11: Effect of fragmentation on avian diversity in oak forest in rural New Jersey (adapted from Forman *et al*., 1976). (Numbers in parenthesis indicate the number of forest blocks and the area of each block).

Parameter	Size	Number of forest blocks		
		1 large block	2 blocks	3 blocks
Number of birds	24 ha	24 (1x24ha)	22 (2x10ha)	20 (3x7.5ha)
	10 ha	17 (1x10ha)	15 (2x4ha)	12 (3x3ha)
	4 ha	11 (1x4ha)	9 (2x2ha)	7 (3x1.2ha)

- McIntyre (1995) surveyed isolated forest patches (average size: 1.3 - 10.59 ha) and large, contiguous forest (control) patches (average size: 144.90 ha) in northwestern Georgia. She observed greater avian diversity in control patches (5.60 species/visit/patch) than in isolated patches (3.89 species/visit/patch). Contiguous forest supported more interior species (21) than the fragmented landscape (17). The yellow-rumped warbler, *Dendroica coronata*; Carolina Chickadee, *Poecile carolinensis*; and tufted titmouse, *Baeolophus bicolor* were the most abundant species in control patches (13.5, 11.6 and 12.9 individuals/patch, respectively). The abundance of these 3 species was low in fragmented forests (2.7, 1.5 and 2.3 individuals/patch, respectively).
- Blake and Karr (1984) reported that species richness within forest tracts in east-central Illinois was significantly correlated with area. The increase in total species richness primarily reflected an increased number of long-distance migrants in large forests. Many long-distance migrants were not present in small forest tracts. Forest-interior species, most of which (9 of 12) were long-distance migrants, were even more heavily dependent on forest area. Occurrence of these species in forests less than 24 ha was rare and irregular (Table 12).

Table 12: Bird species richness (long-distance migrants and forest interior species) on forest islands in east central Illinois (adapted from Blake and Karr, 1984).

Species richness	**Forest area (ha)**											
	1.8	**2.3**	**5.1**	**6.5**	**16.2**	**24**	**24**	**28**	**65**	**65**	**118**	**600**
Long-distance	4	6	6	8	9	10	10	14	15	16	17	21
Forest interior	0	1	0	1	2	3	4	6	7	7	8	12

- In Ottawa, Freemark and Merriam (1986) reported that an increase in log area (forest size) explained 50% of the increase in number of species per forest and 66% of the increase in number of bird pairs per forest.

- In southern Ontario, Tate (1998, quoted in ERIN Consulting Ltd., 2006), observed over 70% of the regional pool of forest bird species in 4 forest tracts ranging from 140 to 201ha. He reported 79 to 89% of the expected forest interior species in individual tracts between 100 - 200ha.

Evidence of reduced nest loss in large woodlot blocks:

- Herkert *et al*. (2003) reported lower nest predation of 4 bird species (grasshopper sparrow, *A. savannarum*; Henslow's sparrow, *A. henslowii*; eastern meadowlark, *Sturnella magna*; and dickcissel, *S. Americana*) in large (>1000 ha; 54 - 68% of all nests lost to predators) than in small (<100 ha; 78 - 84% lost to predators) prairie fragments in Illinois, Kansas, Missouri, North Dakota, and Oklahoma.

Evidence of unique avian species in large woodlot blocks:

- In northwestern Georgia, McIntyre (1995) observed 14 species unique to large continuous forest (American redstart, *Setophaga ruticilla*; great crested flycatcher, *Myiarchus crinitus*; Louisiana waterthrush, *Seiurus motacilla*; summer tanager, *Piranga rubra*; belted kingfisher, *Megaceryle alcyon*; gray catbird, *Dumetella carolinensis*; sharp-shinned hawk, *Accipiter striatus*; wood duck, *Aix sponsa*; black-throated green warbler, *Dendroica dominica*; Kentucky warbler, *Oporornis formosus*; northern parula, *Parula americana*; Canada goose, *Branta Canadensis*; red-shouldered hawk, *Buteo lineatus*; and wild turkey, *Meleagris gallopavo*). Of 23 interior species, 6 occurred solely in non-fragmented landscapes (American redstart, Louisiana waterthrush, summer tanager, sharp-shinned hawk, black-throated green warbler, and Kentucky warbler), while only 2 were found in fragmented landscapes.

4.7.2 Small mammals

Evidence of high population density and species diversity of small mammals:

- Estimating small mammal population density in forest patches in Australia, Bennett (1990) found that no species is likely to have a population of more than 50 individuals in forest patches of 5 ha or less, and only one species is likely to do so in patches of 20 ha in size. Even in a hypothetical patch, equal in size to the largest in the study area (82 ha), only three of the six native species are likely to be represented by populations of more than 50 individuals.
- Silva *et al*. (2005) found that species richness was most strongly influenced by patch area, reporting that the maintenance of forest patches 8 - 10 ha, and of forest cover within 400 m from them, is fundamental for the conservation of small mammals inhabiting agricultural landscapes on Prince Edward Island.
- In the Netherlands, 50 woodlots (0.55 - 13.78 ha) in an agricultural landscape were surveyed by Verboom and van Apeldoorn (1990). The presence of red squirrels was detected in 26 woodlots. The probability of occurrence was greater in larger woodlots and in woodlots with more coniferous trees. Both variables together explain 35% of the variance.

Evidence of high occurrence of native species of small mammal:

- Bolger *et al*. (1997) noted that forest fragments without native rodents were in general smaller (< 10ha) than fragments that did support rodent populations.
- Bennett (1990) indicated an increasing frequency of occurrence of native small mammals in successively larger size-classes of forest patches in Australia (Table 12). Also, native

mammals, being dependent upon forest vegetation, were less tolerant to forest fragmentation than introduced species.

- Bennett (1990) noted that 'core species' (those species that occurred with a frequency > 50%) displayed a consistent nested pattern of occurrence, with those present in the smaller size-classes also being present as core species in successively larger size-classes (Table 13).

Table 13: Number of small terrestrial mammals and number of common species in five size-classes of forest patch in Australia (adapted from Bennett, 1990).

Parameters	**Forest patch size (ha)**				
	< 2	**3 - 7**	**8 - 15**	**16 - 40**	**41 - 100**
Number of small mammals (out of 8 species recorded in the study area)	4	7	7	6	7
Number of core species (frequency of occurrence > 50%)	0	1	2	3	4

- Table 14 provides minimum patch area requirements for maintainenance of populations or communities of animal or plant species in the United States (adapted from Environmental Law Institute, 2003).

Table 14: Minimum patch area requirements reported in the scientific literature (adapted from Environmental Law Institute, 2003).

Patch area	**Finding**	**State**	**Citation**
Taxa: Birds			
≥ 1 ha	Minimum area requirement for breeding wood thrushes is 1 ha, although nesting success on fragments of that size would be extremely low.	MD, PA, VA, WV	Robbins *et al*., 1989
> 1 ha	Five species of chaparral-requiring birds were supported by census plots larger than 1 ha.	CA	Soulé *et al*., 1992
≥ 2 ha (seed-eating birds) ≥ 40 ha (insect-eating birds)	The minimum area point for insect-eating birds was estimated to be at least 40 ha, in contrast to 2 ha for seed-eating birds. This is interpreted as the habitat size needed to support a representative bird community.	NJ	Forman *et al*., 1976; Galli *et al*., 1976
≥ 5 ha (marsh)	Ten of 25 potential species did not occur in marshes less than 5 ha.	IA	Brown and Dinsmore, 1986

Table 14: Minimum patch area requirements reported in the scientific literature (adapted from Environmental Law Institute, 2003).

Patch area	Finding	State	Citation
≥ 5, ≥ 30, ≥ 40, ≥ 50, ≥ 55 ha	Estimates of minimal area requirements for 5 area-sensitive species ranged from 5 to 55 ha.	IL	Herkert, 1994
≥ 6.5 ha, 15.4 -32.6 ha	Black tern required 6.5 ha in heterogeneous landscapes, but required 15.4 - 32.6 ha in homogeneous landscapes.	SD	Naugle *et al.*, 1999
≥ 10 ha (forest)	Forest patches ≥ 10 ha had much greater bird diversity than patches < 3.25 ha.	GA	McIntyre, 1995
≥ 80 ha	In fragments < 80 ha, nesting success was low (43%), and nest predation was high (56%).	PA	Hoover *et al.*, 1995
< 20 ha, >2,500 ha	Based on a study of cowbird parasitism and nest predation on 3 large forest tracts (1,100 – 2,200 ha) in southern Illinois, maintaining wood thrush (*Hylocichla mustelina*) populations in the Midwest might require > 2,500 ha reserves. In the east even a small woodlot (< 20ha) may sustain a population.	IL	Trine, 1998
Taxa: mammals			
> 1 ha	Control plots larger than 1 ha supported most species of rodents.	CA	Soulé *et al.*, 1992
≥ 5 ha	Cottontails may become vulnerable to extinction if large patches ≥ 5.0 ha are not maintained.	NH	Barbour and Litvaitis, 1993
≥ 10 ha	Fragments < 10 ha did not support populations of native rodents	CA	Bolger *et al.*, 1997
≥ 900 ha (9 km^2)	More than 80% of bear sightings occurred in blocks of undisturbed habitat > 9 km^2.	MT	Mace *et al.*, 1996
≥ 2800 ha (28 km^2)	Grizzly bears (*Ursus arctos horribilis*) in the Yellowstone ecosystem should have security blocks 28 km^2 in size.	MT, ID, WY	Mattson, 1990
≥ 220,000 ha (2,200 km^2)	Model predicts low extinction risk for cougars *Puma concolor* in areas as small as 2,200 km^2, but an increasing risk with little immigration.	CA	Beier, 1993
Taxa: Fishes			
> 2,500 ha	Suggests patch size (as defined by watersheds above 1,600 m elevation) influences the occurrence of bull trout. Predicted probability of occurrence is 0.5 for patches larger than 2,500 ha	ID	Rieman and McIntyre, 1995
Taxa: Invertebrates			
≥ .0004 ha (4m^2)	Vegetated patches > 4m^2, as well as open areas, were important to the distribution and abundance of carabid beetles	OH	Crist and Ahern, 1999
≥ 1 ha	Observed minimum patch size for occupancy by populations of 3 butterfly species is 1 ha.	model	Hanski, 1994

Table 14: Minimum patch area requirements reported in the scientific literature (adapted from Environmental Law Institute, 2003).

Patch area	Finding	State	Citation
Taxa: Plants			
≥ 2 ha (5 acres)	Minimum area point for tree communities was estimated as approximately 2 ha.	NJ	Elfstrom, 1974
≥ 10, ≥ 100 ha	Conserving an old-growth forest might require 10 ha if surrounded by comparable forest, but 100 ha if surrounded by a clearcut.	—	Harris, 1984

4.8 Retention of connectivity:

- Corridors, fencerows/shelterbelts, small isolated ponds, canopy coverage, paddock trees, snags and dead trees provide cover, landscape heterogeneity, suitable micro-habitat and connectivity for birds, small mammals and invertebrates.
- Important for juvenile dispersal and movement between activity centers (ERIN Consulting Ltd., 2006).
- Cavity-nesting birds often comprise 20 - 40% of the birds in a forest. Shalaway (1985) recommended leaving a minimum of 1 or 2 large snags per km of fencerow. He reported American kestrel (*Falco sparverius*), northern flicker (*Colaptes auratus*), red-billed woodpecker (*Melanerpes carolinus*) and European starling (*Sturnus vulgaris*) to be nesting only in prominent snags in herbaceous and shrubby fencerows in Michigan. Red-headed woodpecker (*M. erythrocephalus*), eastern bluebird (*Sialia sialis*), and Bewick's wren (*Thryomanes bewickii*) nested in fencerow snags in Oklahoma and Pennsylvania.

4.8.1 Birds

Evidence of high avian movement in corridors:

- Haas (1995) monitored breeding bird movements between shelterbelts in agricultural landscapes in south central North Dakota. For robins (*Turdus migratorius*), an average of 2.5

dispersal events were observed between each pair of sites connected by a wooded corridor, but only 0.17 dispersal events between each pair of unconnected sites. He noted 15 times more movement occurring frequently between connected pairs of sites than between unconnected pairs.

- In Poland, Dmowski and Kozakiewicz (1990) studied movements of passerine birds from a pine forest to a lake littoral zone (reeds), separated by a meadow on one area (discontinuous), and a shrub strip in another area (continuous). They found that the total number of non-littoral birds visiting the reed zone was twice as high in the continuous area as in the discontinuous area.

4.8.2 Small mammals

Evidence of high diversity of small mammals in well connected forest patches:

- Of 15 small mammal species known to occur in Prince Edward Island, Silva *et al*. (2005) recorded nine in woody patches in agricultural landscape. Species richness was similar in continuous forest, large forests patches, and small, relatively well connected forest patches at some location on Prince Edward Island (Table 15). The eastern chipmunk (*Tamias striatus*) was the most frequently captured species (43 % of all individuals), followed by the deer mouse (*Peromyscus maniculatus*; 18% of all individuals).

Table 15: Number of individuals and species richness of small mammals on 12 sites within four agricultural landscapes on Prince Edward Island (adapted from Silva *et al*., 2005).

Forest-agriculture category	Location	Number of individuals	Species richness	Species diversity[1]
Continuous forest	1	44	6	2.321
Large forest patches within an agricultural matrix	1	30	6	2.153
	2	35	8	2.549
Small and relatively well connected	1	46	8	2.475

Table 15: Number of individuals and species richness of small mammals on 12 sites within four agricultural landscapes on Prince Edward Island (adapted from Silva *et al*., 2005).

Forest-agriculture category	Location	Number of individuals	Species richness	Species diversity[1]
forest patches	2	16	4	1.749
	3	7	3	1.149
	4	15	4	1.640
	5	7	4	1.842
	6	9	2	0.918
Isolated forest patches within an agricultural matrix	1	20	3	0.884
	2	62	7	2.346
	3	50	5	1.323

[1] *: Species diversity was calculated using the Shannon–Weiner index of diversity.*

Evidence of high movement of small mammals in corridors:

- In a study of the role of habitat corridors, Bennett (1990) found that 7 of 8 recorded small mammals used corridors between fragmented forests in Australia.

4.8.3 Invertebrates

Evidence of high abundance of invertebrates:

- In Sydney, Australia, Oliver *et al*. (2006) studied the contribution of paddock trees to the conservation of terrestrial invertebrate biodiversity within grazed native pastures. They recorded 15 major arthropod groups under trees (1,042 observations) and 12 (729 observations) in open paddock, respectively. Isopoda (slaters), Blattodea (cockroaches) and Psocoptera (booklice) were only recorded under trees. These 3 major groups were absent in open paddock. The numbers and abundance of Formicidae morphospecies were higher in the treed paddock (32 morphospecies, 744 observations) than in the open paddock (16 morphospecies, 496 observations).

4.8.4 Amphibians and fishes

Evidence of high species richness of amphibians and fishes in small ponds:

- Knutson *et al*. (2004) found that small agricultural ponds in southeastern Minnesota provided breeding habitat for at least 10 species of amphibians (tiger salamander, *Ambystoma tigrinum*; Larval blue-spotted salamander, *A. laterale*; American toad, *Bufo americanus*; gray treefrog, *Hyla versicolor*; western chorus frog, *Pseudacris triseriata*; spring peeper, *P. crucifer*; green frog, *Rana clamitans*; wood frog, *R. sylvatica*; northern leopard frog, *R. pipiens*; and pickerel frog, *R. palustris*) The northern leopard frog (*R. pipiens*) is of conservation concern. Fish species commonly collected included the brook stickleback (*Culea inconstans*), creek chub (*Semotilus atromaculatus*), green sunfish (*Lepomis cyanellus*), and central mud minnow (*Umbra limi*).

4.8.5 Limitations:

- Presence of corridors did not affect foray rate of male hooded warblers between fragmented forest (Norris and Stutchbury, 2001) or movements of adult brown thrashers in patchy wooded habitat (Haas, 1995).

4.9 Shelterbelt establishment:

- Widely developed in western Canada (Great Plains e.g., Manitoba, Alberta). Contribute substantially to the avifauna population of the northern Great Plains. Used by wildlife (birds, mammals, insects) for cover, corridors, food, nesting, protection and refuge.

4.9.1 Birds

Evidence of high avian species richness in shelterbelts:

- Johnson and Beck (1988) reported at least 108 species of birds known to use shelterbelt habitats. In agricultural areas, 29 species of birds benefit substantially, 37 moderately and 42 very little or accidentally.

- Johnson and Beck (1988) reported at least 57 species of birds using shelterbelts during the breeding season.
- In North Dakota, 64 species of birds used shelterbelts during the breeding season and a further 68 species of migratory birds utilized shelterbelts (Schroeder, 1986, quoted in ERIN Consulting Ltd., 2006).
- Schroeder *et al*. (1992) observed 62 breeding bird species on 34 shelterbelts in Kansas (Great Plains) during a 3 year study. Only 3 species that are not native to North America were found in these shelterbelts (European starling, *Sturnus vulgaris*; house sparrow, *Passer domesticus*; and ring-necked pheasant, *Phasianus colchicus*). Bird species richness ranged from 7, in the smallest shelterbelt (0.03 ha), to 47, in the largest shelterbelt (10.4ha). Cavity-nesting bird species comprised 24% of the overall bird species richness, and the richness of cavity nesters was highly correlated with snag density.
- Comparing major types of habitat in the Platte River Valley of Nebraska, Faanes and Lingle (1995) found that maximal breeding densities occurred in shelterbelts (Table 16). They also reported that shelterbelts were used by 26 species, of which 22 were considered nesting species. Eleven species reached their highest density in shelterbelts.

Table 16: Population densities (pairs/km^2) and diversity of breeding species among major habitat types in the Platte River Valley (adapted from Faanes and Lingle, 1995).

Habitats	Density	Number of Species	Diversity	Equitability
Shelterbelt	698.8	24	4.263	1.341
Residential	631.2	23	3.499	1.116
Lowland forest	561.6	50	4.506	1.152
Wetlands	532.6	18	3.494	1.209
River channel Island	522.8	39	4.052	1.106
Upland native Prairie	110.6	30	3.609	1.061

Table 16: Population densities (pairs/km^2) and diversity of breeding species among major habitat types in the Platte River Valley (adapted from Faanes and Lingle, 1995).

Habitats	Density	Number of Species	Diversity	Equitability
Wet meadow	110.3	20	3.508	1.171
Alfalfa	101.2	14	3.004	1.138
Corn	63.0	3	1.509	1.374
Domestic hayland	58.6	7	2.542	1.306
Wheat	47.6	12	2.876	1.157

Evidence of high nest density:

- Of 57 species of bird using shelterbelts during the breeding season, 28 are known to have nested in them at densities from 0.3 - 186 nests/ha (Johnson and Beck, 1988).
- Yahner (1982) reported 93.4 nests/ha in shelterbelts in Minnesota.

4.9.2 Mammals

Evidence of high species richness of mammals in shelterbelts:

- Johnson and Beck (1988) reported at least 28 species of mammal known to use shelterbelt habitats.
- Yahner (1983) reported 11 small mammals in farmstead shelterbelts in Minnesota. The most abundant captured species were the northern short-tail shrew, *Blarina brevicauda* (33.2% of total individuals); white-footed mouse, *Peromyscus leucopus* (31.2% of total individuals); meadow vole, Microtus pennsylvanicus (10.3% of total individuals); red-backed vole, *Clethrionomys gapperi* (10.1 % of total individuals); and Cinereus shrew, *Sorex cinereus* (7.7% of total individuals).

4.9.3 Limitations:

- Establishment of shelterbelts may threaten grassland birds requiring large tracts of unfragmented habitat. Samson (1980) noted that upland sandpiper (*Bartramia longicauda*), Henslow's sparrow (*A. henslowii*) and greater prairie-chicken (*Tympanuchus cupido*) require large expanses of prairie.

4.10 Conservation tillage:

- Increases diversity and abundance of soil fauna (arthropods, earthworms, and insects), insect predators (birds), and aquatic species (amphibians, fishes). Cultivated soils are generally regarded as having a reduced biodiversity compared to uncultivated soils (Dimmick and Minser, 1988; Benckiser, 1997; Holland, 2004).

4.10.1 Birds

Evidence of high avian diversity and abundance in conservation tillage:

- Cowan (1993; cited by ERIN Consulting Ltd., 2006) documented 27 species of birds and 16 mammals utilizing direct seeding crops in Manitoba.
- Warburton and Klimstra (1984) observed nearly three times more birds in no-till than conventionally tilled farms in southern Illinois. Common birds recorded in no-till field included red-winged blackbirds, *Agelaius phoeniceus* (37.7% of observations); mourning doves, *Zenaida macroura* (15.1% of observations); field sparrows, *Spizella pusilla* (10.2% of observations); indigo buntings, *Passerina cyanea* (7.5% of observations); and bobwhite quail *Colinus virginianus* (7.2% of observations).
- Castrale (1985) reported 32% more species of birds using no-till fields in southern Indiana, as compared to conventional tillage.
- Field *et al*. (2007) compared bird use of conservation tillage and conventionally ploughed fields in western Hungary. They recorded, in total, 1,572 birds on conservation tillage plots

and 256 birds on ploughed plots.

- In the mixed grass ecoregion of the Prairie Ecozone in Alberta, Martin and Forsyth (2003) studied the occurrence of songbirds in prairie farmland under conventional versus minimum tillage regimes. They observed a greater total number of birds in minimum (4.65 - 4.76 birds/100-m-radius) versus conventional tillage (3.46 - 3.88 birds/100-m-radius).

Evidence of high nesting species, nest density and nest success:

- Basore *et al*. (1986) studied non-tilled and tilled cropland in southwestern Iowa and observed 12 bird species nesting in no-till fields. Only 3 species nested in tilled fields. Overall nest density was 9 times greater in no-till.
- Lokemoen and Beiser (1997) reported a higher number of nesting species and nest density in minimum-tillage (1.9 species/field and 1.2 nests/10ha, respectively) than conventional tillage (0.9 species/field and 0.5 nests/10ha respectively) fields in the Prairie Pothole Region of Southeastern North Dakota.
- Of 12 bobwhite (*Colinus virginianus*) nests located in agricultural areas in western Tennessee, 11 (92%) were in no-till fields and 1 in a conventional field (Minser and Dimmick, 1988).
- In the Prairie Pothole Region in southwestern Manitoba, Cowan (1982) found that duck nest density was 1.4 - 1.5 times greater in no-till fields, and nest success was 42%, versus 13% on conventionally tilled farms. They estimated an annual potential of 25 broods/260 ha on zero tillage farms compared with only 7 broods on conventional farms.

Evidence of high unique avian species in conservation tillage:

- In Illinois, Warburton and Klimstra (1984) reported 6 species unique to no-till field (song sparrow, *Melospiza melodia*; dickcissel, *Spiza Americana*; lark sparrow, *Chondestes grammacus*; common yellowthroat, *Geothlypis trichas*; ruby-throated hummingbird, *Arehilochus colubris*; and American goldfinch, *Carduelis tristis*).

4.10.2 Small mammals

Evidence of high diversity of small mammals:

- Cowan (1993, as cited by ERIN Consulting Ltd., 2006) documented 16 mammals utilizing direct seeding crops in Manitoba.
- In Illinois, Warburton and Klimstra (1984) noted that deer mice (*Peromyscus maniculatus*) comprised 73% of total captures in the conventionally field and 93% in the no-till field.

4.10.3 Soil fauna

Evidence of high diversity, density and abundance of soil fauna in conservation tillage:

- House (1985) observed higher soil arthropod and earthworm abundances under no-tillage (total mean abundance of macro-arthropods: 94.2; mean abundance of earthworms: 1,706) than conventional tillage (total mean abundance of macro-arthropods: 15.6; mean abundance of earthworms: 414) practices on an Experimental Area near Athens, Georgia.
- Robertson *et al*. (1994) studied soil-dwelling invertebrates in a semi-arid agro-ecosystem in North-eastern Australia. They reported that the highest population abundances of detritivores and predators (537 and 143 respectively) occurred in zero-tilled fields, while conventional cultivation displayed the lowest abundances (113 detritivores and 78 predators).
- Kladivko *et al*. (1997) evaluated earthworm populations and species distribution under no-till and conventional tillage on farmers' fields in Indiana and Illinois. Of the 14 paired study

sites, 8 had higher earthworm populations under no-till than conventional. The mean number of shallow-dwelling earthworms was estimated at 137.9/m^2 under no-till and 64.3/m^2 under conventional tillage. Also, evidence of *Lumbricus terrestris* activity was higher under no-till (presence of *L. terrestris* on 9 of the 14 sites) than conventional tillage (presence of *L. terrestris* only on 3 of the 14 sites).

- Chan (2001) indicated that earthworm populations under no-tillage can be 2 - 9 times greater than under conventional tillage. Edwards *et al*. (1995), quoted by USDA (2001), reported up to 30 times more earthworms in no-till systems than in plowed fields.
- In a Georgia experiment, no-till fields had an average of 967 earthworms/m^2 compared to 149 /m^2 in conventionally tilled fields (Coleman and Crossley, 1996, quoted by USDA, 2001).
- Blumberg and Crossley (1983) reported nearly 50% more arthropod individuals captured in no-till than in conventional till on Research Area near Athens.
- In the Great Plains, though total bacterial numbers were not affected by tillage, Elliott *et al*. (1988), quoted by Kennedy (1999), found elevated numbers of fungi, protozoa and several bacterial and fungal feeding groups in no-till grass compared to a 15-year-tilled field (78 vs. 34 ind./mg; 4.3 vs. 3.7 x104 ind./g; 26 vs. 16 ind./g; 47 vs. 35 ind./g; 1.3 vs.1.0 ind./g, respectively). Gewin *et al*. (1999), quoted by Kennedy (1999), indicated that no-till practices maintained the microbial community structure most closely to those found in ten years of undisturbed grass.

4.10.4 Benthic invertebrates

Evidence of high diversity and density of benthic invertebrates:

- In Ontario, Barton and Farmer (1997) observed high benthic invertebrate diversity in basins under conservation tillage (135 taxa from Kintore Streams sample and 62 taxa from the Essex Streams sample) than conventional tillage (130 taxa from Kintore Streams sample and 39 taxa from the Essex Streams sample).

Table 17: Summary of quantitative evidence for the efficacy of conservation tillage.

Quantitative measure	Study area/ Country	No-till fields[a]	Conventional tillage fields	Source
Birds				
Number of breeding species	Southwestern Iowa, US	12	3	Basore *et al*., 1986
Mean number of breeding species	Prairie Pothole Region, North Dakota	1.9 ± 0.22[a]	0.9 ± 0.18	Lokemoen and Beiser, 1997
Abundance (ind./100-m-radius)	Prairie Ecozone, Alberta, Canada	4.76 ± 0.15[a]	3.88 ± 0.14	Martin and Forsyth, 2003
Abundance (ind./field)	Southern Illinois, US	265	93	Warburton and Klimstra, 1984
	Western Hungary	1572	256	Field *et al*., 2007
Nest density (/100ha)	Southwestern Iowa, US	36	4	Basore *et al*., 1986
	Prairie Pothole Region, North Dakota	12 ± 0.3[a]	5 ± 0.2	Lokemoen and Beiser, 1997
	Prairie Pothole Region, Manitoba	25[α]	20[α]	Cowan, 1982
Nest success (%)	Prairie Pothole Region, Manitoba	42[α]	13[α]	Cowan, 1982
	Prairie Pothole Region, North Dakota	18[βa]	13[β]	Lokemoen and Beiser, 1997
Small mammals				
Species richness	Manitoba, Canada	16	--	Cowan, 1993
Relative abundance (%)	Southern Illinois, US	93[μ]	75[μ]	Warburton and Klimstra, 1984
Soil invertebrates				
Number of orders	Southern Illinois, US	16	13	Warburton and Klimstra, 1984
Number of families	Southern Illinois, US	65	51	Warburton and Klimstra, 1984

Table 17: Summary of quantitative evidence for the efficacy of conservation tillage.

Quantitative measure	Study area/ Country	No-till fields[a]	Conventional tillage fields	Source
Number of genera	Southern Illinois, US	90	64	Warburton and Klimstra, 1984
Number of species	Southern Illinois, US	97	97	Warburton and Klimstra, 1984
Abundance of earthworms (ind.m^{-2})	Ontario, Canada	37.5	13.2	Reeleder *et al*., 2006
	Indiana and Illinois, US	137.9^{γ}	64.3^{γ}	Kladivko *et al*., 1997
	Indiana and Illinois, US	44.5^{θ}	26.6^{θ}	Kladivko *et al*., 1997
	Holland	270	90	Boone *et al*., 1976
	England	137	67	Gerard and Hay, 1979
	Athens, Georgia	$1{,}706^{\lambda}$	414^{λ}	House, 1985
	Athens, Georgia	913^{δ}	213^{δ}	House, 1985
	Georgia	967	149	Coleman and Crossley,1996 quoted by USDA, 2001
	South Australia	342	130	Rovira *et al*., 1987
	Victoria, Australia	275	117	Haines and Uren, 1990
	North Dakota, US	266	48	Deibert *et al*., 1991
	New Zealand	467	52	Springett, 1992
	New Zealand	250	175	Francis and Knight, 1993
Presence of *L. terrestris* middens (%)	Indiana and Illinois, US	64.3	21.4	Kladivko *et al*., 1997
Abundance of arthropods (ind./506m^2)	Athens, Georgia	275	175	Blumberg and Crossley, 1983
Number of arthropod species (/506m^2)	Athens, Georgia	90	62	Blumberg and Crossley, 1983
Density of ground beetles (carabidae: coleoptera) (ind.m^{-2})	Athens, Georgia	40.8	6.8	House, 1985
Density of spiders (araneae) (ind.m^{-2})	Athens, Georgia	16.4	2.2	House, 1985
Density of other arthropods (ind.m^{-2})	Athens, Georgia	37.0	6.6	House, 1985

Table 17: Summary of quantitative evidence for the efficacy of conservation tillage.

Quantitative measure	Study area/ Country	No-till fields[a]	Conventional tillage fields	Source
Density of microarthropods (acarina, collembolan and insects) (ind.m^{-2})	Athens, Georgia	107,846	47,714	House, 1985
Density of herbivores (ind.m^{-2})	North-eastern Australia	179	140	Robertson *et al*., 1994
Density of detritivores (ind.m^{-2})	North-eastern Australia	537	113	Robertson *et al*., 1994
Density of predators (ind.m^{-2})	North-eastern Australia	143	78	Robertson *et al*., 1994
Benthic invertebrates				
Mean number of taxa	Ontario, Canada	197	169	Barton and Farmer, 1997

a *: Minimum / reduced tillage fields.*

$^{\alpha}$ *: Duck species (blue-winged teal, mallard, pintail, shoveler, gadwall and lesser scaup).*

$^{\beta}$ *: Passerine birds.*

$^{\gamma}$*: Including adults and juveniles*

$^{\lambda}$*: Including adults, juveniles and cocoons*

$^{\mu}$ *: Deer mouse.*

$^{\theta}$ *: Adults.*

$^{\delta}$ *: Adults.*

4.10.5 Limitations:

- Castrale (1985) found deer mice (*Peromyscus spp.*) to exhibit a negative relationship with residue amounts.
- Basore *et al*. (1987) reported no significant difference in the number of arthropods collected in no-till (1,307 individuals/field) and tilled corn (1,963 individuals/field) fields in southwestern Iowa. They documented that arthropod availability for pheasant broods did not differ in no-till and conventional tillage fields in southwestern Iowa.

4.11 Strip cropping:

- Provides wildlife cover and food.
- Attracts insects and insectivorous birds.

4.11.1 Birds

Evidence of high avian species richness, density and abundance:

- Stallman and Best (1996) observed 35 bird species using a strip intercropping system in northeastern Iowa. The total number of species observed in the strip was greater than counts recorded for other row crop fields in Iowa, Indiana, and Illinois (range: 14 - 31 species) (Warburton and Klimstra, 1984; Castrale 1985; Best *et al*., 1990; Bryan and Best 1991; Camp and Best 1993). Stallman and Best (1996) estimated abundance in the strips at 107.8 birds/census count/100ha.
- On north-central Florida farmlands, Jones and Sieving (2006) reported that intercropping sunflower (*Helianthus annuus*) promoted significantly greater mean abundance of insectivorous birds than did control plots. Additionally, both mean numbers of individual birds foraging on insect prey, and mean insect-foraging time per hour were significantly greater in crops with sunflower rows than without.

Evidence of high avian nest density in strip cover:

- Good and Dambach (1943) studied the effects of land use practices on breeding bird population in Ohio. Analysis of five years of data revealed two to three times greater avian density in strip crop than in normal fields. The grasshopper sparrow, *Ammodramus savannarum* and vesper sparrow, *Pooecetes gramineus* were the most abundant species (91 vs. 48 and 31 vs. 8 breeding pairs/100 acres in field strips vs. conventional cropland, respectively).
- Basore *et al.* (1986) reported a higher nest density in strip cover (400 nests/100ha) than on no-till (36 nests/100ha) and tilled corn (4 nests/100ha) fields in southwestern Iowa.

4.11.2 Soil fauna

Evidence of high diversity and abundance of soil fauna:

- Kladivko (1993) observed higher earthworm populations in a Bluegrass-Clover alleyway (400 individuals/m^2) than in continuous corn plowed fields (10 individuals/m^2) in Indiana and Illinois.

Table 18: Summary of quantitative evidence of the efficacy of strip cropping.

Quantitative measures	Study area/ Country	Strip cropping / intercropping	Conventional cropland	Source
Birds				
Species richness	Northeastern Iowa, US	35	14 - 31	Stallman and Best, 1996
Density (birds/ha)	North-central Florida, US	6	0.8	Jones and Sieving, 2006
Abundance (breeding pairs /100 acres)	Ohio, US	31	22	Good and Dambach, 1943
Nest density (/100ha)	Southwestern, Iowa, US	400	4	Basore *et al.*, 1986
Earthworms				
Abundance (ind./m^2)	Indiana and Illinois, US	400	10	Kladivko, 1993

4.12 Crop rotations:

- Create cover for wildlife and increase insect, earthworm and bird populations.
- Maintain soil fertility, particularly nitrogen levels.

4.12.1 Birds

Evidence of high avian abundance and species richness:

- Beecher *et al*. (2002) compared bird populations in organic (using crop rotation) and nonorganic (use of fertilizers and herbicides) sites in east-central Nebraska. They recorded greater species richness in organic (51 bird species) than in nonorganic (39 bird species) sites. On average, bird abundance on organic sites was 2.6 times higher than on nonorganic sites, and mean species richness per visit was 2.0 times greater.

Evidence of high nesting species and nest density in crop rotation:

- Lokemoen and Beiser (1997) reported a higher number of breeding species and increased nest density in organic farming using crop rotation with legumes (1.6 species/field and 1.0 nests/10ha, respectively) than conventional tillage crops (0.9 species/field and 0.5 nests/10ha, respectively) in the Prairie Pothole Region of Southeastern North Dakota.

Evidence of high occurrence of native species and species of concern:

- Of the 39 bird species with sufficient relevent data, Beecher *et al*. (2002) reported that 13 speciest are often found in organic farmland. These include 5 common native species (American robin, *Turdus migratorius*; barn swallow, *Hirundo rustica*; eastern kingbird, *Tyrannus tyrannus*; mourning dove, *Zenaida macroura*; and Northern rough-winged swallow, *Stelgidopteryx serripennis*); 2 nest predators (blue jay, *Cyanocitta cristata*; and common grackle, *Quiscalus quiscula*); 4 species of conservation concern (dickcissel, *Spiza americana*; indigo bunting, *Passerina cyanea*; lark sparrow, *Chondestes grammacus*; and vesper sparrow, *Pooecetes gramineus*); and 2 species that have adapted to agriculture, relatively stabilizing their numbers (Baltimore oriole, *Icterus galbula*; and upland sandpiper, *Bartramia longicauda*).

4.12.2 Earthworms

Evidence of high earthworm abundance in grass-legume rotation:

- Kladivko (1993) counted more earthworm populations in a corn-soybean rotation (56 and

167 individuals/m^2 under plow and no-till farming respectively) than in continuous corn field (10 and 20 individuals/m^2 under plow and no-till farming respectively) and in continuous soybeans field (60 and 140 individuals/m^2 under plow and no-till farming respectively) in Indiana and Illinois.

Table 19: Summary of quantitative evidence of the efficacy of crop rotation.

Quantitative measure	Study area/ Country	Crop rotation	Continuous farming	Source
Birds				
Species richness	East-central Nebraska, US	51	39	Beecher *et al.*, 2002
Mean number of breeding species (/field)	Prairie Pothole Region, North Dakota	1.6	0.9	Lokemoen and Beiser, 1997
Nest density (/10ha)	Prairie Pothole Region, North Dakota	1.0	0.5	Lokemoen and Beiser, 1997
Earthworms				
Abundance (ind./m^2)	Indiana and Illinois, US	167	20	Kladivko, 1993

4.13 Cover crops:

- Combined with crop rotation.
- Provides nesting habitat for birds, and food for wildlife.

4.13.1 Birds

Evidence of high avian nest density in cover crops:

- In Alberta, Soetaert (2005, quoted in ERIN Consulting Ltd., 2006), reported that fall seeded crops support on average 1 waterfall nest for every 10 to 15 acres, whereas conventional crops have only 1 nest for every 150 to 200 acres.

4.13.2 Soil fauna

Evidence of high species diversity and density of soil fauna:

- Boyer *et al*. (2001) assessed the effects of cover crops on soil invertebrate populations (macrofauna) in Réunion, Indian Ocean. They noted that macrofauna density was 16 times greater, and biomass 15 times greater under cover crops, as compared to bare soil. Also, they recorded higher diversity under cover crops (14 taxa) than under bare soil (6 taxa).
- Reeleder *et al*. (2006) found significantly greater populations under crop cover (rye cover, 33.1 worms.m^{-2}) than in no cover (12.8 worms.m^{-2}) plots on a research farm in Ontario.

Table 20: Summary of quantitative evidence of the efficacy of cover crops.

Quantitative measure	Study area/ Country	Cover crop	Bare soil field	Source
Birds				
Nest density (/100acres)	Alberta, Canada	6.7 - 10.0$^{\alpha}$	0.5 - 0.7$^{\alpha}$	Soetaert, 2005
Soil invertebrates				
Density (ind.m^{-2})	Indian Ocean	1015	65	Boyer *et al*., 2001
Biomass (g.m^{-2})	Indian Ocean	65	4	Boyer *et al*., 2001
Earthworm abundance (ind.m^{-2})	Ontario, Canada	33.1	12.8	Reeleder *et al*., 2006
Micro-arthropods (Mites *Acari*) abundance (indx10^3.m^{-2})	Ontario, Canada	60	30	Reeleder *et al*., 2006

$^{\alpha}$ *: Waterfowl.*

4.14 Grassed waterways:

- Create habitat for birds. Function as corridors.
- Can be applied in any ecoregion where agriculture activities take place (Young, 2005).

4.14.1 Birds

Evidence of high avian species richness and nest density in grassed waterways:

- Bryan and Best (1991) reported 48 species using smooth brome grass waterways during the breeding season in central Iowa, compared with only 14 species using adjacent corn and soybean fields. Total bird abundance was also higher, averaging 2,198 birds observed/census/247acres (100 ha) in waterways, compared with 682 in crop fields.
- Bryan and Best (1994) observed high total nest density in waterways (1,104 nests/100ha for the 10 most common bird species) relative to strip cover (383 nests/100ha reported by Basore *et al*., 1986 for 14 species) in similar agricultural areas in central Iowa. Nest densities in waterways were also higher than those in no-till (20 nests/100ha) and tilled (5 nests/100ha) crop fields, reported by Basore *et al*., 1986. Red-winged blackbird (*Agelaius phoeniceus*) and dickcissel (*Spiza americana*) nests were most common of the 10 bird species that nested in the waterways (566 and 276 nests/100 ha, respectively).

Table 21: Summary of quantitative evidence of the efficacy of grassed waterways.

Quantitative measure	**Study area/ Country**	**Grassed waterways**	**Cropland**	**Strip cover**	**Source**
Birds					
Number of breeding species	Central Iowa, US	48	14	--	Bryan and Best, 1991
Abundance (/census/100ha)	Central Iowa, US	2,198	682	--	Bryan and Best, 1991
Nest density (/100ha)	Central Iowa, US	1,104	5 - 20[a]	383	Bryan and Best, 1994

[a] *: Densities in tilled and no-till crop fields.*

4.15 Vegetative filter strips:

- Serve as wildlife corridors; create habitat for breeding birds.

4.15.1 Birds

Evidence of high avian species richness and abundance:

- Kammin (2003), quoted by Brady (2007), studied 92 filter strips in central Illinois and reported 89 species of birds using them. Seventeen (17) species nested in filter strips.
- Smith et al. (2005) observed greater wintering densities of song sparrow, *Melospiza melodia* (30.96 ± 4.19 vs. 8.29 ± 2.58 birds/ha along grassland habitat); savannah sparrow, *Passerculus sandwichensis* (14.95 ± 6.14 vs. 4.74 ± 1.45 birds/ha along grassland habitat); and other sparrows (78.20 ± 12.99 vs. 19.36 ± 7.96 birds/ha along grassland habitat) in bordered (6.1 m wide strip) than in non-bordered agricultural field edges on a private farm in Mississippi. Most field sparrow (92.6%) and swamp sparrow (91.8%) observations occurred along bordered transects.

4.15.2 Spiders

Evidence of high species richness of spiders, *Araneae*:

- Maelfait and De Keer (1990) observed higher spider species richness in the grassy border zone of intensively grazed pasture (30.4 species/pitfall) than in the middle of pastures (18.0 species/pitfall) on an experimental farm in eastern Ghent, Belgium.

4.15.3 Limitations/weaknesses:

- Smith et al. (2005) noted that song sparrow (*M. melodia*) and savannah sparrow (*P. sandwichensis*) densities did not differ between bordered and non-bordered transects adjacent to wooded habitats in agricultural landscapes in Mississippi. Also, no difference in the densities of other sparrows were observed between bordered and non-bordered transects adjacent to wooded strip (<30 m wide).

Table 22: Summary of quantitative evidence of the efficacy of vegetative filter strips.

Quantitative measure	Study area/ Country	Vegetative filter strips	Control field	Source
Birds				
Number of species	Central Illinois, US	89	--	Kammin (2003, quoted by Brady, 2007)
Number of nesting species	Central Illinois, US	17	--	Kammin (2003, quoted by Brady, 2007)
Spiders				
Species richness (/pitfall)	Eastern Ghent, Belgium.	30.4	18.8	Maelfait and De Keer, 1900

4.16 Wooded fencerows:

- Provides winter and nesting habitat for birds.
- Provides perches for birds, cover and food.

4.16.1 Birds

Evidence of high avian species richness and abundance density:

- Best (1983) censused three fencerow vegetation types in Iowa. He observed 36 bird species in fencerow with continuous trees and shrubs, 23 in herbaceous fencerow with scattered trees and shrubs and 9 in herbaceous fencerow. Bird density was nearly 5 times greater in woody fencerow than in herbaceous fencerow. Five (5) species of warblers were found only in fencerow with continuous trees and shrubs.
- In the agricultural landscape along the Boyer River watershed in Québec, Deschênes *et al*. (2003) reported higher avian diversity in wooded (44 species) and tall shrubby strips (29 species) than in grassy (12 species) and non-grassy (9 species) riparian strips.
- Jobin *et al*. (2001) studied bird use of field margins in intensive farmlands of southern Québec. They observed more bird species in hedgerows with trees and shrubs growing

naturally between cultivated fields (39), and in planted windbreaks with mainly coniferous trees (25), than in herbaceous field margins (19). Thirteen (13) species, generally insectivorous, were found in hedgerows only.

Evidence of high nesting species and nest density in wooded fencerows:

- Shalaway (1985) reported 16 bird species nesting in herbaceous and woody fencerows in south central Michigan. Eight (8) species nested only in shrubby or woody fencerow. They noted that nest density was 10 times greater in fencerows (19 nests/km/year or 43.5 nests/ha) than in natural, deciduous shrub habitat in Indiana (4.2 nests/ha reported by Nolan, 1963 quoted by Shalaway, 1985).

Evidence of high occurrence of unique bird species

- Jobin *et al*. (2001) found 13 species (generally insectivorous) in hedgerows only; the most abundant being the Downy woodpecker, *Picoides pubescens*; alder flycatcher, *Empidonax alnorum*; willow flycatcher, *E. traillii*; warbling vireo, *Vireo gilvus*; yellow warbler, *Dendroica petechia*; and Baltimore oriole, *Icterus galbula*. Some dominant species were found only in hedgerows and windbreaks, for example, the northern flicker, *Colaptes auratus*; American crow, *Corvus brachyrhynchos*; black-capped chickadee, *Parus atricapillus*; and gray catbird, *Dumetella carolinenseis*.

4.16.2 Small mammals

Evidence of high species richness and abundance of small mammals:

- Maisonneuve and Rioux (2001) observed significantly higher abundance and species diversity of small mammals in wooded (total of 660 individuals and 14 species, respectively) than in herbaceous (total of 344 individuals and 11 species, respectively) riparian strips along the Boyer River watershed in Québec. The deer mouse (*Peromyscus maniculatus*), smoky shrew (*Sorex fumeus*) and red-backed vole (*Clethrionomys gapperi*) were associated more closely to wooded strips.

4.16.3 Insects

Evidence of high species richness of insects:

- Holland and Fahrig (2000) reported that woody borders increase diversity but not density of herbivorous insects within crop fields in agro-ecosystems in Ottawa.

4.16.4 Herpetofauna

Evidence of high species richness and abundance of herpetofauna:

- Maisonneuve and Rioux (2001) reported a higher abundance of herpetofauna in wooded (total of 225 individuals) than in herbaceous (total of 35 individuals) riparian strips. The Northern leopard frog (*Rana pipiens*) was associated more closely to wooded strips, whereas wood frogs (*Rana sylvatica*) were captured mostly in shrubby strips.

Table 23: Summary of quantitative evidence of the efficacy of wooded fencerows.

Quantitative measure	Study area/ Country	Wooded fencerow strip[ab]	Shrubby fencerow strip [cd]	Herbaceous strip fencerow	Non-grassy habitat	Source
Birds						
Number of species	Iowa, US	36[a]	23[c]	9		Best, 1983
	Québec, Canada	44	29	12	9	Deschênes *et al*., 2003
	Québec, Canada	39[b]	25[d]	19	--	Jobin *et al*., 2001
Species richness (species/km)	Québec, Canada	19[b]	14[d]	7	--	Jobin *et al*., 2001
Mean species	Québec,	26.0 ± 6.9	12.0 ± 5.3	3.8 ± 2.2	4.0 ± 1.4	Deschênes *et*

Table 23: Summary of quantitative evidence of the efficacy of wooded fencerows.

Quantitative measure	Study area/ Country	Wooded fencerow strip[ab]	Shrubby fencerow strip [cd]	Herbaceous strip fencerow	Non-grassy habitat	Source
richness	Canada					*al*., 2003
Density (/10km of fencerow)	Iowa, US	11.7[a]	6.3[c]	2.5	--	Best, 1983
Density (ind./ha)	Québec, Canada	57[b]	50[d]	19	--	Jobin *et al*., 2001
Abundance (ind./10km of fencerow)	Iowa, US	179[a]	98[c]	37	--	Best, 1983
Abundance (Ind./km)	Québec, Canada	30[b]	27[d]	8	--	Jobin *et al*., 2001
Mean abundance	Québec, Canada	71.8± 13.6	28.7 ± 8.7	12 ± 5.5	10.0±4.6	Deschênes *et al*., 2003
Number of nests	Michigan, US	25	30	33	--	Shalaway, 1985
Small mammals						
Mean number of species/site	Québec, Canada	9.3	6.8	6.5	--	Maisonneuve and Rioux, 2001
Mean abundance /site	Québec, Canada	103.3	82.7	57.3	--	Maisonneuve and Rioux, 2001
Herpetofauna						
Mean number of species/site	Québec, Canada	4.0	4.2	2.2	--	Maisonneuve and Rioux, 2001
Mean abundance /site	Québec, Canada	34.2	14.8	5.8	--	Maisonneuve and Rioux, 2001

[a] *: With continuous trees.* [b] *: Hedgerows with trees and shrubs*

[c] *: With scattered trees and shrubs.* [d] *: Windbreaks with coniferous trees.*

4.16.5 Limitations/weaknesses:

- O'Leary and Nyberg (2000), quoted by Brady (2007), observed that establishment of treelines in landscapes dominated by grasslands, may fragment grassland habitats, with negative consequences for grassland wildlife.

4.17 Salinity control:

- Creates healthier vegetation and more habitats for birds and wildlife.
- Maintains native plants.
- Evidence of efficacy is that provided for conservation tillage, cover crops and forage (using salt tolerate crops).

4.18 Manure and nutrient application:

- Increases organic matter.
- Supports a greater abundance of invertebrates, e.g., earthworms, insects, arthropods, carabids, and more diverse microbial communities.

4.18.1 Birds

Evidence of high avian abundance:

- Although similar numbers of bird species were counted on organic farms under manure application (58), and conventional farms (59) in southern Ontario, Freemark and Kirk (2001) observed significantly greater total bird abundance on organic farms (1,680 individuals, versus 1,360 individuals on conventional farms).
- Of the 43 bird species with sufficient data observations, Freemark and Kirk (2001) reported 12 species that were more abundant on organic (under manure application) than conventional sites: red-tailed hawk, *Buteo jamaicensis*; mourning dove, *Zenaida macroura*; eastern wood-pewee, *Contopus virens*; great crested flycatcher, *Myiarchus crinitus*; eastern kingbird, *Tyrannus tyrannus*; red-eyed vireo, *Vireo olivaceus*; rose-breasted grosbeak, *Pheucticus ludovicianus*; brown headed cowbird, *Molothrus ater*; black-and-white warbler, *Mniotilta varia*; vesper sparrow, *Pooecetes gramineus*; red-winged blackbird, *Agelaius phoeniceus*;

eastern meadowlark, *Sturnella magna*. Only 5 species were more abundant on conventional than organic sites (indigo bunting, *Passerina cyanea*; white-crowned sparrow, *Zonotrichia leucophrys*; barn swallow, *Hirundo rustica*; warbling vireo, *V. gilvus*; and common grackle, *Quiscalus quiscula*).

4.18.2 Invertebrates

Evidence of high abundance of earthworms under manure application:

- Indiana and Illinois, Kladivko (1993) reported larger earthworm populations under manure (340 earthworm/m^2 in pasture and 1,300 earthworm/m^2 in pasture where manure of grazing animals was supplemented by heavy applications of manure from the barnyard) than under insecticide and anhydrous ammonia application (10 earthworm/m^2 in continuous corn plowed field).

Evidence of high abundance of ground beetles under manure application:

- Dritschilo and Wanner (1980) compared the abundance of ground beetles (Coleoptera: carabidae) under conventional (herbicide and fertilizer use) and organic (manure application only) farming in Illinois and Iowa. They collected a larger number of beetles under organic (mean of 2.42 beetles/ trap/ day/ site) than conventional (mean of 1.22 beetles/ trap/ day/ site) farming. A larger number of species was also collected under organic (maximum of 19 species/ sample) than conventional (maximum of 11 species/ sample) farming.
- Kromp (1989) monitored the carabid beetle fauna in biological (under manure application) and conventional (use of fertilizers) farms in Vienna. He collected larger numbers of carabid species and individuals in the biologically farmed fields (44 species and 3,034 individuals, respectively) than in conventionally farmed ones (38 species and 1,687 individuals,

respectively).

4.18.3 Weed species

Evidence of high diversity and abundance of weed species:

- Hyvönen *et al*. (2003) compared the diversity and species composition of weed communities in conventionally cultivated (use of NPK fertilizers) and organic (use of manure and legumes) fields in southern Finland. In organically cultivated fields, the adjusted mean number of species per field exceeded that of conventionally cultivated fields by about two species. The total number of observed species was higher in organic fields (50 and 66 sampled in May-June and July-August, respectively) than in conventional fields (for cereal fields: 43 and 53 sampled in May-June and July-August, respectively).

Evidence of high occurrence of unique weed species:

- Hyvönen *et al*. (2003) noted that organic fields had 14 weed species (or taxa) not found in conventional fields in southern Finland.

Table 24: Summary of quantitative evidence of the efficacy of manure and nutrient application.

Quantitative measure	Study area/ Country	Manure application	Conventional farming	Source
Birds				
Abundance (/site)	Southern Ontario, Canada	1,680	1,360	Freemark and Kirk, 2001
Earthworms				
Abundance (ind/m^2)	Indiana and Illinois, US	340	10 - 20	Kladivko, 1993
Ground beetles				
Number of species	Vienna, Austria	44	38	Kromp, 1989
Max. number of species (/sample)	Illinois and Iowa, US	19	11	Dritschilo and Wanner, 1980
Abundance	Illinois and Iowa,	2.42	1.22	Dritschilo and

Quantitative measure	Study area/ Country	Manure application	Conventional farming	Source
(/trap/day/site)	US			Wanner, 1980
Abundance (/field)	Vienna, Austria	3,034	1,687	Kromp, 1989
Weed species				
Number of species	Southern Finland	50[a]	43[a]	Hyvönen *et al*., 2003
	Southern Finland	56[b]	53[b]	Hyvönen *et al*., 2003
Number of individuals	Southern Finland	20,458[a]	17,382[a]	Hyvönen *et al*., 2003
	Southern Finland	21,160[b]	8,544[b]	Hyvönen *et al*., 2003

[a]: May - June sample (before herbicide treatment).

[b]: July - August sample (after herbicide treatment).

4.18.4 Limitations/weaknesses:

- Creamer *et al*. (2007) noted that abundances of earthworm (0.11 ± 0.0 vs. 0.01 ± 0.0 in uncontaminated sludge treatment vs. treatment of high copper enriched sludge), nematode (32.4 ± 5.3 vs. 4.78 ± 1.9 in uncontaminated sludge treatment vs. treatment of high zinc enriched sludge) and enchytraeid (30.6 ± 4.0 vs. 3.72 ±1.9 and 8.36 ± 4.2 in uncontaminated sludge treatment vs. treatment of high zinc and copper enriched sludge, respectively) were significantly reduced at elevated soil metal concentrations resulting from sewage sludge application in Nottinghamshire, UK.

4.19 Riparian buffer strips:

- Serve as wildlife corridors; create habitat for breeding birds.

4.19.1 Birds

Evidence of high avian species richness and abundance:

- Henningsen and Best (2005) studied grassland bird use of riparian filter strips in southern Iowa and found 46 bird species using filter strips, with 41 species in sites dominated by cool season grasses, and 31 species in sites dominated by warm season grasses. The common yellowthroat (*Geothlypis trichas*), red-winged blackbird (*Agelaius phoeniceus*), dickcissel (*Spiza americana*), and song sparrow (*Melospiza melodia*) comprised 83% of all birds observed; red-winged blackbirds accounted for 54% of the total bird abundance.

- In the agricultural landscape along the Boyer River watershed in Québec, Deschênes *et al*. (2003) recorded 75 bird species, of which 48 were specifically associated with riparian strips. The 3 most abundant species were the red-winged blackbird (*Agelaius phoeniceus*), song sparrow (*Melospiza melodia*) and savannah sparrow (*Passerculus sandwichensis*). Certain species, such as the ruby-throated hummingbird (*Archilochus colubris*), tree swallow (*Tachycineta bicolor*), Baltimore oriole (*Icterus galbula*), Wilson's warbler (*Wilsonia pusilla*) and yellow-rumped warbler (*Dendroica coronata*) were observed only in wooded strips and/or strips dominated by tall shrubs. Yellow warblers (*D. petechia*) were found in all strip types while other warbler species were observed in strips dominated by shrubs and trees exclusively. Total diversity was highest in wooded (44 species) and tall shrubby strips (29 species) with little variation among other strip types (14 in low shrubby, 9 in non-grassy, 11 in grassy and 14 in grazed strips). Deschênes *et al*. (2003) also noted that, on average, wooded riparian strips (7.6 m) were about 5 times wider than the other strip types (tall shrubby, 2.0 m; low shrubby, 0.7 m; non-grassy, 0.9 m; grassy, 0.6 m; and grazed strips, 0.9 m).
- In the boreal forest area, Whitaker and Montevecchi (1999) observed greater avian abundance in 20-50-m-wide riparian buffer strips (total relative abundance: 13.2 individuals/transect) than in undisturbed shoreline habitats (total relative abundance: 10.7 individuals/transect) along watersheds in the western Newfoundland Ecoregion. Further, Whitaker *et al*. (2000) reported a >30% increase in total numbers of birds in riparian buffer

strips than in undisturbed shorelines. Open-ground and edge birds (olive-sided flycatcher, *Contopus norealis*; gray jay, *Perisoreus canadensis*; dark-eyed junco, *Junco hyemalis*; Lincoln's sparrow, *Melospiza lincolnii*; white-throated sparrow, *Zonotrichia albicollis*; mourning warbler, *Oporornis philadelphia*; and magnolia warbler, *Dendroica magnolia*) and ubiquitous species (northern flicker, *Colaptes auratus*; American robin, *Turbus migratorius*; blackpoll warbler, *Dendroica striata*; yellow-rumped warbler, *D. coronata*; and fox sparrow, *Passerella iliaca*) were significantly more abundant along buffer strips (4.06 and 4.12 individuals/transect, respectively) than undisturbed shorelines (1.06 and 2.94 individuals/transect, respectively).

- In Québec, Darveau *et al.* (1995) noted that control riparian strips (>300 m) and 60 m-wide riparian strips supported greater forest-dwelling bird species richness and density than 20-40-m-wide riparian strips within 80 m of shorelines in Montmorency boreal forest in the Laurentian Mountains. They reported that forest-dwelling bird species richness decreased from 9.9 in control riparian strips to 7.1 species/strip in 20 m-wide riparian strips, whereas the number of territories varied from 13.2 in control strips to 5.8 in 20-m-thinned strips. In 40 and 60 m-wide strips, species richness was 8.3 and 7.9 species/strip, respectively, while density was 9.0 and 11.2 territories/strip, respectively.

Evidence of high avian nesting species and nest density:

- Henningsen and Best (2005) observed 11 nesting species with an average nest density of 770 nests/100ha in riparian filter strips in southern Iowa. They recorded high nest abundance for the red-winged blackbird, *A. phoeniceus* (514 nests); dickcissel, *S. americana* (47); song sparrow, *M. melodia* (28); common yellowthroat, *G. trichas* (27); and ring-necked pheasant, *P. colchicus* (8).

Evidence of high occurrence of avian unique species and species of concern:

- Deschênes *et al*. (2003) observed 11 bird species of concern (declining populations) specifically associated with riparian strips along the Boyer River watershed in Québec. These species include the bobolink (*Dolichonyx oryzivorus*), brown-headed cowbird (*Molothrus ater*), gray catbird (*Dumetella carolinensis*), killdeer (*Charadrius vociferous*), least flycatcher (*Empidonax minimus*), red-winged blackbird (*Agelaius phoeniceus*), rose-breasted grosbeak (*Pheucticus ludovicianus*), savannah sparrow (*Passerculus sandwichensis*), song sparrow (*Melospiza melodia*), veery (*Catharus fuscescens*) and wood thrush (*Hylocichla mustelina*). Deschênes *et al*. (2003) reported that wooded and tall shrubby strips harbored 9 and 8 declining bird species, respectively. Five (5) declining bird species were observed in the grassy and grazed strips and 4 in the low shrubby and non-grassy strips.

4.19.2 Small mammals

Evidence of high species richness of small mammals:

- Chapman and Ribic (2002) found more small mammal species (mean of 6-7) on buffer sites (7 - 14 m in width) than on pasture sites (mean of 2-5 species) along the cold-water streams in southwestern Wisconsin. Total abundance on buffer sites was also greater than in pastures, with 3 - 5 times as many animals on the buffer sites. Species found on buffer sites that were relatively uncommon on pastures included the western harvest mouse, *Reithrodontomys megalotis* (4.3 vs. 0.0 individuals /1000 traps nights), masked shrew, *Sorex cinereus* (1.3 vs. 0.0 individuals/1000 traps nights); northern short-tailed shrew, *Blarina brevicauda* (4.9 vs. 1.3 individuals /1000 traps nights); house mouse, *Mus musculus* (4.3 vs. 0.0 individuals/1000 traps nights); and *Peromyscus spp.* (37.4 vs. 1,1 individuals/1000 traps nights) which was the most abundant species captured on buffer sites.

- Maisonneuve and Rioux (2001) recorded 14 species (total of 1,460 individuals) of small mammals in riparian strips along the Boyer River watershed in agricultural landscapes in Québec. 23.6% (11 species) of individuals were captured in herbaceous riparian strips (3.7 ± 1.0 m wide), 34.0% (12 species) in shrubby strips (3.2 ± 1.0 m wide), and 42.5% (14 species) in wooded strips (19.2 ±14.0 m wide). The most abundant species were the meadow jumping mouse (*Zapus hudsonius*), Cinereus shrew (*S. cinereus*), and northern short-tail shrew (*B. brevicauda*), comprising 42.1, 28.5 and 10.4% of the captures, respectively.

4.19.3 Insects

Evidence of high abundance of flying insects:

- Whitaker *et al*. (2000) collected 1.2 to 2.0 times more insects along riparian buffer strips than on undisturbed shorelines in Newfoundland.

4.19.4 Herpetofauna

Evidence of high species richness of herpetofauna:

- Maisonneuve and Rioux (2001) captured 11 species (total of 329 individuals) of herpetofauna, comprising 9 amphibians (more than 98% of all captures) and 2 reptiles, in riparian strips along the Boyer River watershed in Québec.

Evidence of high occurrence of herpetofauna species of concern in buffer strip:

- Maisonneuve and Rioux, (2001) reported a greater abundance of species of concern: northern leopard frogs (*Rana pipens*), American toads (*Bufo americanus*) and wood frogs (*R.*

sylvatica), comprising 30.4, 47.7, and 9.1% of captures, respectively, in riparian strips in Québec.

Table 25: Summary of quantitative evidence of the efficacy of riparian buffer strips.

Quantitative measure	Study area/ Country	Riparian buffer strips	Undis-turbed areas	Continuous grazing sites	Source
Birds					
Number of species	Southern Iowa, US	46	--	--	Henningsen and Best, 2005
	Québec, Canada	48	--	--	Deschênes *et al.* (2003)
Number of nesting species	Southern Iowa, US	11	--	--	Henningsen and Best, 2005
Nest density (/100ha)	Southern Iowa, US	770		--	Henningsen and Best, 2005
Abundance (ind./200-m transect)	Newfoundland, Canada	13.2 ± 1.1	10.7±0.9	--	Whitaker and Montevecchi, 1999
Small mammals					
Species richness	Southwestern Wisconsin, US	5.8 ± 0.3[a] (7 ± 0.3)[b]	--	2 ± 0.4[a] (2 ± 0.4)[b]	Chapman and Ribic, 2002
Abundance (/1000 traps)	Southwestern Wisconsin, US	46.9 ± 6.1[a] 118.6±14.7[b]	--	6.7 ± 2.7[a] 27.8 ± 8.7[b]	Chapman and Ribic, 2002

[a] *: First year (1997) trapping.* [b] *: Second year (1998) trapping.*

4.19.5 Limitations/weaknesses

- In the boreal forest area, Whitaker and Montevecchi (1999) reported that, riparian buffer strips, if wide enough, may support greater numbers of birds selecting this habitat. Nevertheless, even the widest buffers they sampled (40 - 50 m) supported densities <50% of that observed in interior forest habitats.

4.20 Manure management and improved storage and handling / Relocation of livestock facilities / Wintering site management:

- Important for aquatic biodiversity and healthier populations of amphibians and fishes.

4.20.1 Amphibians

Evidence of high density of amphibians:

- In the Holland River watershed in southern Ontario, Bishop *et al*. (1999) observed higher densities (22.5% vs. 1.7 % of occurrences of calling) of 7 frog species (western chorus frog, *Pseudacris triseriata triseriata*; wood frog, *Rana sylvatica*; northern leopard frog, *R. pipiens*; wood frog, *R. sylvatica*; spring peeper, *Hyla crucifer*; gray treefrog, *H. versicolor*; and eastern American toad, *Bufo americanus americanus*) in the upstream area (low nutrient concentrations: 0.288, 1.635 and 1.020 mg/l for phosphorus, nitrogen and ammonia, respectively) than in the agricultural zone (high nutrient concentrations: 0.828, 4.163 and 0.198 mg/l for phosphorus, nitrogen and ammonia, respectively).

Evidence of high occurrence of native species:

- Zampella and Bunnell (2000) surveyed anurans on Mullica River system (upland-agricultural land intensely farmed; high nitrate-nitrogen values in river system) and Wading River system (unaltered sites) in the New Jersey Pinelands. They reported wide distributions of 6 native Pinelands species (Pine Barrens treefrog, *Hyla andersonii*; carpenter frog, *R. virgatipes*; southern leopard frog, *R. utricularia*; Fowler's toad, *Bufo woodhousii fowleri*; spring peeper, *Pseudacris crucifer*; and green frog, *R. clamitans melanota*) in the Wading River system. Four (4) non-native Pinelands species occurred only in the degraded Mullica River system (bullfrog, *R. catesbeiana*; pickerel frog, *R. palustris*; northern cricket frog, *Acris crepitans crepitans*; and gray treefrog, *H. versicolor*).

4.20.2 Fishes

Evidence of high density of fishes:

- In the northeastern United States, Baker *et al*. (1996) reported a significantly higher density of brook trout, *Salvelinus fontinnlis*, in non-acidic streams than in streams episodically or chronically acidic (215 vs. 82 or 46 fishes per 0.1 hectare, respectively).

Evidence of high occurrence of unique species:

- Baker *et al*. (1996) noted that 3 (blacknose dace, *Rhinichthys atratulus*; slimy sculpin, *Cottus cognatus*; and mottled sculpin, *C. bairdii*) of the 10 fish species caught, occurred only in non-acidic streams in the northeastern United States.

Table 26: Summary of quantitative evidence of the efficacy of manure management and improved storage and handling.

Quantitative measure	Study area/ Country	Low nutrient concentrations[a]	High nutrient concentrations[b]	Source
Anurans				
Density (mean % of occurrences of calling)	Southern Ontario, Canada	22.5	1.7	Bishop *et al*., 1999
Fishes				
Density (brook trout ind./0.1 ha)	Northeastern US	215[b]	46[b]	Baker *et al*., 1996

[a] : Non-acidic streams. *[b] : Chronically acidic streams.*

4.21 Proper treatment of manure / management of agricultural wastes:

- Increases the abundance of invertebrates.

4.21.1 Ground beetles

Evidence of high abundance of ground beetles:

- Larsen *et al*. (1996) found a significantly higher ground beetle (*Caloeptera: caribidea*) abundance on a sludge treated field (18 beetles) and fertilizer field (17 beetles) than on the control field (11 beetle) in Ohio.

- Kielhorn *et al*. (1999) studied the effects of different organic amelioration substances on the ground beetle fauna in Germany. They observed a higher number of beetles on sewage sludge, compost, and mineral fertilizer fields (58, 50 and 50 total catch / 5traps / 288 days, respectively) than on untreated control fields (38 total catch / 5traps / 288 days). Relative to the control, they reported an increase of more than 200% in the number of beetles on the compost plot and over 300% on the sewage sludge plot.

Table 27: Summary of quantitative evidence of the efficacy of proper treatment of manure.

Quantitative measure	Study area/ Country	Sewage sludge	Compost	Mineral fertilizer	Untreated control	Source
Ground beetles						
Number of species	Germany	58	50	50	38	Kielhorn *et al*., 1999
	Ohio, US	18	--	17	11	Larsen *et al*., 1996

4.22 Pesticide and herbicide storage and handling:

4.22.1 Plant species

Evidence of high plant species richness:

- Field margins and non-target plants could receive up to 20–25% of the applied pesticide field dosage (De Snoo and de Wit, 1998; De Snoo, 1999; Boutin *et al*., 2001 all quoted by Aude *et al*., 2003). Aude *et al*. (2003) studied vegetation of comparable hedgerows, in the same area, situated within organic (absence of pesticides and artificial fertilizers) and conventional farming systems in Denmark. They recorded 101 plant species in conventional hedgerows, while 128 species occurred in organic hedgerows. Total numbers of hedge bottom species (gamma diversity) ranged from 24 to 53 (mean = 38.7/plot, S.E. = 1.6) in organic and from

20 to 36 (mean = 28.8/plot, S.E. = 1.1) in conventional hedgerows. The difference in average species richness of sample plots (alpha diversity) was highly significant (organic 15.1 versus conventional 12.5), with boundary samples also being significantly different (organic 17.2 versus conventional 12.8).

Evidence of high occurrence of semi-natural species and species of concern:

- In Denmark, Aude *et al*. (2003) found more species that are typical of semi-natural habitats on organic (5.1 species/plot) as compared to conventional (3.9 species/plot) farms. Further, 1 protected species (*Epipactis helleborine*, L. Crantz.) was found in an organic hedgerow.

Table 28: Summary of quantitative evidence of the efficacy of pesticide and herbicide storage and handling.

Quantitative measure	Study area/ Country	Organic farming (no pesticide)	Conventional farming	Source
Plants				
Number of species	Denmark.	128	101	Aude *et al*., 2003
Gamma diversity	Denmark.	38.7 ± 1.6	28.8 ± 1.1	Aude *et al*., 2003
Alpha diversity	Denmark.	15.1	12.5	Aude *et al*., 2003

4.23 Minimizing chemical inputs to soils / Optimized nutrients in animals feed:

- Increases invertebrate diversity and abundance; favors herbicide-susceptible and less nitrophilous species (Hyvönen *et al*., 2003).
- Reducing the use and dependency of chemicals can increase species richness from 15 to 30% (Environment Canada, 2007).

4.23.1 Birds

Evidence of avian recovery:

- Newton and Wyllie (1992) documented the recovery of a sparrowhawk, *Accipiter nisus*, population in eastern England, associated with a reduction in contamination with pesticides. Sparrowhawks had been absent from the study area - centered on Rockingham Forest, Northamptonshire - for approximately 20 years. Following a withdrawal, in 1975, of aldrin and dieldrin (two pesticides used in agriculture), sparrowhawks were observed and the number of nests increased progressively from 3, in 1979, to 84, in 1989. Over the same period, breeding success improved from an average of 1.8 (in 1980) to 2.9 young per clutch (in 1989).

4.23.2 Carabid beetles

Evidence of high diversity and abundance of carabid beetles:

- Kromp (1989) monitored the carabid beetle fauna in biological (absence of fungicide and growth regulator) and conventional (use of fungicide and growth regulator) farms in Vienna. He collected higher numbers of carabid species and individuals in the biologically farmed fields (50 species and 3,208 individuals, respectively) than in conventionally farmed fields (41 species and 936 individuals, respectively).
- Kromp (1989) reported a greater number of species and individuals in conventional farms without herbicides than in those with herbicides (28 species and 417 individuals vs. 18 species and 195 individuals, respectively).

4.23.1 Weed species

Evidence of high diversity and abundance of weed species:

- Hyvönen *et al*. (2003) compared the diversity and species composition of weed communities in conventional fields in southern Finland before (May-June) and after (July-August) herbicide treatment. They noted that the total number of individuals declined in conventional cropping from May–June to July–August, i.e., after herbicide treatment (17,382 to 8,544 individuals). In contrast, in organic cropping the number of individuals increased from May–June to July–August (20,458 to 21,160 individuals).

Evidence of high occurrence of unique weed species:

- Hyvönen *et al*. (2003) noted that organic fields had 14 weed species (or taxa) not found in conventional fields. They encountered *Centaurea cyanus* (a species regarded as endangered or extinct in many countries) in organic fields only. *C. cyanus* is susceptible to herbicide treatments and suffers with high rates of nitrogen fertilization (Svensson and Wigren, 1986 quoted by Hyvönen *et al*., 2003).

Table 29: Summary of quantitative evidence of the efficacy of minimizing chemical inputs to soils.

Quantitative measures	Study area/ Country	Without herbicide /fungicide	With herbicide /fungicide	Source
Birds				
Number of nests (/220km^2)	Eastern England	84[α]	0[α]	Newton and Wyllie, 1992
Caribid beetle				
Number of species	Vienna, Austria	50	41[a]	Kromp, 1989
	Vienna, Austria	28	18[b]	Kromp, 1989
Abundance	Vienna, Austria	3,034	1,687[a]	Kromp, 1989
	Vienna, Austria	417	195[b]	Kromp, 1989
Weed species				
Number of individuals	Southern Finland	17,382	8,544	Hyvönen *et al*., 2003
Adjusted mean number of species	Southern Finland	11.2	12.8	Hyvönen *et al*., 2003

[α] *: Sparrow hawk.*

[a] *: Fungicide treatment.* [b] *: Herbicide treatment.*

4.24 Wetland restoration:

- Wetlands serve as crucial "pit-stops" for migratory birds, and house several species of plants and animals.
- Wetland connectivity (Haig *et al.*, 1998).

4.24.1 Birds

Evidence of high avian abundance, density and species richness:

- In the Frank Lake prairie pothole marsh in southern Alberta, during the first five years after restoration, White and Bayley (1999) documented 50 shorebird species, 44 waterfowl species, 15 raptor species, and 28 other new bird species using a 1,246-ha formerly drained northern prairie wetland that was restored and flooded with municipal wastewater. LaGrange and Dinsmore (1989) found a total of 11 bird species in 4 formerly drained prairie wetland basins several years after the basins were reflooded in Iowa.
- Ratti *et al.* (2001) compared avian use of restored and natural wetlands in North and South Dakota and concluded that, restored wetlands in the prairie Pothole Region supported similar avian communities with equal or higher abundance than those of natural wetlands. They detected in total 108 wetland bird species. They reported greater overall mean densities of birds for 14 common wetland species on restored than natural wetlands (mean difference: 0.99 ± 0.252 birds/10ha). Canada goose, *Branta canadensis* (1.4 vs. 0.28); mallard, *Anas platyrhyncos* (2.72 vs. 0.89); redhead, *Aythya americana* (0.47 vs. 0.10); and ruddy duck, *Oxyura jamaicensis* (0.62 vs. 0.24 individuals/10ha) had higher densities on restored wetlands. Wetland avian richness and abundance were similar in restored wetlands (84.269 individuals and 9.383 species, respectively) and natural wetlands (52.750 individuals and 9.112 species, respectively).

- Further, Ratti *et al.* (2001) detected 124 upland bird species. The most common species included the bobolink, *Dolichonyx oryzivorus* (4.34 vs. 5.82); clay-colored sparrow, *Spizella pallida* (1.73 vs. 1.51); common yellowthroat, *Geothlypis trichas* (1.81 vs. 1.57); eastern kingbird, *Tyrannus tyrannus* (0.48 vs. 0.37); grasshopper sparrow, *Ammodramus savannarum* (3.25 vs. 1.74); red-winged blackbird, *Agelaius phoeniceus* (4.14 vs. 6.28); savannah sparrow, *Passerculus sandwichensis* (6.56 vs. 7.70); sedge wren, *Cistothorus platensis* (4.71 vs. 3.70); song sparrow, *Melospiza melodia* (0.94 vs. 0.78); and western meadow, *Sturnella neglecta* (0.67 vs. 0.70 individuals/10ha in restored vs. natural wetlands).
- In restored wetlands in northern New York, Brown and Smith (1998) observed average bird species and population densities of 6.3 species/ha and 15.0 individuals/ha, respectively. They reported slightly higher densities in natural wetlands, 8.2 species/ha and 20.0 individuals/ha.
- Hands *et al.* (1991) examined shorebird use of 3 wetland management treatments in northeastern Missouri. They reported more shorebirds on marsh and moist-soil units than agricultural borrow ditches (18.6 - 63.2 and 8.1 - 9.0 vs. 2.9 - 4.9 individuals/ha).

Evidence of high nesting species and density:

- In Prince Edward Island, Canada, Stevens *et al.* (2003) observed that 6 (American black buck, *Anas rubripes* 1.38 vs. 0.67: blue-winged teal, *A. discors* 0.43 vs. 0.06; gadwall, *A. strepera* 0.55 vs. 0; green-winged teal *A. crecca* 0.8 vs. 0.18; mallard, *A. platyrhynchos* 0.32 vs. 0.06; and ring-necked duck, *Aythya collaris* 1.02 vs. 0.06 pairs) of the 8 breeding waterfowl species had significantly more pairs on restored versus reference wetlands. American black duck pairs occurred on most (86%) restored wetlands. Four (American black buck, 0.7 vs. 0.06; green-winged teal, 0.45 vs. 0.08; gadwall, 0.11 vs. 0; and ring-necked duck, 0.11 vs. 0.04 broods) species had significantly more broods on restored versus reference wetlands.

- Ratti *et al.* (2001) reported higher density (4.66 vs. 4.01 pairs/10ha) of breeding dabblers on restored and natural wetlands in North and South Dakota.
- Delphey and Dinsmore (1993) compared the breeding bird communities of natural and restored prairie wetlands in northern Iowa. They reported no differences for species richness and abundance of upland-nesting waterfowl between wetland types (2.3 vs. 2.3 species/18-m-circular plots and 5.9 vs. 3.3 pairs/18-m-circular plots in restored vs. natural wetland, respectively). Mallard, *A. platyrhynchos* (2.6 vs. 0.9 pairs/18-m-circular plots) and blue-winged teal, *A. discors* (1.9 vs. 1.6 pairs/18-m-circular plots) were more common in restored than natural wetlands.

4.24.2 Amphibians

Evidence of species richness and abundance:

- In central and southern Minnesota, Lehtinen and Galatowitsch (2001) observed that 6 of 7 restored wetlands supported amphibian populations. Eight (northern leopard frog, *Rana pipiens*; wood frog, *R. sylvatica*; western chorus frog, *Pseudacris triseriata*; Cope's grey tree frog, *Hyla chrysoscelis*; gray tree frog, *H. versicolor*; American toad, *Bufo americanus*; Canadian toad, *B. hemiophrys*; tiger salamander, *Ambystoma tigrinum*) of 12 amphibian species found in reference wetland, rapidly colonized restored wetlands and established breeding populations. The mean number of amphibian species was lower in restored wetlands (3.6 species) compared to reference wetlands (5.2 species), but this difference was not significant.
- Fowler *et al.* (1985) quoted by Rewa (2007) documented 12 species of breeding amphibians

in newly constructed coal surface mine sediment ponds in western Tennessee, and all 9 ponds surveyed contained at least one breeding amphibian species.

- Lacki *et al.* (1992) found that a wetland constructed for treatment of mine water drainage in east central Ohio supported greater abundance and species richness of herpetofauna (frogs, snakes, lizards and turtles) than surrounding natural wetlands (98.3 vs. 7.8 - 24.8 individuals/habitat and 6.67 vs. 2.0 – 4.5 species).

4.24.3 Invertebrates

Evidence of species richness and rapid colonization of restored wetland:

- Brown *et al.* (1997) found similar invertebrate taxa between natural wetlands and restored wetlands in northern New York. In recently constructed coal surface mine sediment ponds, Fowler *et al.* (1985) quoted by Rewa (2007) found 66 and 44 invertebrate taxa in the first and second years sampled, respectively, indicating rapid invertebrate colonization.
- In Iowa, LaGrange and Dinsmore (1989) found a total of 18 wetland invertebrate species in 4 formerly drained prairie wetland basins several years after the basins were reflooded. In a survey of restored seasonal and semi-permanent wetlands in Minnesota and South Dakota, Sewell and Higgins (1991) quoted by Rewa (2007) found 31 taxa of aquatic macroinvertebrates in restored wetlands, 12 of which occurred in wetlands the first year following restoration.

4.24.4 Benthic invertebrates

- In northeastern Ohio, Stanczak and Keiper (2004) indicated that the created wetlands developed benthic invertebrate communities that were similar to the adjacent natural wetlands in a short period of time (four years).

Table 30: Summary of quantitative evidence of the efficacy of wetland restoration.

Quantitative measures	Study area/ Country	Restored wetland	Natural Wetland	Agric. units	Source
Birds					
Species richness (habitat)	North and South Dakota	9.383	9.112	--	Ratti *et al.*, 2001
Species density (/ha)	Northern New York, US	6.3	8.2	--	Brown and Smith, 1998
Density (Ind./ha)	Northern New York, US	15.0	20.0	--	Brown and Smith, 1998
Density (Ind./100ha)	Northeastern Missouri, US	63.2^{α}	--	4.9^{α}	Hands *et al.*, 1991
Density (pairs./10ha)	North and South Dakota	$4.6 \pm 1.4^{\beta}$	$4.0 \pm 1.1^{\beta}$	--	Ratti *et al.*, 2001
Abundance (habitat)	North and South Dakota	84.269	52.750	--	Ratti *et al.*, 2001
Breeding species richness (18-m-circular plots)	Prairie Potholes, northern Iowa	5.4	8.6	--	Delphey and Dinsmore, 1993
	Prairie Potholes, northern Iowa	2.3^{μ}	2.3^{μ}	--	Delphey and Dinsmore, 1993
Amphibians					
Number of species	Central and southern Minnesota	3.6	5.2	--	Lehtinen and Galatowitsch, 2001

$^{\alpha}$ *: Shorebirds.* $^{\beta}$ *: Breeding dabblers.* $^{\mu}$ *: Upland nesting waterfowl.*

4.24.5 Limitations/weaknesses:

- Although the restoration program successfully increased the amount of bird habitat available in northern New York, Brown and Smith (1998) noted that, hectare-for-hectare, after 3 years, the restored wetland sites did not replace the habitat functions of natural wetlands.
- Restoration may not provide appropriate habitat for 4 amphibian species - blue-spotted salamander, *Ambystoma laterale*; spring peeper, *Pseudacris crucifer*; green frog, *Rana clamitans*; and eastern newt, *Notophthalmus viridescens* - present in reference wetlands in central and southern Minnesota (Lehtinen and Galatowitsch, 2001).

5 SPECIES MANAGEMENT:

- Maintain viable populations of species of concern or at risk.

- Findings and results under identified BMPs are provided for each taxa and species.

5.1 Birds

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Horned lark	*Eremophila alpestris*	Adapted to nest on bare or nearly bare soil. Nesting period: April 20 - July 20 (Lokemoen and Beiser, 1997).	Occurred more frequently on annually hayed than periodically hayed habitats (17 – 67% vs. 0 - 38% of census plots) and on mowed than unmowed plots of annual hayed habitat (25% vs. 17% of census plots) in south central Saskatchewan (Dale *et al.*, 1997).	Hayland management
			Quoted in ERIN Consulting Ltd. (2006)	Shelterbelt
			Quoted in ERIN Consulting Ltd. (2006).	Pasture management
American robin	*Turdus migratorius*	Native species in east-central Nebraska (Johnsgard, 1979 quoted by Beecher *et al.*, 2002).	Nested in corn-corn no-till fields in Iowa; no nests in tilled corn fields (Basore *et al.*, 1986).	Conservation tillage
			More abundant (0.08 vs. 0.04 ind./ha) on hybrid poplar plantations than hay/pasture fields in Minnesota, Wisconsin and South Dakota. Not observed in rowcrops (Hanowski *et al*, 1998).	Short Rotation Forestry
			More abundant (3.4 vs. 1.5 ind./10ha) in organic (using crop rotation) than non-organic sites in Nebraska (Beecher *et al*., 2002).	Crop rotation
			Haas (1995) noted 15 times more movement occurring frequently between connected pairs of sites than between unconnected pairs in agricultural landscapes in south-central North Dakota.	Retention of connectivity
			Nested more abundantly in woody than in shrubby and grassy fencerows (22 vs. 2 and 0 nests/fencerow type, respectively) in Michigan (Shalaway, 1985).	Wooded fencerow

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Eastern meadowlark	*Sturnella magna*		More abundant in reduced tillage fields than in conventional tillage fields in the Texas Panhandle (7.78 vs. 0.33 ind./field in winter) (Flickinger and Pendleton, 1994).	Conservation tillage
			Greater abundance in CRP fields than in rowcrop fields in Midwest (0.49 vs. 0.12 ind./km of transect) (Best *et al*., 1997).	Permanent Cover Program
			More abundant on organic (under manure application) than in conventional sites in southern Ontario (36 vs. 19 ind.) (Freemark and Kirk, 2001).	Manure application
Western meadowlark	*S. neglecta*	Grassland bird (Christian *et al*., 1997). Nesting period: April 15 - July 30 (Best *et al*., 1986).	Nested abundantly (12nests/100ha) in no-till corn-sod fields in Iowa; no nests in tilled corn fields (Basore *et al*., 1986).	Conservation tillage
			More abundant in CRP fields than in Cropland in North Dakota (6.4 vs. 1.2 pairs/100ha) (Johnson and Igl, 1995). Nested more in CRP fields (7.8 pairs/100ha) than in cropland (4.3 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993). Greater abundance (0.49 vs. 0.12 ind./km of transect) in CRP fields than in rowcrop fields in Midwest (Best *et al*., 1997). Observed more commonly in CRP (27.5% of sites) than in cropland (4.3% of sites) in the Prairies Ecozone (McMaster and Davis, 2001).	Permanent Cover Program
			Occurred on restored wetlands in North and South Dakota (0.67 ind./10ha) (Ratti *et al.*, 2001).	Wetland restoration
			Abundant on hybrid poplar plantations in north central US (Christian *et al*., 1997).	Short Rotation Forestry

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			Most common in grassed waterways in Iowa (Bryan and Best, 1991, 1994).	Grassed waterways
			Occurred more commonly on annual-hayed than periodic-hayed habitats (8 - 42 vs. 0 - 30% of census plots) and on mowed than unmowed plots of annual hayed habitat (42 vs. 17% of census plots) in south central Saskatchewan (Dale *et al.*, 1997).	Hayland management
			Quoted in ERIN Consulting Ltd. (2006).	Pasture management
Dickcissel	*Spiza americana*	Species of conservation concern (Sauer *et al.*, 1996 quoted by Best *et al.*, 1997; Robinson, 1997; Sauer *et al.*, 2001 quoted by Beecher *et al.*, 2002). Declining grassland bird; has undergone significant population declines in Midwest (Johnson and Schwartz, 1993; Johnson and Igl, 1995; Ryan, 2000).	Nested exclusively in no-till fields in Iowa (Basore *et al.*, 1986). Occurred only in no-till farms in Illinois (6 ind., 2.3% of total bird observations) (Warburton and Klimstra, 1984).	Conservation tillage
			Observed only in CRP fields in North Dakota (0.1 pairs/100ha) (Johnson and Igl, 1995). Nested more in CRP fields (1.6 pairs/100ha) than in cropland (0.2 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993). Greater abundance in CRP fields than in rowcrop fields in the Midwest (3.06 vs. 0.08 ind./km of transect) (Best *et al.*, 1997).	Permanent Cover Program
			Nested abundantly (276 nests/100ha) in grassed waterways in Iowa (Bryan and Best, 1991, 1994).	Grassed waterways
			Most abundant in riparian filter strips in Iowa (103.3 ind./100ha in warm-season grasses, 47 nests) (Henningsen and Best, 2005).	Riparian buffer strip
			More abundant in organic (using crop rotation) than non-organic sites in Nebraska (8.6 vs. 2.2 ind./10ha) (Beecher *et al.*, 2002).	Crop rotation

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			More abundant in strip-harvest biomass than rowcrop fields in Iowa (5.1 vs. 1.7 ind./100ha) (Murray *et al.*, 2003).	Perennial energy crops
			Nested abundantly (12 nests/100ha) in strip cover fields in Iowa. No nests in tilled corn fields (Basore *et al.*, 1986).	Strip cropping
			Benefit from haying (Walk and Warner, 2000).	Hayland management
			Quoted in ERIN Consulting Ltd. (2006).	Pasture management
Savannah sparrow	*Passerculus sandwichensis*	Declining population in Québec (Deschênes *et al.*, 2003). Declining grassland bird.	Nested only in no-till fields in Iowa (Basore *et al.*, 1986). More abundant in reduced than in conventional tillage fields in the Texas Panhandle (1.67 vs. 0.22 ind./field in fall, Flickinger and Pendleton, 1994) and in Alberta (2.13 vs. 1.03 ind./100-m-radius, Martin and Forsyth, 2003).	Conservation tillage
			Detected commonly more in CRP (60.4% of sites) than crop fields (28.7% of sites) in the Prairie Ecozone (McMaster and Davis, 2001). More abundant in CRP fields than in cropland in North Dakota (8.1 vs. 1.5 pairs/100ha) (Johnson and Igl, 1995). Nested more in CRP fields (6.1 pairs/100ha) than in cropland (1.9 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993). Greater abundance (0.18 vs. 0.01 ind./km of transect) in CRP fields than in rowcrop fields in Midwest (Best et al., 1997).	Permanent Cover Program
			Occurred (6.59 ind./10ha) on restored wetlands in North and South Dakota (Priarie Pothole Region (PPR)) (Ratti *et al.*, 2001).	Wetland restoration

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			Most abundant in riparian strips in Québec (Deschênes *et al*., 2003).	Riparian buffer strip
			Greater density in bordered (14.95 birds/ha) than non-bordered (4.79 birds/ha) agricultural fields adjacent to grassland habitats in Mississippi (Smith *et al.*, 2005).	Vegetative filter strip
			Observed on hybrid poplar plantations in north central US (Christian *et al*., 1997).	Short Rotation Forestry
			Occurred most commonly on idle, annual-hayed, and periodic-hayed habitats, and on mowed and unmowed plots (up to 100% of census plots) in south central Saskatchewan. Greater abundance on periodic hayed fields (4 male territories/100-m-radius) than on annual hayed and native unhayed fields (1.5 and 2.0 male territories/100-m-radius, respectively) (Dale *et al.*, 1997). Increase in the rate of fledging from 0 to 56% with 1.5 weeks (to 1 July) delay in hay harvesting (Nocera *et al*., 2005).	Hayland management
			Occurred more abundantly on moderately grazed (78% of observations, 2.12 ind./ha) than ungrazed (16% of observations, 1.27 ind./ha) and intensively grazed (6% of observations, 1.40 ind./ha) prairie in Québec (Bélanger and Picard, 1999).	Pasture and range management
Grasshopper sparrow	*Ammodramus savannarum*	Species of conservation concern. Has undergone significant population declines in the Midwest (Johnson and Schwartz, 1993;	Nested exclusively (36 nests/100ha) in no-till corn-sod fields in Iowa; no nests in tilled fields (Basore *et al*., 1986). Nested in minimum tillage fields in north Dakota (Lokemoen and Beiser, 1997).	Conservation tillage
			Most abundant in organic (using crop rotation) fields in North Dakota (Lokemoen and Beiser, 1997).	Crop rotation

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
		Johnson and Igl, 1995; Sauer et al., 1996 quoted by Best et al., 1997; Lokemoen and Beiser, 1997; Ryan, 2000). Nesting period: May 20 - June 20 (Lokemoen and Beiser, 1997).	More abundant (3.25 vs. 1.74 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001).	Wetland restoration
			More abundant (7.2 vs. 1.4 ind./100ha) in strip-harvest biomass than in rowcrop fields in Iowa (Murray *et al.*, 2003).	Perennial energy crops
			Detected only in CRP fields (11.9% of sites) in the Prairies Ecozone (McMaster and Davis, 2001). More abundant (11.7 vs. 0.6 pairs/100ha) in CRP fields than in Cropland in North Dakota (Johnson and Igl, 1995). Nested more in CRP fields (21.2 pairs/100ha) than in cropland (0.5 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993). Greater abundance (1.28 vs. 0.02 ind./km of transect) in CRP fields than in rowcrop fields in the Midwest (Best *et al.*, 1997).	Permanent Cover Program
			More abundant (91 vs. 48 breeding pairs/100 acres) on field strips than conventional cropland in Ohio (Good and Dambach, 1943). Nested (1 nest/100ha) in strip cover fields in Iowa (Basore *et al.*, 1986).	Strip cropping
			Nested in grassed waterways in Iowa (Bryan and Best, 1991, 1994).	Grassed waterways
			Occurred more commonly on annual hayed than periodic hayed habitats (0 - 29 vs. 0% of census plots) and on mowed than unmowed plots of annual hayed habitat (33 vs. 25% of census plots) in south central Saskatchewan (Dale *et al.*, 1997). Benefit from haying (Walk and Warner, 2000).	Hayland management

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			Quoted in ERIN Consulting Ltd. (2006).	Pasture management
Henslow's sparrow	*A. henslowii*	Declining grassland bird. Species of high conservation concern (Sauer *et al*., 1996 quoted by Best *et al*., 1997).	Occurred only in CRP habitats (0.06 ind./km of transect) in the Midwest (Best *et al*., 1997).	Permanent Cover Program
			Benefit from haying (Walk and Warner, 2000).	Hayland management
Baird's sparrow	*A. bairdii*	Grassland bird endemic to the Canadian mixed grass prairie. Declining population (Dale *et al*., 1997). Has undergone significant population declines in the northern Great Plains (Johnson and Schwartz, 1993) and in North Dakota (Johnson and Igl, 1995). Species of high management concern in Saskatchewan (McMaster *et al.*, 2005).	Detected commonly more in CRP fields (18.1% of sites) than in cropland (1.9% of sites) in the Prairies Ecozone (McMaster and Davis, 2001). Observed only in CRP fields in North Dakota (1.4 pairs/100ha) (Johnson and Igl, 1995). Nested only in CRP fields (1.6 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993).	Permanent Cover Program
			Observed (3 nests; 0.2% of all nests) in hayland in southern Saskatchewan (McMaster *et al.*, 2005). Occurred most commonly on idle, annual hayed and periodic hayed habitats, and on mowed and unmowed plots (up to 100% of census plots) in south central Saskatchewan. Greater abundance on annual hayed and native unhayed fields (3 and 3.5 male territories/100-m-radius, respectively) than on periodic hayed fields (1.5 male territories/100-m-radius) (Dale *et al.*, 1997).	Hayland management
			Occurred only on minimum-till farms in Alberta (0.21 ind./100-m-radius) (Martin and Forsyth, 2003).	Conservation tillage
			Quoted in ERIN Consulting Ltd. (2006).	Pasture management

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Le Conte's sparrow	*A. leconteii*	Species of high management concern in Saskatchewan (McMaster *et al.*, 2005).	Detected only in CRP fields (8.4 % of sites) in the Prairies Ecozone (McMaster and Davis, 2001).	Permanent Cover Program
			Observed in hayland in southern Saskatchewan (1 nest; 0.07% of all nests) (McMaster *et al.*, 2005). Occurred more commonly on periodic hayed than annual hayed and idle fields (17 - 50 vs. 0 - 13 and 0% of census plots, respectively) in south central Saskatchewan (Dale *et al.*, 1997).	Hayland management
Sharp-tailed sparrow	*A. caudacutus*	Species of management concern (Bélanger and Picard, 1999).	Occurred only on moderately grazed prairie (0.26 ind./ha) in Québec (Bélanger and Picard, 1999).	Pasture and range management
Nelson's sharp-tailed sparrow	*A. nelsoni*		Increase in the rate of fledging from 0 to 44% with 1.5 weeks (to 1 July) delay in hay harvesting (Nocera *et al*., 2005).	Hayland management
Field sparrow	*Spizella pusila*	Grassland bird (Christian *et al*., 1997). Species of conservation concern (Sauer *et al*., 1996 quoted by Best *et al*., 1997).	Nested (2 nests/100ha) only in no-till soybean-corn fields in Iowa. No nests in tilled corn fields (Best *et al*., 1986). More abundant in no-till fields (66 % of total observations) than conventional till fields (34%) in Illinois (Warburton and Klimstra, 1984).	Conservation tillage
			Observed on hybrid poplar plantations in north central US (Christian *et al*., 1997).	Short Rotation Forestry
			Nested in strip cover fields in Iowa (2 nests/100ha); no nests in tilled corn fields (Best *et al*., 1986). Higher abundance on field strips than conventional cropland in Ohio (8 vs. 4 breeding pairs/100 acres) (Good and Dambach, 1943).	Strip cropping

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			More abundant in strip-harvest biomass than rowcrop fields in Iowa (3.1 vs. 0.9 ind./100ha) (Murray *et al.*, 2003).	Perennial energy crops
			Greater abundance in CRP fields than in rowcrop fields in the Midwest (1.13 vs. 0.07 ind./km of transect) (Best *et al*., 1997).	Permanent Cover Program
			Nested in grassed waterways in Iowa (Bryan and Best, 1991, 1994).	Grassed waterways
			Most observed (92.6 % of total observations) along bordered transects in Mississippi (Smith *et al*., 2005).	Vegetative filter strip
Clay-colored sparrow	*S. pallida*	Declining grassland bird. Species of conservation concern (Sauer *et al*., 1996 quoted by Best *et al*., 1997). Has undergone significant population declines in the northern Great Plains (Johnson and Schwartz, 1993) and in North Dakota (Johnson and Igl, 1995). Species of management concern in Saskatchewan (McMaster *et al.*,	Detected commonly more in CRP (12.8% of sites) than in cropland (1% of sites) in the Prairies Ecozone (McMaster and Davis, 2001). Observed only in CRP fields in North Dakota (4.0 pairs/100ha) (Johnson and Igl, 1995). Nested only in CRP fields in the northern Great Plains (4.5 pairs/100ha) (Johnson and Schwartz, 1993).	Permanent Cover Program
			More abundant (7.12 vs. 6.54 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001).	Wetland restoration
			Observed on hybrid poplar plantations in north central US (Christian *et al*., 1997). More abundant (0.07 vs. 0.02 ind./ha) on hybrid poplar plantations than hay/pasture fields in Minnesota, Wisconsin and South Dakota. Not observed in rowcrops (Hanowski *et al*., 1998).	Short Rotation Forestry

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
		2005).	Observed (10 nests; 0.7% of all nests) in hayland in southern Saskatchewan (McMaster *et al.*, 2005). Occurred more commonly on native grasslands than annual hayed and periodic hayed habitats (33 - 75 vs. 0 - 38 and 0 - 20% of census plots, respectively) in south central Saskatchewan (Dale *et al.*, 1997).	Hayland management
Chipping sparrow	*S. passerina*		Observed (0.08 ind./km of transect) only in CRP fields in Midwest (Best *et al.*, 1997).	Permanent Cover Program
Vesper sparrow	*Pooecetes gramineus*	Adapted to nest on bare or nearly bare soil. Nesting period: April 30 - July 31 (Lokemoen and Beiser, 1997). Species of concern in Nebraska (Robinson, 1997; Sauer *et al.*, 2001 quoted by Beecher *et al.*, 2002).	Abundant in strip cover in Iowa (Stallman and Best, 1996). Nested more frequently in strip cover fields (16 nests/100ha) than in tilled fields (2 nests/100ha) in Iowa (Best *et al.*, 1986). Higher abundance (32 vs. 8 breeding pairs/100 acres) on field strips than conventional cropland in Ohio (Good and Dambach, 1943).	Strip cropping
			Detected commonly more in CRP (40.5% of sites) than in cropland (11.9% of sites) in the Prairies Ecozone (McMaster and Davis, 2001).	Permanent Cover Program
			Nests more abundant in no-till (5 - 8 nests/100ha) than in tilled fields (2 nests/100ha) in Iowa (Best *et al.*, 1986). Occurred (1.11 ind./field in fall) only in reduced tillage fields in the Texas Panhandle (Flickinger and Pendleton, 1994).	Conservation tillage
			Nests most abundant (269 nests; 19.0% of all nests) in hayland in southern Saskatchewan (McMaster *et al.*, 2005).	Hayland management
			Nested frequently in mowed grassed waterways, Iowa (Bryan and Best, 1991, 1994).	Grassed waterways

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			Observed (0.8 ind./10ha) only in organic (using crop rotation) sites in Nebraska (Beecher *et al*., 2002).	Crop rotation
			More abundant (82 vs. 55 ind.) on organic (under manure application) than in conventional sites in southern Ontario (Freemark and Kirk, 2001).	Manure application
			Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt
Song sparrow	*Melospiza melodia*	Declining population in Québec (Deschênes *et al*., 2003). Habitat generalist (Christian *et al*., 1997).	Greater abundance (1.38 vs. 0.10 ind./km of transect) in CRP fields than in rowcrop fields in the Midwest (Best *et al*., 1997).	Permanent Cover Program
			Occurred (11 ind., 4.1% of total bird observations) only in no-till farms in Illinois (Warburton and Klimstra, 1984).	Conservation tillage
			More abundant (0.94 vs. 0.78 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001).	Wetland restoration
			Nested (4 nests/100ha) only in strip cover fields in Iowa. No nests in tilled corn fields (Basore *et al*., 1986). Occurred (6 breeding pairs/100 acres) only on field strips in Ohio (Good and Dambach, 1943).	Strip cropping
			Most common in grassed waterways in Iowa (Bryan and Best, 1991, 1994).	Grassed waterways
			Greater density in bordered (30.96 birds/ha) than non-bordered (8.29 birds/ha) agricultural field edges adjacent to grassland habitats in Mississippi (Smith *et al*., 2005).	Vegetative filter strip

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			Most abundant in riparian strips in Québec (Deschênes *et al*., 2003) and in Iowa (93.5 ind/100ha in warm-season grasses, 28 nests, Henningsen and Best, 2005).	Riparian buffer strip
			Observed on hybrid poplar plantations in north central US (Christian *et al*., 1997). Abundant (0.10 ind./ha) on hybrid poplar plantations in Minnesota, Wisconsin and South Dakota. Not observed in rowcrop and hay/pasture fields (Hanowski *et al*., 1998).	Short Rotation Forestry
			Occurred more on ungrazed (84% of observations, 067 ind./ha) than moderately grazed (16% of observations, 0.09 ind./ha) prairie in Québec. Not observed on intensively grazed prairie (Bélanger and Picard, 1999).	Pasture and range management
			Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt
Swamp sparrow	*M. georgiana*		Most observed (91.8 % of observations) along bordered transects in Mississippi (Smith *et al*., 2005).	Vegetative filter strip
			Occurred abundantly on moderately grazed and ungrazed prairie (60% and 40% of observations, 3.03 and 4.93 ind./ha, respectively) in Québec. No observations on intensively grazed prairie (Bélanger and Picard, 1999).	Pasture and range management
Lincoln's sparrow	*M. lincolnii*	Open-ground and edge bird (Whitaker and Montevecchi, 1999).	More abundant along riparian buffer strips (0.19 ind./transect) than undisturbed shorelines (0.06 ind./transect) in the boreal forest area in Newfoundland (Whitaker and Montevecchi, 1999).	Riparian buffer strip

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Lark sparrow	*Chondestes grammacus*	Species of concern in Nebraska (Robinson, 1997; Sauer *et al*., 2001 quoted by Beecher *et al*., 2002).	Occurred (4 ind.; 1.5% of total bird observations) only in no-till farms in Illinois (Warburton and Klimstra, 1984).	Conservation tillage
			More abundant (1.1 vs. 0.05 ind./10ha) in organic (using crop rotation) than non-organic sites in Nebraska (Beecher *et al*., 2002).	Crop rotation
White-throated sparrow	*Zonotrichia albicollis*	Open-ground and edge bird (Whitaker and Montevecchi, 1999).	More abundant along riparian buffer strips (1.63 ind./transect) than undisturbed shorelines (0.75 ind./transect) in the boreal forest area in Newfoundland (Whitaker and Montevecchi, 1999).	Riparian buffer strip
Fox sparrow	*Passerella iliaca*	Ubiquitous bird (Whitaker and Montevecchi, 1999).	Observed only along riparian buffer strips (0.31 ind./transect) in the boreal forest area in Newfoundland (Whitaker and Montevecchi, 1999).	Riparian buffer strip
American kestrel	*Falco sparverius*		Nested only in prominent snags in herbaceous and shrubby fencerow in Michigan (Shalaway, 1985).	Retention of connectivity
Red-winged blackbird	*Agelaius phoeniceus*	Declining population in Québec (Deschênes *et al*., 2003). Nesting period: June 20 - July 20 (Lokemoen and Beiser, 1997).	Nested principally (294 nests/100ha) in strip cover fields in Iowa; no nests in tilled corn fields. (Basore *et al*., 1986).	Strip cropping
			More abundant (9.7 vs. 0.9 pairs/100ha) in CRP fields than in cropland in North Dakota (Johnson and Igl, 1995). Nested more in CRP fields (16.4 pairs/100ha) than in cropland (1.1 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993). Greater abundance (3.92 vs. 0.92 ind./km of transect) in CRP fields than in rowcrop fields in the Midwest (Best *et al*., 1997).	Permanent Cover Program

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			More abundant in no-till fields (79% of total observation) than in conventional till fields (21%) in Illinois (Warburton and Klimstra, 1984). More abundant (2.67 vs. 0.50 ind./field in summer) in reduced than conventional tillage fields in the Texas Panhandle (Flickinger and Pendleton, 1994). Most abundant in minimum tillage in North Dakota (Lokemoen and Beiser, 1997).	Conservation tillage
			Occurred (4.14 ind./10ha) on restored wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001).	Wetland restoration
			Most abundant in organic fields in North Dakota (Lokemoen and Beiser, 1997) and in Nebraska (3.0 ind./10ha, Beecher *et al.*, 2002).	Crop rotation
			More abundant (116.6 vs. 47.4 ind./100ha) in strip-harvest biomass than rowcrop fields in Iowa (Murray *et al.*, 2003).	Perennial energy crops
			Most abundant in all riparian strip types in Québec (Deschênes *et al.*, 2003) and in Iowa (428 ind./100ha, 54% of total abundance, 514 nests, Henningsen and Best, 2005).	Riparian buffer strip
			More abundant (119 vs. 83 ind.) on organic (under manure application) than conventional sites in southern Ontario (Freemark and Kirk, 2001).	Manure application
			Nested abundantly (566 nests/100ha) in grassed waterways in Iowa (Bryan and Best, 1991, 1994).	Grassed waterways

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			More abundant on moderately grazed (81% of observations, 1.68 ind./ha) than ungrazed prairie (19% of observations, 0.93 ind./ha) in Québec. No observations on intensively grazed prairie (Bélanger and Picard, 1999).	Pasture and range management
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*		Occurred (3.78 ind./field) only in reduced tillage fields in the Texas Panhandle (Flickinger and Pendleton, 1994).	Conservation tillage
Brown-headed cowbird	*Molothrus ater*	Declining population in Québec (Deschênes *et al*., 2003; Bélanger and Picard, 1999). Habitat generalist (Christian *et al*., 1997). Nesting period: April 15 - July 30 (adapted from Best *et al.*, 1986).	Nested principally in strip cover fields in Iowa (186 nests/100ha) (Basore *et al*., 1986). Abundant in strip cover in Iowa (Stallman and Best, 1996).	Strip cropping
			More abundant in no-till corn-sod (19 nests/100ha) than in tilled corn fields (2 nests/100ha) in Iowa (Basore *et al*., 1986).	Conservation tillage
			More abundant on restored than natural wetlands in North and South Dakota (1.73 vs. 1.51 ind./10ha) (Ratti *et al.*, 2001).	Wetland restoration
			Detected commonly more in CRP (5.9% of sites) than in cropland (2.7% of sites) in the Prairies Ecozone (McMaster and Davis, 2001). More abundant (4.6 vs. 1.5 pairs/100ha) in CRP fields than in cropland in North Dakota (Johnson and Igl, 1995). Nested more in CRP fields (5.5 pairs/100ha) than in cropland (2.7 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993). Greater abundance (0.62 vs. 0.23 ind./km of transect) in CRP fields than in rowcrop fields in the Midwest (Best et al., 1997).	Permanent Cover Program

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			Occurred only on moderately grazed prairie (0.09 ind./ha) in Québec (Bélanger and Picard, 1999). Quoted in ERIN Consulting Ltd. (2006).	Pasture and range management
			Most common in grassed waterways in Iowa (Bryan and Best, 1991	Grassed waterways
			Most observed in grassy strips in Mississippi (Smith *et al*., 2005).	Vegetative filter strip
			Observed only in wooded riparian strips in Québec (Deschênes *et al*., 2003).	Riparian buffer strip
			Observed on hybrid poplar plantations in north central US (Christian *et al*., 1997). More abundant on hybrid poplar plantations (0.10 ind./ha) than in rowcrops (0.01 ind./ha) and hay/pasture fields (0.01 ind./ha) in Minnesota, Wisconsin and South Dakota (Hanowski *et al*., 1998).	Short Rotation Forestry
			More abundant on organic (under manure application) than conventional sites in southern Ontario (Freemark and Kirk, 2001).	Manure application
Eastern kingbird	*Tyrannus tyrannus*	Grassland bird (Christian *et al*., 1997). Native species in east central Nebraska (Johnsgard, 1979 quoted by Beecher *et al*., 2002).	Abundant on hybrid poplar plantations in north central US (Christian *et al*., 1997).	Short Rotation Forestry
			More abundant (101 vs. 55 ind.) on organic (under manure application) than in conventional sites in southern Ontario (Freemark and Kirk, 2001).	Manure application
			More abundant on restored than natural wetlands in North and South Dakota (0.48 vs. 0.37 ind./10ha) (Ratti *et al*., 2001).	Wetland restoration

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			Nested more in CRP fields (2.1 pairs/100ha) than in cropland (0.2 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993). Greater abundance in CRP fields than in rowcrop fields in Midwest (0.09 vs. 0.05 ind./km of transect) (Best *et al*., 1997).	Permanent Cover Program
			More abundant in organic (using crop rotation) than non-organic sites in Nebraska (2.3 vs. 0.8 ind./10ha) (Beecher *et al*., 2002).	Crop rotation
Western kingbird	*T. verticalis*		Nested more in CRP fields (1.8 pairs/100ha) than in cropland (0.3 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993).	Permanent Cover Program
Chestnut-collared longspur	*Calcarius ornatus*	Species of high management concern in Saskatchewan (McMaster *et al.*, 2005).	Occurred predominantly (0.46 vs. 0.18 ind/100-m-radius) in minimum till, versusconventional till farms, in Alberta (Martin and Forsyth, 2003). More abundant in reduced than in conventional tillage fields in the Texas Panhandle (439.44 vs. 123.22 ind./field in winter for all 3 longspur species) (Flickinger and Pendleton, 1994).	Conservation tillage
			Detected more commonly in CRP (9.7% of sites) than in cropland (2.1% of sites) in the Prairies Ecozone (McMaster and Davis, 2001). Nested only in CRP fields (2.3 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993).	Permanent Cover Program
			Quoted in ERIN Consulting Ltd. (2006).	Pasture management

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			Observed (10 nests; 0.7% of all nests) in hayland in southern Saskatchewan (McMaster *et al.*, 2005). Occurred more commonly on native grassland than annual hayed habitats (0 - 50 vs. 4 - 25% of census plots) and only on moved plots (8% of census plots) of annual hayed fields in south central Saskatchewan. Not observed on periodic hayed fields (Dale *et al.*, 1997).	Hayland management
McCown's longspur	*C. mccownii*		More abundant (1.08 vs. 0.72 ind/100-m-radius) in minimum than conventional till fields in Alberta (Martin and Forsyth, 2003). More abundant in reduced than in conventional tillage fields in the Texas Panhandle (439.44 vs. 123.22 ind./field in winter for all 3 longspur species) (Flickinger and Pendleton, 1994).	Conservation tillage
Lapland longspur	*C. lapponicus*		More abundant in reduced than conventional tillage fields in the Texas Panhandle (439.44 vs. 123.22 ind./field in winter for all 3 longspur species) (Flickinger and Pendleton, 1994).	Conservation tillage
Killdeer	*Charadrius vociferus*	Declining population in Québec (Deschênes *et al.*, 2003). Not of concern in Midwest. Adapted to nest on bare or nearly bare soil. Nesting period: April 1 - June 30 (adapted from Best *et al.*, 1986).	Occurred in grazed and grassy riparian strip types in Québec (Deschênes *et al.*, 2003).	Riparian buffer strip
			More abundant (0.33 vs. 0.19 ind./10ha) on restored than natural wetlands in North and South Dakota (Ratti *et al.*, 2001).	Wetland restoration

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Bobolink	*Dolichonyx oryzivorus*	Species of conservation concern (Sauer *et al*., 1996 quoted by Best *et al*., 1997) and of high management concern in Saskatchewan (McMaster *et al.*, 2005). Has undergone significant population declines in Midwest (Johnson and Schwartz, 1993; Johnson and Igl, 1995; Ryan, 2000). Declining population in Québec (Deschênes *et al*., 2003).	More abundant (3.9 vs. 2.1 pairs/100ha) in CRP fields than in Cropland in North Dakota (Johnson and Igl, 1995).Nested more in CRP fields (4.2 pairs/100ha) than in cropland (1.2 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993). Observed (0.79 ind./km of transect) only in CRP fields in Midwest (Best *et al*., 1997).	Permanent Cover Program
			Nested (1 nest/100ha) only in no-till corn-sod fields in Iowa (Basore *et al*., 1986).	Conservation tillage
			Occurred on restored wetlands in North and South Dakota (4.34 ind./10ha) (Ratti *et al.*, 2001).	Wetland restoration
			Observed (1 nest; 0.07% of all nests) in hayland in southern Saskatchewan (McMaster *et al.*, 2005). Seldom occurred on native grassland (0 - 17% of census plots). Occurred commonly on annual hayed (0 - 38% of census plots) and periodic hayed (8 - 98% of census plots) habitats in south central Saskatchewan (Dale *et al.*, 1997). Increase in the rate of fledging from 0 to 20% with 1.5 weeks delay in hay harvesting (to 1 July) (Nocera *et al*., 2005).	Hayland management
			Observed in riparian strips in Québec (Deschênes *et al*., 2003).	Riparian buffer strip
			Observed (6.4 ind./100ha) only in strip-harvest biomass in Iowa (Murray *et al.*, 2003).	Perennial energy crops

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			More abundant on moderately grazed (89% of observations) than ungrazed prairie (11% of observations) in Québec. No observation on intensively grazed prairie (Bélanger and Picard, 1999; as cited by ERIN Consulting Ltd., 2006).	Pasture and range management
Northern bobwhite	*Colinus virginianus*	Species of conservation concern (Sauer *et al*., 1996 quoted by Best *et al*., 1997).	Nested exclusively in no-till fields in Tennessee (Minser and Dimmick, 1998; Dimmick and Minser, 1998).	Conservation tillage
			Greater abundance (0.17 vs. 0.03 ind./km of transect) in CRP fields than in rowcrop fields in the Midwest (Best *et al*., 1997).	Permanent Cover Program
			Occurred in fencerow habitat (Brennan, 1991).	Wooded fencerow
			Occurred in filter strip habitat (Brennan, 1991).	Vegetative filter strip
			Quoted in ERIN Consulting Ltd. (2006).	Hayland management
Bobwhite quail	*C. virginianus*		More abundant in no-till than conventional fields in Illinois (95% vs. 5% of total observations) (Warburton and Klimstra, 1984).	Conservation tillage
			Occurred on filter strips in North Carolina (Puckett *et al*., 2000 quoted by Brady, 2007).	Vegetative filter strip
Sedge wren / Short-billed marsh wren	*Cistothorus platensis*	Species of high conservation concern (Sauer *et al*., 1996 quoted by Best *et al*., 1997; Bélanger and Picard, 1999).	Observed only in CRP fields in North Dakota (1.5 pairs/100ha) (Johnson and Igl, 1995). Nested only in CRP fields in the northern Great Plains (2.6 pairs/100ha) (Johnson and Schwartz, 1993). Occurred only in CRP fields in Midwest (0.31 ind./km of transect) (Best *et al*., 1997).	Permanent Cover Program

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			More abundant on restored than natural wetlands in North and South Dakota (4.71 vs. 3.70 ind./10ha) (Ratti *et al.*, 2001).	Wetland restoration
			Observed only in strip-harvest biomass in Iowa (10.8 ind./100ha) (Murray *et al.*, 2003).	Perennial energy crops
			Occurred only on ungrazed grazed prairie (0.20 ind./ha) in Québec (Bélanger and Picard, 1999).	Pasture and range management
			Occurred (17.5 ind./100ha in cool-season grasses) in riparian filter strips in Iowa (Henningsen and Best, 2005).	Riparian buffer strip
			Nested commonly in grassed waterways in Iowa (Bryan and Best, 1991, 1994).	Grassed waterways
Marsh wren / Long-billed marsh wren	*C. palustris*		More abundant on moderately grazed and ungrazed prairies (83% and 17% of observations; 0.26 and 0.20 ind./ha) than intensively grazed prairie (0% of observations, 0 ind./ha) in Québec (Bélanger and Picard, 1999).	Pasture and range management
Carolina wren	*Thryothorus ludovicianus*		More abundant (7.2 vs. 2.0 ind./patch) in large contiguous forests than in a fragmented forest landscape in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Mourning dove	*Zenaida macroura*	Adapted to nest on bare or nearly bare soil (Lokemoen and Beiser, 1997). Habitat generalist bird	Nested (2 - 5 nests/100ha) only in no-till fields in Iowa. No nests in tilled corn fields (Basore *et al.*, 1986). More abundant in no-till fields (71% of total observations) than conventional till fields (29%) in Illinois (Warburton and Klimstra, 1984).	Conservation tillage

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
		(Christian *et al*., 1997). Native species in east central Nebraska (Johnsgard, 1979 quoted by Beecher *et al*., 2002)	Observed on hybrid poplar plantations in north central US (Christian *et al*., 1997). More abundant on hybrid poplar plantations (0.04 ind./ha) than rowcrops (0.01 ind./ha) and hay/pasture fields (0.01 ind./ha) in Minnesota, Wisconsin and South Dakota (Hanowski *et al*., 1998).	Short Rotation Forestry
			Nested (4nests/100ha) in strip cover fields in Iowa. No nests in tilled corn fields (Basore *et al*., 1986).	Strip cropping
			More abundant (2.8 vs. 0.7 ind./10ha) on organic (using crop rotation) than non-organic sites in Nebraska (Beecher *et al*., 2002).	Crop rotation
			Nested more in CRP fields (1.7 pairs/100ha) than in cropland (1.3 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993).	Permanent Cover Program
			More abundant (40 vs. 12 ind.) on organic (under manure application) than in conventional sites in southern Ontario (Freemark and Kirk, 2001).	Manure application
			Occurred (3 nests) only in woody fencerow in Michigan (Shalaway, 1985).	Wooded fencerow
			Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt
Short eared owl	*Asio flammeus*	Species of management concern in Saskatchewan (McMaster *et al.*, 2005).	Nested abundantly in managed grasslands in southeastern Illinois (Herkert *et al*., 1999) and in hayland in southern Saskatchewan (1 nest; 0.07% of all nests, McMaster *et al.*, 2005).	Hayland management
Burrowing owl	*Athene cunicularia*		Quoted in ERIN Consulting Ltd. (2006).	Pasture management

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Barn owl	*Tyto alba*		Quoted in ERIN Consulting Ltd. (2006).	Hayland management
Northern harrier	*Circus cyaneus*	Species of management concern in Saskatchewan (McMaster *et al.*, 2005).	Nested abundantly (62%) in undisturbed grassland tracks in southeastern Illinois (Herkert *et al.*, 1999) and in hayland in southern Saskatchewan (2 nests; 0.1% of all nests, McMaster *et al.*, 2005).	Hayland management
Upland sandpiper	*Bartramia longicauda*	Species of conservation concern (Sauer *et al.*, 1996 quoted by Best *et al.*, 1997). High-priority shorebird in Saskatchewan (McMaster *et al.*, 2005).	Most abundant in minimum tillage in North Dakota (Lokemoen and Beiser, 1997).	Conservation tillage
			Most abundant in organic fields (using crop rotation) in north Dakota (Lokemoen and Beiser, 1997). More abundant (1.0 vs. 0.005 ind./10ha) in organic than conventional sites in Nebraska (Beecher *et al.*, 2002).	Crop rotation
			Observed (17 nests; 1.2 of all nests) in hayland in southern Saskatchewan (McMaster *et al.*, 2005).	Hayland management
			Greater nest density (18.5 nests/100ha) observed on fields with autumn grazing than fields with spring or season-long (7.5 or 8.5 nests/100ha) graze in south central North Dakota (Bowen and Kruse, 1993). Quoted in ERIN Consulting Ltd. (2006).	Pasture and range management
Willet	*Catoptrophorus semipalmatus*	High-priority shorebird in Saskatchewan (McMaster *et al.*, 2005).	Observed (4 nests; 0.3 of all nests) in hayland in southern Saskatchewan (McMaster *et al.*, 2005).	Hayland management
Marblet godwit	*Lomosa fedoa*	High-priority shorebird in Saskatchewan (McMaster *et al.*, 2005).	Observed (6 nests; 0.4 of all nests) in hayland in southern Saskatchewan (McMaster *et al.*, 2005).	Hayland management

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Wilson's phalarope	*Phalaropus tricolor*	High-priority shorebird in Saskatchewan (McMaster *et al.*, 2005).	Observed (12 nests; 0.9 of all nests) in hayland in southern Saskatchewan (McMaster *et al.*, 2005).	Hayland management
Lark Bunting	*Calamospiza melanocorys*	Species of concern in Midwest. Has undergone significant population declines in North Dakota (Johnson and Igl, 1995; Lokemoen and Beiser, 1997). Nesting period: May 20 - June 30.	Most abundant in minimum tillage in North Dakota (Lokemoen and Beiser, 1997).	Conservation tillage
			More abundant (8.6 vs. 1.3 pairs/100ha) in CRP fields than in cropland in North Dakota (Johnson and Igl, 1995). Nested more in CRP fields (22.4 pairs/100ha) than in cropland (4.2 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993).	Permanent Cover Program
			Nest abundantly in organic fields (using crop rotation) in North Dakota (Lokemoen and Beiser, 1997). More abundant in organic than nonorganic sites in Nebraska (1.1 vs. 0.05 ind./10ha) (Beecher *et al*., 2002).	Crop rotation
Indigo bunting	*Passerine cyanea*	Species of conservation concern in Nebraska (Robinson, 1997 and Sauer *et al*., 2001 quoted by Beecher *et al*., 2002).	More abundant in no-till fields (95% of total observations) than in conventional till fields (5%) in Illinois (Warburton and Klimstra, 1984).	Conservation tillage
			More abundant (1.5 vs. 0.5 ind./10ha) in organic (using crop rotation) than non-organic sites in Nebraska (Beecher *et al*., 2002).	Crop rotation
			Occurred in riparian filter strips in Iowa (3.6 ind./100ha in cool-season grasses) (Henningsen and Best, 2005).	Riparian buffer strip

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Sprague's pipit	*Anthus spragueii*	Obligate grassland species. Endemic to the Canadian mixed grass prairie (Dale *et al.*, 1997).	Occurred more commonly on idle and annual hayed than periodic hayed habitats (83 - 100 and 58 - 88% vs. 0 - 67% of census plots) and on mowed than unmowed plots (83 vs. 58% of census plots) in south central Saskatchewan. Greater abundance on native unhayed and annual hayed fields (2.5 and 1.5 male territories/100-m-radius, respectively) than on periodic hayed fields (1 male territory/100-m-radius) (Dale *et al.*, 1997). Quoted in ERIN Consulting Ltd. (2006).	Hayland management
			Quoted in ERIN Consulting Ltd. (2006).	Pasture management
Bell's vireo	*Vireo belli*	Species of conservation concern (Sauer *et al.*, 1996 quoted by Best *et al.*, 1997)		
Red-eyed vireo	*V. olivaceus*	Interior species (McIntyre, 1995)	More abundant (0.8 vs. 0.2 ind./patch) in large continuous forests than in fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Warbling vireo	*V. gilvus*		Found (0.11 ind./km^2) only in hedgerows in southern Québec (Jobin *et al*., 2001).	Wooded fencerow
Black-billed cuckoo	*Coccyzus erythropthalmus*		Occurred (1 nest) only in shrubby fencerow in Michigan (Shalaway, 1985).	Wooded fencerow
Northern flicker / common flicker	*Colaptes auratus*	Ubiquitous bird (Whitaker and Montevecchi, 1999).	Occurred (3 nests) in woody fencerows in Michigan (Shalaway, 1985). Found abundantly in hedgerows (0.31 ind./km^2) and in windbreaks (0.14 ind./km^2) in southern Québec. No observations in herbaceous fencerows (Jobin *et al*., 2001).	Wooded fencerow

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			More abundant (1.2 vs. 0.2 ind/patch) in large continuous forests than in fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
			Observed (0.04 ind./km of transect) only in CRP fields in Midwest (Best *et al*., 1997).	Permanent Cover Program
			Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt
			Observed only along riparian buffer strips (0.06 ind./transect) in the boreal forest area in Newfoundland (Whitaker and Montevecchi, 1999)	Riparian buffer strip
Northern cardinal	*Cardinalis cardinal*		Nested in shrubby (9 nests) or woody (6 nests) fencerows in Michigan (Shalaway, 1985).	Wooded fencerow
Brown thrasher	*Toxostoma rufum*		Nested (3 nests) in woody fencerows in Michigan (Shalaway, 1985).	Wooded fencerow
Gray catbird	*Dumetella carolinensis*	Declining population in Québec (Deschênes *et al*., 2003). Edge species (McIntyre, 1995)	Nested in shrubby (3 nests) or woody (2 nests) fencerows in Michigan (Shalaway, 1985). Found abundantly (0.11 ind/km^2) in hedgerows in southern Québec (Jobin *et al*., 2001).	Wooded fencerow
			Occurred in riparian strips in Québec (Deschênes *et al*., 2003).	Riparian buffer strip
			Occurred only in large continuous forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Black-capped chickadee	*Parus atricapillus*	Habitat generalist bird (Christian *et al*., 1997).	Occurred (2 nests) only in shrubby fencerows in Michigan (Shalaway, 1985). Found abundantly in windbreaks (0.74 ind./km^2) and in hedgerows (0.23 ind./km^2) in southern Québec (Jobin *et al*., 2001).	Wooded fencerow
			Observed on hybrid poplar plantations in north central US (Christian *et al*., 1997).	Short Rotation Forestry

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Carolina chickadee	*Poecile carolinensis*	Interior species (McIntyre, 1995).	More abundant (11.6 vs. 2.3 ind./patch) in large continuous forests than in fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Blue jay	*Cyanocitta cristata*		Occurred (1 nest) only in shrubby fencerow in Michigan (Shalaway, 1985).	Wooded fencerow
			More abundant (1.3 vs. 0.4 ind./10ha) in organic (using crop rotation) than non-organic sites in Nebraska (Beecher *et al*., 2002).	Crop rotation
Gray jay	*Perisoreus canadensis*	Open-ground and edge bird (Whitaker and Montevecchi, 1999).	Observed only along riparian buffer strips (0.25 ind./transect) in the boreal forest area in Newfoundland (Whitaker and Montevecchi, 1999).	Riparian buffer strip
Ruby-throated hummingbird	*Arehilochus colubris*		Occurred (1 ind., 0.4% of observations) only on no-till farms in Illinois (Warburton and Klimstra, 1984).	Conservation tillage
			Occurred only in large contiguous forests in Illinois (Blake and Karr, 1984).	Conservation of large woodlot block
American goldfinch	*Carduelis tristis*		Occurred (1 ind., 0.4% of observations) only in no-till farms in Illinois (Warburton and Klimstra, 1984).	Conservation tillage
			More abundant on hybrid poplar plantations (0.10 ind./ha) than in rowcrops (0.01 ind./ha) in Minnesota, Wisconsin and South Dakota. Not observed in hay/pasture fields (Hanowski *et al*., 1998).	Short Rotation Forestry
			Greater abundance (0.27 vs. 0.03 ind./km of transect) in CRP fields than in rowcrop fields in Midwest (Best *et al*., 1997).	Permanent Cover Program
			Nested (2 nests/100ha) only in strip cover fields in Iowa. No nests in tilled corn fields (Basore *et al*., 1986).	Strip cropping

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			Occurred (6.5 ind./100ha in cool-season grasses) in riparian filter strips in Iowa (Henningsen and Best, 2005).	Riparian buffer strip
Barn swallow	*Hirundo rustica*	Native species in east central Nebraska (Johnsgard, 1979 quoted by Beecher *et al*., 2002).	Most common in grassed waterways in Iowa (Bryan and Best, 1991).	Grassed waterways
			Nested more in CRP fields (1.8 pairs/100ha) than in cropland (0.3 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993). Greater abundance (0.14 vs. 0.12 ind./km of transect) in CRP fields than in rowcrop fields in Midwest (Best *et al*., 1997).	Permanent Cover Program
			More abundant (12.1 vs. 5.7 ind./10ha) in organic (using crop rotation) than non-organic sites in Nebraska (Beecher *et al*., 2002).	Crop rotation
			Abundant (64.7 ind./100ha in cool-season grasses) in riparian filter strips in Iowa (Henningsen and Best, 2005).	Riparian buffer strip
Cliff swallow	*Petrochelidon pyrrhonota*		Abundant (64.7 ind./100ha in warm-season grasses) in riparian filter strips in Iowa (Henningsen and Best, 2005).	Riparian buffer strip
Northern rough-winged Swallow	*Stelgidopteryx serripennis*	Native species in east central Nebraska (Johnsgard, 1979 quoted by Beecher *et al*., 2002).	More abundant (1.7 vs. 0.6 ind./10ha) in organic (using crop rotation) than non-organic sites in Nebraska (Beecher *et al*., 2002).	Crop rotation
Least flycatcher	*Empidonax minimus*	Declining population in Québec (Deschênes *et*	Observed only in wooded riparian strips in Québec (Deschênes *et al*., 2003).	Riparian buffer strip

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
		al., 2003).	Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt
Olive-sided flycatcher	*Contopus borealis*	Open-ground and edge bird (Whitaker and Montevecchi, 1999).	Occurred only along riparian buffer strips (0.13 ind./transect) in the boreal forest area in Newfoundland (Whitaker and Montevecchi, 1999).	Riparian buffer strip
Great crested flycatcher	*Myiarchus crinitus*		Occurred only in large contiguous forest patches in Georgia (McIntyre, 1995).	Conservation of large woodlot block
			Occurred (8 ind.) on organic (under manure application). Only 2 observations in conventional sites in southern Ontario (Freemark and Kirk, 2001).	Manure application
Alder flycatcher	*Empidonax alnorum*		Found (0.16 ind./km^2) only in hedgerows in southern Québec (Jobin *et al*., 2001).	Wooded fencerow
Willow flycatcher	*E. traillii*		Found (0.15 ind./km^2) only in hedgerows in southern Québec (Jobin *et al*., 2001).	Wooded fencerow
Blue-gray gnatcatcher	*Polioptila caerulea*	Interior species (McIntyre, 1995).	More abundant (4.2 vs. 0.2 ind./patch) in large continuous forests than in fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Rose-breasted grosbeak	*Pheucticus ludovicianus*	Declining population in Québec (Deschênes *et al*., 2003).	Occurred (6 ind.) on organic (under manure application). Only 1 observation in conventional sites in southern Ontario (Freemark and Kirk, 2001).	Manure application
			Observed only in tall shrubby riparian strips in Québec (Deschênes *et al*., 2003).	Riparian buffer strip
Veery	*Catharus fuscescens*	Declining population in Québec (Deschênes *et al*., 2003).	Observed only in tall shrubby and wooded riparian strips in Québec (Deschênes *et al*., 2003).	Riparian buffer strip
Wood thrush	*Hylocichla mustelina*	Declining population in Québec (Deschênes *et al*., 2003).	Observed only in tall shrubby and wooded riparian strips in Québec (Deschênes *et al*., 2003).	Riparian buffer strip

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Louisiana waterthrush	*Seiurus motacilla*	Interior species (McIntyre, 1995).	Occurred only in large continuous forest in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Golden-crowned kinglet	*Regulus satrapa*	Interior species (McIntyre, 1995).	More abundant (4.9 vs. 0.9 ind./patch) in large continuous forests than in fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Ruby-crowned kinglet	*R. calendula*	Interior species (McIntyre, 1995).	More abundant (2.7 vs. 0.7 ind./patch) in large continuous forests than in fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Common yellowthroat	*Geothlypis trichas*		Occurred (2 ind., 0.7% of total observations) only in no-till farms in Illinois (Warburton and Klimstra, 1984).	Conservation tillage
			More abundant (1.81 vs. 1.57 ind./10ha) on restored than natural wetlands in North and South Dakota (Ratti *et al.*, 2001).	Wetland restoration
			Nests located most frequently in CRP field (Best et al., 1997). Observed (2.1 pairs/100ha) in CRP fields in North Dakota (Johnson and Igl, 1995). Nested only in CRP fields (3.3 pairs/100ha) in the northern Great Plains (Johnson and Schwartz, 1993). Greater abundance (0.77 vs. 0.02 ind./km of transect) in CRP fields than in rowcrop fields in Midwest (Best *et al.*, 1997).	Permanent Cover Program
			More abundant in strip-harvest biomass than rowcrop fields in Iowa (106.5 vs. 1.0 ind./100ha) (Murray *et al.*, 2003).	Perennial energy crops
			Nested commonly in grassed waterways in Iowa (Bryan and Best, 1991, 1994)	Grassed waterways

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			Abundant (112.2 ind./100ha in warm-season grasses, 27 nests) in riparian filter strips in Iowa (Henningsen and Best, 2005.	Riparian buffer strip
			More abundant on hybrid poplar plantations (0.04 ind./ha) than in rowcrops (0.01 ind./ha) and hay/pasture fields (0.03 ind./ha) in Minnesota, Wisconsin and South Dakota (Hanowski *et al*., 1998).	Short Rotation Forestry
			Occurred abundantly on moderately and ungrazed grazed prairie (54% and 46% of observations, 0.65 and 1.20 ind./ha) in Québec. No observation on intensively grazed prairie (Bélanger and Picard, 1999).	Pasture and range management
			Quoted in ERIN Consulting Ltd. (2006).	Shelterbelts
Yellow-rumped warbler	*Dendroica coronata*	Ubiquitous bird (Whitaker and Montevecchi, 1999).	More abundant (13.5 vs. 1.5 ind./patch) in large continuous forests than in fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
			More abundant along riparian buffer strips (2.31 ind./transect) than undisturbed shorelines (1.75 ind./transect) in the boreal forest area in Newfoundland (Whitaker and Montevecchi, 1999).	Riparian buffer strip
Yellow warbler	*D. petechia*		Found (0.82 ind./km^2) only in hedgerows in southern Québec (Jobin *et al*., 2001).	Wooded fencerow
			Observed in all riparian strip types in Québec (Deschênes *et al*., 2003).	Riparian buffer strip
			Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			Occurred more on ungrazed (71% of observations, 1.27 ind./ha) than moderately grazed prairie (29% of observations, 0.35 ind./ha) in Québec. No observation on intensively grazed prairie (Bélanger and Picard, 1999).	Pasture and range management
Pine warbler	*D. pinus*	Interior species (McIntyre, 1995).	More abundant (2.9 vs. 1.5 ind./patch) in large contiguous forestpatches than in fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Black-throated green warbler	*D.virens*	Interior species (McIntyre, 1995).	Occurred only in large contiguous forest patches in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Yellow-throated warbler	*D. dominica*	Interior species (Blake and Karr, 1984).	Occurred only in large contiguous forest patches in Illinois (Blake and Karr, 1984).	Conservation of large woodlot block
Cerulean warbler	*D. cerulea*	Forest interior species (Blake and Karr, 1984).	Occurred only in large contiguous forest patches in Illinois (Blake and Karr, 1984).	Conservation of large woodlot block
Magnolia warbler	*D. magnolia*	Open-ground and edge bird (Whitaker and Montevecchi, 1999).	More abundant along riparian buffer strips (0.81 ind./transect) than undisturbed shorelines (0.13 ind./transect) in the boreal forest area in Newfoundland (Whitaker and Montevecchi, 1999).	Riparian buffer strip
Blackpoll warbler	*D. striata*	Ubiquitous bird (Whitaker and Montevecchi, 1999).	More abundant along riparian buffer strips (0.56 ind./transect) than undisturbed shorelines (0.25 ind./transect) in the boreal forest area in Newfoundland (Whitaker and Montevecchi, 1999).	Riparian buffer strip
Hooded warbler	*Wilsonia citrina*	Forest interior species (Blake and Karr, 1984).	Occurred only in large contiguous forest patches in Illinois (Blake and Karr, 1984).	Conservation of large woodlot block

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Mourning warbler	*Oporornis philadelphia*	Open-ground and edge bird (Whitaker and Montevecchi, 1999).	More abundant along riparian buffer strips (0.75 ind./transect) than undisturbed shorelines (0.13 ind./transect) in the boreal forest area in Newfoundland (Whitaker and Montevecchi, 1999).	Riparian buffer strip
Kentucky warbler	*O. formosus*	Interior species (McIntyre, 1995).	Occurred only in large contiguous forest patches in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Black-and-white warbler	*Mniotilta varia*	Interior species (McIntyre, 1995).	More abundant (2.7 vs. 0.1 ind/patch) in large contiguous forest patches than in fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
			Occurred (7 ind.) on organic (under manure application); only 2 observations in conventional sites, in southern Ontario (Freemark and Kirk, 2001).	Manure application
Downy woodpecker	*Picoides pubescens*		More abundant (4.3 vs. 1.1 ind./patch) in large contiguous forest patches than fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
			Found (0.15 ind./km^2) only in hedgerows in southern Québec (Jobin *et al*., 2001).	Wooded fencerow
Pileated woodpecker	*Dryocopus pileatus*	Interior species (McIntyre, 1995).	More abundant (1.2 vs. 0.1 ind./patch) in large contiguous forest patches than in fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Red-bellied woodpecker	*Melanerpes carolinus*	Interior species (McIntyre, 1995).	More abundant (5.2 vs. 1.9 ind./patch) in large contiguous forest patches than fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Eastern wood-pewee	*Contopus virens*		Occurred (13 ind.) on organic (under manure application). Only 2 observations in conventional sites in southern Ontario (Freemark and Kirk, 2001).	Manure application

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Northern parula	*Parula americana*		Occurred only in large contiguous forest patches in Georgia (McIntyre, 1995) and in Illinois (Blake and Karr, 1984).	Conservation of large woodlot block
American redstart	*Setophaga ruticilla*	Interior species (McIntyre, 1995; Blake and Karr, 1984).	Occurred only in large contiguous forest patches in Georgia (McIntyre, 1995) and in Illinois (Blake and Karr, 1984).	Conservation of large woodlot block
American crow	*Corvus brachyrhynchos*		Found abundantly in windbreaks (1.24 ind./km^2) and hedgerows (0.44 ind./km^2) in southern Québec (Jobin *et al*., 2001).	Wooded fencerow
Dark-eyed junco	*Junco hyemalis*	Open-ground and edge bird (Whitaker and Montevecchi, 1999).	Observed only along riparian buffer strips (0.19 ind./transect) in the boreal forest area in Newfoundland (Whitaker and Montevecchi, 1999).	Riparian buffer strip
Common grackle	*Quiscalus quiscula*		More abundant (1.6 vs. 0.4 ind./10ha) on organic (using crop rotation) than non-organic sites in Nebraska (Beecher *et al*., 2002).	Crop rotation
			Observed in all riparian strip types in Québec (Deschênes *et al*., 2003).	Riparian buffer strip
Baltimore oriole	*Icterus galbula*		More abundant (2.0 vs. 0.5 ind./10ha) in organic (using crop rotation) than non-organic sites in Nebraska (Beecher *et al*., 2002).	Crop rotation
			Found (0.38 ind./km^2) only in hedgerows in southern Québec (Jobin *et al*., 2001).	Wooded fencerow
Northern oriole	*I. galbula*		Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt
Summer tanager	*Piranga rubra*	Interior species (McIntyre, 1995).	Occurred only in large contiguous forest patchess in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Sharp-shinned hawk	*Accipiter striatus*	Interior species (McIntyre, 1995).	Occurred only in large contiguous forest patches in Georgia (McIntyre, 1995).	Conservation of large woodlot block

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Red-shouldered hawk	*Buteo lineatus*	Edge species (McIntyre, 1995).	Occurred only in large contiguous forest patches in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Red-tailed hawk	*B. jamaicensis*		Occurred (7 ind.) on organic (under manure application); only 2 observations in conventional sites in southern Ontario (Freemark and Kirk, 2001).	Manure application
Belted kingfisher	*Megaceryle alcyon*	Edge species (McIntyre, 1995).	Occurred only in large, contiguous forest patches in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Tufted titmouse	*Baeolophus bicolor*	Interior species (McIntyre, 1995).	More abundant (11.9 vs. 2.7 ind./patch) in large contiguous forest patches than in fragmented forests in Georgia (McIntyre, 1995).	Conservation of large woodlot block
Ring-necked pheasant	*Phasianus colchicus*	Species of conservation concern (Sauer *et al*., 1996 quoted by Best *et al*., 1997). Nesting period: April 15 - July 30 (Best *et al*., 1986).	Nested (12 nests/100ha) only in no-till corn-sod fields in Iowa. No nests in tilled corn fields (Basore *et al*., 1986).	Conservation tillage
			Nested (35 nests/100ha) principally in strip cover fields in Iowa (Basore *et al*., 1986).	Strip cropping
			More abundant (3.3 vs. 1.0 ind./100ha) in strip-harvest biomass than rowcrop fields in Iowa (Murray *et al*., 2003).	Perennial energy crops
			More abundant (2.43 vs. 1.71 ind./station) in areas with approximately 20% of cropland in the CRP program than in areas with <5%, in southeast Nebraska (King and Savidge, 1995). Greater abundance in CRP fields than in rowcrop fields in Midwest (0.18 vs. 0.04 ind./km of transect) (Best *et al*., 1997). Nested exclusively in CRP land in Texas (Berthelsen *et al*. 1990).	Permanent Cover Program

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			Abundant in grassed waterways in Iowa (Bryan and Best, 1991, 1994).	Grassed waterways
			Nested (8 nests) in riparian filter strips in Iowa (Henningsen and Best, 2005).	Riparian buffer strip
			Abundant tracks on hybrid poplar plantations in Minnesota, Wisconsin and South Dakota Christian (1997).	Short Rotation Forestry
			Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt
Gray partridge	*Perdix perdix*		Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt
Sharp-tailed grouse	*Tympanuchus phasianellus*	Species of management concern in Saskatchewan (McMaster *et al*., 2005).	Nested (11 nests; 0.8% of all nests) in hayland in southern Saskatchewan (McMaster *et al*., 2005).	Hayland management
			Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt
Greater prairie chicken	*Tympanuchus cupido*	Species of conservation concern	Quoted in ERIN Consulting Ltd. (2006).	Hayland management
Waterfowl				
Northern pintail	*Anas acuta*	Declining population. Species of high management concern (Bélanger and Picard, 1999; McMaster *et al*., 2005). Nesting period: April 15 - May 30 (Lokemoen and Beiser, 1997).	Nested commonly in minimum tillage fields in North Dakota (Lokemoen and Beiser, 1997) and in zero tillage fields in Manitoba (Cowan, 1982).	Conservation tillage
			Nested abundantly in hayland in southern Saskatchewan (136 nests, 11.4% of all nests, 13.5% of waterfowl nests, McMaster *et al*., 2005).	Hayland management
			Abundant on moderately grazed and ungrazed prairie (26% of observations of the 5 species recorded) in Québec (Bélanger and Picard, 1999).	Pasture and range management

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			More abundant (1.29 vs. 0.17 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001).	Wetland restoration
			Most abundant in organic fields in North Dakota (Lokemoen and Beiser, 1997).	Crop rotation
Mallard	*A. platyrynchos*		Nested commonly in zero tillage fields in Manitoba (Cowan, 1982).	Conservation tillage
			Nested mostly in hayland in southern Saskatchewan (181 nests, 18.5% of waterfowl nests, McMaster *et al*., 2005).	Hayland management
			Nested more commonly in restored than natural wetlands in prairie potholes (2.6 vs. 0.9 pairs/18-m-circular plots in northern Iowa, Delphey and Dinsmore, 1993; .0.32 vs. 0.06 pairs/habitat in Prince Edward Island (Stevens et al., 2003). More abundant (2.72 vs. 0.89ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al*., 2001).	Wetland restoration
			Occurred only on moderately grazed and ungrazed prairies in Québec (Bélanger and Picard, 1999). Abundant nests in rotationally grazed fields, 17 nests (65.4%) - 42 nests (63.6% of all dabbling duck nests) observed in pasture land in California (Carroll *et al.*, 2007).	Pasture and range management
Northern shoveler	*A. clypeata*		Nested commonly in zero tillage fields in Manitoba (Cowan, 1982).	Conservation tillage
			Occurred only on moderately grazed and ungrazed prairie in Québec (Bélanger and Picard, 1999).	Pasture and range management

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
			More abundant (1.59 vs. 0.26 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001).	Wetland restoration
			Nested mostly (160 nests, 15.9% of waterfowl nests) in hayland in southern Saskatchewan (McMaster et al., 2005).	Hayland management
Gadwall	*A. strepera*		Nest commonly in zero tillage fields in Manitoba (Cowan, 1982).	Conservation tillage
			Occurred only on moderately grazed and ungrazed prairie in Québec (Bélanger and Picard, 1999). Abundant nests in rotationally grazed fields, 4 nests (15.4%) - 13 nests (19.7% of all dabbling duck nests) observed in pasture land in California (Carroll *et al.*, 2007).	Pasture and range management
			More abundant (3.02 vs. 0.97 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001). Nested more commonly (0.55 vs. 0 pairs/habitat) in restored than in reference wetlands in Prince Edward Island (Stevens *et al.*, 2003).	Wetland restoration
			Nested mostly in hayland in southern Saskatchewan (272 nests; 29% of waterfowl nests, McMaster et al., 2005).	Hayland management
Cinnamon teal	*A. cyanoptera*		Abundant nests in rotational grazed fields, 5 nests (19.2%) - 11 nests (16.7% of all dabbling duck nests) observed in pasture land in California (Carroll *et al.*, 2007).	Pasture and range management

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
American green-winged teal	*A. crecca*		More abundant (0.43 vs. 0.07 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001). Nested more commonly (0.8 vs. 0.18 pairs/habitat) in restored than reference wetlands in Prince Edward Island (Stevens *et al.*, 2003).	Wetland restoration
Blue-winged teal	*A. discors*		Occurred only on moderately and ungrazed prairies in Québec (Bélanger and Picard, 1999).	Pasture and range management
			More abundant (3.48 vs. 1.61 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001). Nested more commonly (0.43 vs. 0.06 pairs/habitat) in restored than reference wetlands in Prince Edward Island (Stevens *et al.*, 2003).	Wetland restoration
			Nested mostly in hayland in southern Saskatchewan (198 nests; 19.2% of waterfowl nests, McMaster *et al.*, 2005).	Hayland management
			Nested more commonly in restored than natural wetlands in prairie potholes in northern Iowa (1.9 vs. 1.6 pairs/18-m-circular plots) (Delphey and Dinsmore, 1993).	Wetland restoration
			Nested commonly in zero tillage fields in Manitoba (Cowan, 1982).	Conservation tillage
American black duck	*A. rubripes*		Occurred only on moderately grazed and ungrazed prairie in Québec (Bélanger and Picard, 1999).	Pasture and range management
			Nested more commonly (1.38 vs. 0.67 pairs/habitat) in restored than reference wetlands in Prince Edward Island (Stevens *et al.*, 2003).	Wetland restoration

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Lesser scaup	*Aythya affinis*		Nests only in zero tillage field in Manitoba (Cowan, 1982).	Conservation tillage
			More abundant (.0.27 vs. 0.21 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001).	Wetland restoration
			Nested in hayland in Saskatchewan (11 nests; 0.8% of all nests, McMaster *et al.*, 2005)	Hayland management
Wood duck / Carolina duck	*Aix sponsa*	Edge species (McIntyre, 1995).	Occurred only in large contiguous forest patches in Georgia (McIntyre, 1995).	Conservation of large woodlot block
			Occurred (0.14 ind./10ha) on restored wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001).	Wetland restoration
Canada goose	*Branta canadensis*		Occurred only in large contiguous forest patches in Georgia (McIntyre, 1995).	Conservation of large woodlot block
			More abundant (1.40 vs. 0.28 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001).	Wetland restoration
American coot	*Fulica americana*		More abundant (3.90 vs. 0.84 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001).	Wetland restoration
Pied-billed grebe	*Podilymbus podiceps*		More abundant (0.32 vs. 0.10 ind./10ha) on restored than natural wetlands in North and South Dakota (Ratti *et al.*, 2001).	Wetland restoration
Redhead	*Aythya americana*		More abundant (0.47 vs. 0.10 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001).	Wetland restoration

Table 31: Summary of avian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Ring-necked duck	*A. collaris*		Nested more commonly (1.02 vs. 0.06 pairs/habitat) in restored than reference wetlands in Prince Edward Island (Stevens *et al*., 2003).	Wetland restoration
Ruddy duck	*Oxyura jamaicensis*		More abundant (0.62 vs. 0.24 ind./10ha) on restored than natural wetlands in North and South Dakota (PPR) (Ratti *et al.*, 2001).	Wetland restoration
Turkey				
Wild turkey	*Meleagris gallopavo*	Interior species (McIntyre, 1995).	Occurred only in large contiguous forest patches in Georgia (McIntyre, 1995).	Conservation of large woodlot block

5.2 Mammals

Table 32: Summary of mammalian studies.

Common name	**Scientific name**	**Population trend or status / remarks**	**Efficacy of agricultural BMPs / comments**	**BMPs**
Small mammals				
Prairie deer mice	*Peromyscus maniculatus*		73% of total captures in conventional fields and 93% in no-till fields, in Illinois (Warburton and Klimstra, 1984).	Conservation tillage
			Most abundant in hybrid poplar plantations in Oregon (77.5% of total observations, Moser *et al*., 2002) and in north central US (5.3 ind./50 traps; Christian *et al*., 1997).	Short rotation forestry
			Most abundant in woody patches in agricultural landscapes (Silva *et al*., 2005).	Retention of connectivity
			95% of individuals captured in wooded riparian strips in Québec (Maisonneuve and Rioux, 2001). More abundant in buffer strips (37.4 ind./1000 trap nights) than on pasture sites (1.1 ind./1000 trap nights) along the cold-water streams in southwestern Wisconsin (Chapman and Ribic, 2002).	Riparian buffer strip
White-footed mice	*P. leucopus*	Considered as woodland species (Yahner, 1983).	Observed in no-till fields in Illinois (Warburton and Klimstra, 1984).	Conservation tillage
			Most abundant (31.2% of total individuals) in shelterbelts in Minnesota (Yahner, 1983).	Shelterbelt
			Most abundant (0.3 ind./50 traps) in hybrid poplar plantations in north central US (Christian *et al*., 1997).	Short rotation forestry

Table 32: Summary of mammalian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
House mice	*Mus musculus*		Dependent on greater residue in no-tilled row crop fields (Castrale, 1985). Observed in no-till fields in Illinois (Warburton and Klimstra, 1984).	Conservation tillage
			Occurred (6.1% of observations) in hybrid poplar plantations in Oregon (Moser *et al*., 2002).	Short rotation forestry
			More abundant on buffer strips (4.3 ind./1000 trap nights) than pasture sites (0.3 ind./1000 trap nights) along the cold-water streams in southwestern Wisconsin (Chapman and Ribic, 2002).	Riparian buffer strip
Great basin pocket mice	*Perognathus parvus*		Occurred (9.0% of observations) in hybrid poplar plantation in Oregon (Moser *et al*., 2002).	Short rotation forestry
Western harvest mouse	*Reithrodontomys megalotis*		Occurred (1.1% of observations) in hybrid poplar plantation in Oregon (Moser *et al*., 2002).	Short rotation forestry
			Observed only on buffer strips (4.3 ind./1000 trap nights) along the cold-water streams in southwestern Wisconsin (Chapman and Ribic, 2002).	Riparian buffer strip
			Captured only in prairie-grass habitat (100% of individuals) in Oklahoma (Payne and Caire, 1999).	Permanent Cover Program
Eastern harvest mouse	*R. humulis*		Captured only in prairie-grass habitat (100% of individuals) in Oklahoma (Payne and Caire, 1999).	Permanent Cover Program
Plains harvest mouse	*R. montanus*		Most captures in prairie-grass habitat (97% of individuals); no captures in disturbed areas (0%) in Oklahoma (Payne and Caire, 1999).	Permanent Cover Program

Table 32: Summary of mammalian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Woodland jumping mouse	*Napaeozapus insignis*		Occurred in riparian strips in Québec (Maisonneuve and Rioux, 2001).	Riparian buffer strip
Meadow jumping mouse	*Zapus hudsonius*		Most abundant (42.1% of all captures) in riparian strips in Québec (Maisonneuve and Rioux, 2001).	Riparian buffer strip
Meadow vole / field mouse	*Microtus pennsylvanicus*		Abundant (10.3% of total individuals) in shelterbelts in Minnesota (Yahner, 1983).	Shelterbelt
			Quoted in ERIN Consulting Ltd. (2006).	Pasture management
Montane vole	*M. montanus*		Occurred (1.6% of observations) in hybrid poplar plantation in Oregon (Moser *et al*., 2002).	Short rotation forestry
Woodland vole	*M. pinetorum*		Captured only in prairie-grass habitat (100% of individuals) in Oklahoma (Payne and Caire, 1999).	Permanent Cover Program
Prairie vole	*M. ochrogaster*		Most captures in prairie-grass habitat (92% of individuals); few in disturbed areas (3%) in Oklahoma (Payne and Caire, 1999).	Permanent Cover Program
Red-backed vole	*Clethrionomys gapperi*	Considered as woodland species (Yahner, 1983).	58% of individuals captured in wooded riparian strips in Québec (Maisonneuve and Rioux, 2001).	Riparian buffer strip
			Abundant (10.1% of total individuals) in shelterbelts in Minnesota (Yahner, 1983).	Shelterbelt
Ord's kangaroo rat	*Dipodomys ordii*		Occurred (0.7% of observations) in hybrid poplar plantations in Oregon (Moser *et al*., 2002).	Short rotation forestry
Hispid cotton rat	*Sigmodon hispidus*		Primarily captured in prairie-grass habitat (71% of individuals), compared to disturbed areas (6%) in Oklahoma (Payne and Caire, 1999).	Permanent Cover Program

Table 32: Summary of mammalian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Cinereus shrew/masked shrew/ common shrew	*Sorex cinereus*		Most abundant in riparian strips in Québec (28.5% of all captures) (Maisonneuve and Rioux, 2001). More abundant on buffer strips (1.3 ind./1000 trap nights) than pasture sites (0.3 ind./1000 trap nights) along the cold-water streams in southwestern Wisconsin (Chapman and Ribic, 2002).	Riparian buffer strip
			Abundant (7.7% of total individuals) in shelterbelts in Minnesota (Yahner, 1983).	Shelterbelt
Smoky shrew	*S. fumeus*		75% of individuals captured in shrubby riparian strips in Québec (Maisonneuve and Rioux, 2001).	Riparian buffer strip
Merriam's shrew	*S. merriami*		Occurred (4.1% of observations) in hybrid poplar plantation in Oregon (Moser *et al*., 2002).	Short rotation forestry
Northern short-tail shrew	*Blarina brevicauda*		Abundant (10.4% of all captures) in riparian strips in Québec (Maisonneuve and Rioux, 2001). More abundant on buffer strips (4.9 ind./1000 trap nights) than pasture sites (1.3 ind./1000 trap nights) along the cold-water streams in southwestern Wisconsin (Chapman and Ribic, 2002).	Riparian buffer strip
			Most abundant (33.2% of total individuals) in shelterbelts in Minnesota (Yahner, 1983).	Shelterbelt
			Quoted in ERIN Consulting Ltd. (2006).	Pasture management
Elliot's short-tailed shrew	*B. hylophaga*		Primarily captured in prairie-grass habitat (82% of individuals); no captures in disturbed areas (0%) in Oklahoma (Payne and Caire, 1999).	Permanent Cover Program

Table 32: Summary of mammalian studies.

Common name	**Scientific name**	**Population trend or status / remarks**	**Efficacy of agricultural BMPs / comments**	**BMPs**
Star-nosed mole	*Condylura cristata*		Occurred in riparian strips in Québec (Maisonneuve and Rioux, 2001).	Riparian buffer strip
North American red squirrel	*Tamiasciurus hudsonicus*	Obligate coniferous cone seed feeders.	Winter use of hybrid poplar plantations as travel corridors in Minnesota, Wisconsin and South Dakota (Christian, 1997).	Short rotation forestry
			Generally depended on mature coniferous pine and spruce trees (Fisher *et al.*, 2005, quoted in ERIN Consulting Ltd., 2006).	Retention of connectivity
Eastern gray squirrel	*Sciurus carolinensis*		Winter use of hybrid poplar plantations as travel corridors in Minnesota, Wisconsin and South Dakota (Christian, 1997).	Short rotation forestry
Fox squirrel	*S. niger*		Winter use of hybrid poplar plantations as travel corridors in Minnesota, Wisconsin and South Dakota (Christian, 1997).	Short rotation forestry
Eastern chipmunk	*Tamias striatus*		Benefited from the presence of hedgerow cover within 400 m of forest patches, possibly allowing them to move between patches. Most abundant in woody and relatively well connected patches in agricultural landscape (43% of all small mammal individuals) (Silva *et al*., 2005)	Retention of connectivity
Mid-sized and large mammals				
Opossum	*Didelphis virginiatum*		Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt
Raccoon	*Procyon lotor*		Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt
			Most frequent in fencerows (Koford and Best, 1996, quoted in ERIN Consulting Ltd. (2006)).	Wooded fencerow

Table 32: Summary of mammalian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Elk / wapiti	*Cervus canadensis*		Quoted in ERIN Consulting Ltd. (2006).	Pasture management
White-tailed deer	*Odocoileus virginiatus*		More abundant tracks in hybrid poplar plantations (mean count of 31) than in rowcrop (1 track) and hayfield/pasture (4 tacks) during winter in Minnesota, Wisconsin and South Dakota (Christian, 1997).	Short rotation forestry
			Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt
Red fox	*Vulpes vulpes*		Winter use of hybrid poplar plantations as travel corridors in Minnesota, Wisconsin and South Dakota (Christian, 1997).	Short rotation forestry
			Most frequent in fencerows (Koford and Best, 1996, quoted in ERIN Consulting Ltd., 2006).	Wooded fencerow
Striped skunk	*Mephitis mephitis*		Most frequent in fencerows (Koford and Best, 1996, quoted in ERIN Consulting Ltd., 2006).	Wooded fencerow
Long-tailed weasel	*Mustela frenata*		Most frequent in fencerows (Koford and Best, 1996, quoted in ERIN Consulting Ltd., 2006).	Wooded fencerow
Snowshoe hare	*Lepus americanus*		Winter use of hybrid poplar plantations as travel corridors in Minnesota, Wisconsin and South Dakota (Christian, 1997).	Short rotation forestry
White-tailed jackrabbit/ prairie hare	*L. townsendii*		Winter use of hybrid poplar plantations as travel corridors in Minnesota, Wisconsin and South Dakota (Christian, 1997).	Short rotation forestry
Eastern cottontail rabbit	*Sylvilagus floridanus*		Winter use of hybrid poplar plantations as travel corridors in Minnesota, Wisconsin and South Dakota (Christian, 1997).	Short rotation forestry
			Quoted in ERIN Consulting Ltd. (2006).	Shelterbelt

Table 32: Summary of mammalian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Coyote	*Canis latrans*		Winter use of hybrid poplar plantations as travel corridors in Minnesota, Wisconsin and South Dakota (Christian, 1997).	Short rotation forestry

5.3 Soil invertebrates

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Earthworm	*Aporrectodea turgida* (Lumbricidae)		Predominated no-till soil in experimental area in Athens (House, 1985).	Conservation tillage
	Lumbricus rubellus (Lumbricidae)		Predominated no-till soil in experimental area in Athens (House, 1985). Abundant in no-till fields in Indiana and Illinois (Kladivko *et al*., 1997).	Conservation tillage
	L. terrestris		Activity noted mainly in no-till fields in Indiana and Illinois (Kladivko *et al*., 1997).	Conservation tillage
Macro-arthropod	Ground beetles (Carabidae: Coleoptera)		Predominated no-till soil in experimental area in Athens (House, 1985).	Conservation tillage
	Spiders (Araneae)		Predominated no-till soil in experimental area in Athens (House, 1985).	Conservation tillage
	Detritivores (Oligochaeta, Coleoptera)		Abundant in no-till fields in central Queensland, Australia (Robertson *et al*., 1994).	Conservation tillage

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
	Predators (Chilopoda, Coleoptera)		Abundant in no-till fields in central Queensland, Australia (Robertson *et al*., 1994).	Conservation tillage
Micro-arthropod	Acarina (meso-stigmatids, prostig-matids, oribatids and astigmatids)		Predominated no-till soil in experimental area in Athens (House, 1985).	Conservation tillage
	Collembola		Predominated no-till soil in experimental area in Athens (House, 1985).	Conservation tillage

5.4 Amphibians

Table 33: Summary of amphian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
American toad	*Bufo americanus*		Most abundant species in riparian strips in Québec (Maisonneuve and Rioux, 2001).	Riparian buffer strip
			Occurred on restored wetlands in Minnesota (Lehtinen and Galatowitsch, 2001).	Wetland restoration
			Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity
Canada toad	*B. hemiophrys*		Occurred on restored wetlands in Minnesota (Lehtinen and Galatowitsch, 2001).	Wetland restoration

Table 33: Summary of amphian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Fowler's toad	*B. woodhousii fowleri*	Native species in the New Jersey Pinelands (Zampella and Bunnell, 2000).	Occurred only in an unaltered river system in the New Jersey Pinelands (Zampella and Bunnell, 2000).	Manure management and improved storage and handling
Northern leopard frog	*Rana pipiens*	Species of concern.	Most abundant species in riparian strips in Québec (Maisonneuve and Rioux, 2001).	Riparian buffer strip
			Occurred on restored wetlands in Minnesota (Lehtinen and Galatowitsch, 2001).	Wetland restoration
			Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity
Wood frog	*R. sylvatica*		Most abundant species in riparian strips in Québec (Maisonneuve and Rioux, 2001).	Riparian buffer strip
			Occurred on restored wetlands in Minnesota (Lehtinen and Galatowitsch, 2001).	Wetland restoration
			Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity
Green frog	*R. clamitans*		Occurred in riparian strips in Québec (Maisonneuve and Rioux, 2001).	Riparian buffer strip
			Occurred on restored wetlands in Minnesota (Lehtinen and Galatowitsch, 2001).	Wetland restoration
			Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity
Pickerel frog	*R. palustris*		Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity

Table 33: Summary of amphian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Northern green frog	*R. clamitans melanota*	Native species in the New Jersey Pinelands (Zampella and Bunnell, 2000).	Occurred only in an unaltered river system in the New Jersey Pinelands (Zampella and Bunnell, 2000).	Manure management and improved storage and handling
Carpenter frog	*R. virgatipes*	Native species in the New Jersey Pinelands (Zampella and Bunnell, 2000).	Occurred only in an unaltered river system in the New Jersey Pinelands (Zampella and Bunnell, 2000).	Manure management and improved storage and handling
Southern leopard frog	*R. utricularia*	Native species in the New Jersey Pinelands (Zampella and Bunnell, 2000).	Occurred only in an unaltered river system in the New Jersey Pinelands (Zampella and Bunnell, 2000).	Manure management and improved storage and handling
Pine Barrens treefrog	*Hyla andersonii*	Native species in the New Jersey Pinelands (Zampella and Bunnell, 2000).	Occurred only in an unaltered river system in the New Jersey Pinelands (Zampella and Bunnell, 2000).	Manure management and improved storage and handling
Gray tree frog	*H. versicolor*		Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity
			Occurred on restored wetlands in Minnesota (Lehtinen and Galatowitsch, 2001).	Wetland restoration
Cope's grey tree frog	*H. chrysoscelis*		Occurred on restored wetlands in Minnesota (Lehtinen and Galatowitsch, 2001).	Wetland restoration
Spring peeper	*Pseudacris crucifer*	Native species in the New Jersey Pinelands (Zampella and Bunnell, 2000).	Occurred only in an unaltered river system in the New Jersey Pinelands (Zampella and Bunnell, 2000).	Manure management and improved storage and handling
			Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity

Table 33: Summary of amphian studies.

Common name	Scientific name	Population trend or status / remarks	Efficacy of agricultural BMPs / comments	BMPs
Western chorus frog	*P. triseriata*		Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity
			Occurred on restored wetlands in Minnesota (Lehtinen and Galatowitsch, 2001).	Wetland restoration
Tiger salamander	*Ambystoma tigrinum*		Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity
			Occurred on restored wetlands in Minnesota (Lehtinen and Galatowitsch, 2001).	Wetland restoration
Larval blue-spotted salamander	*A. laterale*		Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity
Eastern Newt	*Notophthalmus viridescens*		Occurred on restored wetlands in Minnesota (Lehtinen and Galatowitsch, 2001).	Wetland restoration

5.5 Fishes

Table 34: Summary of fish studies.

Common name	Scientific name	Status / population trend / other	Comments	BMPs
Blacknose dace	*Rhinichthys atratulus*	Acid-sensitive fish species (Baker *et al*., 1996).	Occurred only in non-acidic streams in the northeastern United States (Baker *et al*., 1996).	Manure management and improved storage and handling
Slimy sculpin	*Cottus cognatus*	Acid-sensitive fish species (Baker *et al*., 1996).	Occurred only in non-acidic streams in the northeastern United States (Baker *et al*., 1996).	Manure management and improved storage and handling
Mottled sculpin	*C. bairdii*	Acid-sensitive fish species (Baker *et al*., 1996).	Occurred only in non-acidic streams in the northeastern United States (Baker *et al*., 1996).	Manure management and improved storage and handling
Brook stickleback	*Culea inconstans*		Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity
Creek chub	*Semotilus atromaculatus*		Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity
Green sunfish	*Lepomis cyanellus*		Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity
Central mud minnow	*Umbra limi*		Observed in small agricultural ponds in southeastern Minnesota (Knutson *et al*., 2004).	Retention of connectivity

6 CONCLUSION

An extensive review of the literature, documenting qualitative and quantitative evidence for the efficacy of BMPs has revealed that the majority do, to some degree, contribute to the conservation of biodiversity in agricultural areas. BMPs clearly help supplement habitat for many wildlife species, including unique species and certain species of conservation concern. Evidently, those practices of upmost priority, in terms of overall benefit to biodiversity, include permanent cover and conservation reserve plantings, grassland/ hayland management, pasture and range management, retention of connectivity, conservation tillage, wooded fencerows, riparian buffer strips and wetland restoration. For example, 14 bird and 3 small mammal studies yielded increases in species richness and abundance in the permanent cover and conservation reserve plantings. Five (5) bird studies, and 1 small mammal study provided positive results for the grassland/ hayland management BMPs. Seven (7) bird studies found positive effects of pasture and range management. With respect to conservation tillage BMPs, 9, 2, 17 studies, examining bird, small mammal and soil fauna, respectively, yielded increases in species diversity and/or abundance.

In total, at least 126 bird species, 28 small mammals, 12 mid-sized and large mammals, 18 amphibians, 7 fishes and many soil fauna species have been documented to have directly benefited from the BMPs (details are provided in the species management section). There is an apparent lack of research on the enhancement of native plants species diversity and abundance by agricultural BMPs, and we were unable to evaluate the size or percentage of all agricultural land under BMPs.

For all BMPs reviewed, birds are the principal taxa studied. A considerable abundance and diversity of small mammals were reported in the permanent cover and grassland management, woodlot management, soil management, and riparian areas and water management categories. However, 1 study on extensive grazing (pasture and range management BMPs) yielded no effects on small mammal diversity and abundance. Existing literature on the efficacy of BMPs in contribution to mammal diversity remains insufficient, and therefore further research is needed.

Enhanced soil fauna diversity and abundance were observed primarily under soil management practices (conservation tillage, strip cropping, crop rotations and cover crops) and the manure and nutrient application category. Few studies have been carried out on nutrient management BMPs, and those available provide little evidence to evaluate their contribution to wildlife species richness or abundance. It is recommended that more research be conducted, to monitor the biodiversity conservation benefits of this category of BMPs.

Available literature pertaining to biodiversity in short rotation forestry and large woodlot conservation s BMPs has provided significant evidence of increases in the richness and abundance of long-distance migrant birds, and mid-sized and large mammals. Surprisingly, these BMPs are not included in national and provincial BMP lists. Similarly, the agroforestry system (alley cropping), known to increase plant diversity (Pimentel *et al.*, 1992), is not considered on national and provincial BMP lists.

This review has also highlighted the fact that BMPs must be tailored to the local landscape. For example, the CRP is suitable in prairie grasslands and unsuitable in forested landscapes. Also, establishment of plantations and conservation of large woodlots is not recommended in grassland habitats. Other limitations of BMPs include the small size of BMP lands, low abundance and diversity of forest-dwelling mammals on plantations, and insufficient impact of BMPs on the conservation of certain species at risk and unique species (e.g., only 5 of 11 songbirds of conservation concern nested in managed haylands of the Missouri Coteau, red-listed species such as dormouse and red squirrel are unlikely to find suitable habitat in short rotation forestry).

The majority of BMP studies were carried out in the US and it would be favorable to verify these results in a Canadian context prior to application. The procedures used to study the impact of BMPs on biodiversity varied enormously, making it difficult to compare and assess their overall efficacy. For example, the most common approach involved comparative analysis of biodiversity in agriculture under BMPs versus control areas (e.g., rowcrops, natural lands, field margins and road side). However some studies evaluated biodiversity, examined changes in biodiversity or trends in time, in areas with and without BMPs. Other studies compared selected species diversity or abundance. For an accurate evaluation of BMPs, it will be important to establish a standard method of scientific evaluation, including:

- Establishing indictor species for each ecological habitat (e.g., wetland, riparian area) or ecosystem (savannah, forest);
- Using a paired study approach (e.g., BMPs area vs. cropland);
- Identifying reliable measurable parameters (e.g., species diversity, density, abundance);
- Carrying out statistical tests.

7 REFERENCES

Agriculture and Agri-Food Canada. AAFC. 2008a. National Farm Stewardship Program. Lists of provincial Beneficial Management Practices (BMPs). Agriculture and Agri-Food Canada website. http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1181580600540&lang=e. Downloaded on March 26, 2008.

Agriculture and Agri-Food Canada. AAFC. 2008b. The Permanent Cover Program - Is Twice Enough? Agriculture and Agri-Food Canada website. http://www.agr.gc.ca/pfra/pub/pcpaper2.htm. Downloaded on April 2, 2008.

Aude, E., K. Tybirk, and M. Bruus Pedersen. 2003. Vegetation diversity of conventional and organic hedgerows in Denmark. Agriculture, Ecosystems and Environment. 99 (1/3): 135-147.

Baker, J.P., J. Van Sickle, C.J. Gagen, D.R. DeWalle, W.E. Sharpe, R.F. Carline, B.P. Baldigo, P.S. Murdoch, D.W. Bath, W.A. Krester, H.A. Simonin, and P.J. Wigington, Jr. 1996. Episodic acidification of small streams in the Northeastern United States: Effects on fish populations. Ecological Applications. 6 (2): 422-437.

Barbour, M. and J. Litvaitis. 1993. Niche dimensions of New England cottontails in relation to habitat patch size. Oecologia. 95: 321-327.

Barton, D.R. and M.E.D. Farmer. 1997. The effects of conservation tillage practices on benthic invertebrate communities in headwater streams in southwestern Ontario, Canada. Environmental Pollution. 96: 207-215.

Basore, N.S., L.B. Best, and J.B. Wooley. 1986. Bird nesting in Iowa no-tillage and tilled cropland. Journal Wildlife Management. 50 (1): 19-28.

Basore, N.S., L.B. Best, and J.B. Wooley. 1987. Arthropod availability to pheasant broods in no-tillage fields. Wildlife Society Bulletin. 15 (2): 229-233.

Beecher, N.A., R.J. Johnson, J.R. Brandle, R.M. Case, and L.J. Young. 2002. Agroecology of birds in organic and nonorganic Farmland. Conservation Biology. 16 (6): 1620-1631.

Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. Conservation Biology. 7 (1): 94-108.

Bélanger, L. and M. Picard. 1999. Cattle grazing and avian communities of the St. Lawrence River islands. Journal of Range Management. 52 (4): 332-338.

Benckiser, G. 1997. Organic inputs and soil metabolism. In: G. Benckiser (ed.). Fauna in Soil Ecosystems. Marcel Dekker, New York. pp. 7-62.

Bennett, A.F. 1990. Habitat corridors and the conservation of small mammals in a fragmented forest environment. Landscape Ecology. 4(2/3): 109-122.

Berthelsen, P.S., L.M. Smith, and R.R. George. 1990. Ring-necked pheasant nesting ecology and production on CRP lands in the Texas southern High Plains. Transactions of the North American Wildlife and Natural Resources Conference. 55: 46-56.

Best, L.B. 1983. Bird use of fencerows: Implications of contemporary fencerow management practices. Wildlife Society Bulletin. 11 (4): 343-347.

Best, L.B., R.C. Whitmore, and G.M. Booth. 1990. Use of cornfields by birds during the breeding season: the importance of edge habitat. American Midland Naturalist. 123: 84-99.

Best, L.B., H. Campa III, K.E. Kemp, R.J. Robel, M.R. Ryan, J.A. Savidge, H.P. Weeks, and S.R. Winterstein. 1997. Bird abundance and nesting in CRP fields and cropland in the Midwest: A regional approach. Wildlife Society Bulletin. 25: 864-877.

Best, L.B., H. Campa III, K.E. Kemp, R.J. Robel, M.R. Ryan, J.A. Savidge, H.P. Weeks, and S.R. Winterstein. 1998. Avian abundance in CRP and crop fields during winter in the Midwest. American Midland Naturalist. 139: 311-324.

Bishop, C.A., N.A. Mahony, J. Struger, P. Ng, and K.E. Pettit. 1999. Anuran development, density and diversity in relation to agricultural activity in the Holland river watershed, Ontario, Canada (1990-1992). Environmental Monitoring and Assessment. 57: 21-43.

Blake, J.G.and J.R. Karr. 1984. Species composition of bird communities and the conservation benefit of large versus small forests. Biological Conservation. 30 (2): 173-187.

Blumberg, A.Y. and D.A. Crossley, Jr. 1983. Comparison of soil surface arthropod populations in conventional tillage, no-tillage and old field systems. Agro-Ecosystems. 8 (2/4): 247- 253.

Bolger, D., A. Alberts, R. Sauvajot, P. Potenza, C. McCalvin, D. Tran, S. Mazzoni, and M. Soulé. 1997. Response of rodents to habitat fragmentation in coastal southern California. Ecological Applications. 7 (2): 552-563.

Boone, F.R., S. Slager, R. Miedema, and R. Eleveld. 1976. Some influences of zero-tillage on the structure and stability of a fine textured river levee soil. Netherlands Journal of Agricultural Science. 24: 105-119.

Bowen, B. S. and A.D. Kruse. 1993. Effects of grazing on nesting by upland sandpipers in south central North Dakota. Journal of Wildlife Management 57: 291-301.

Boyer, J., A. Chabanne, and L. Seguy. 2001. Impact of cultivation practices (cover crops) on soil macrofauna in Réunion. CIRAD-editions. September 2001. 1p. http://agroecologie.cirad.fr/pdf/postjben.pdf. Downloaded on January 8, 2008

Brady, S.J. 2007. Effects of Cropland Conservation Practices on Fish and Wildlife Habitat. In Fish and Wildlife Response to Farm Bill Conservation Practices. The Wildlife Society. Technical Review 07-1. pp. 9-23.

Brennan, L.A. 1991. How can we reverse the Northern Bobwhite population decline? Wildlife Society Bulletin. 19: 544-555.

Brown, M. and J. Dinsmore 1986. Implications of marsh size and isolation for marsh bird management. Journal of Wildlife Management. 50 (3): 392-397.

Brown, S.C. and C.R. Smith. 1998. Breeding season bird use of recently restored versus natural wetlands in New York. Journal of Wildlife Management. 62 (4): 1480-1491.

Brown, S.C., K. Smith, and D. Batzer. 1997. Macroinvertebrate responses to wetland restoration in northern New York. Environmental Entomology. 26: 1016-1024.

Bryan, G.G. and L.B. Best. 1991. Bird abundance and species richness in grassed waterways in Iowa rowcrop fields. American Midland Naturalist. 126: 90-102.

Bryan, G.G. and L.B. Best. 1994. Avian nest density and success in grassed waterways in Iowa rowcrop fields. Wildlife Society Bulletin. 22: 583-592.

Calladine, J., D. Baines, and P. Warren. 2002. Effects of reduced grazing on population density and breeding success of black grouse in northern England. Journal of Applied Ecology. 39 (5): 772-780.

Calverley, B.K. and T. Sankowski. 1995. Effectiveness of tractor-mounted flushing devices in reducing accidental mortality of upland-nesting ducks in Central Alberta hayfields. Alberta NAWMP Centre. NAWMP-019. Edmonton, AB. 21 p.

Camp, M and L.B. Best. 1993. Bird abundance and species richness in roadsides adjacent to Iowa rowcrop fields. Wildlife Society Bulletin. 21 (3): 315-325.

Canadian Biodiversity Strategy. 1995. Canadian Biodiversity Strategy. Canada's Response to the Convention on Biological Diversity. Minister of Supply and Services Canada, Ottawa.

Carroll, L.C., T.W. Arnold, and J.A. Beam. 2007. Effects of rotational grazing on nesting ducks in California. Journal of Wildlife Management. 71 (3): 902-905.

Castrale, J.S. 1985. Responses of wildlife to various tillage conditions. Transactions of the North American Wildlife and Natural Resources Conference. 50: 142-156.

Chan, K.Y. 2001. An overview of some tillage impacts on earthworm population abundance and diversity - implications for functioning in soils. Soil & Tillage Research. 57: 179-191.

Chapman, E.W. and C.A. Ribic. 2002. The impact of buffer strips and stream-side grazing on small mammals in southwestern Wisconsin. Agriculture, Ecosystems and Environment. 88: 49-59.

Christian, D.P. 1997. Wintertime use of hybrid poplar plantations by deer and medium-sized mammals in the Midwestern US. Biomass and Bioenergy. 12 (1): 35-40.

Christian, D.P., P.T. Collins, J.M. Hanowski, and G.J. Niemi. 1997. Bird and small mammal use of short rotation hybrid poplar plantations. Journal of Wildlife Management. 61 (1): 171-182.

Christian, D.P., W. Hoffman, J.M. Hanowski, G.J. Niemi, and J. Beyea. 1998. Bird and small diversity on woody biomass plantations in North America. Biomass and Bioenergy. 14 (4): 395-402.

Cowan, W.F. 1982. Waterfowl production on zero tillage farms. Wildlife Society Bulletin. 10: 305-308.

Cowan, W.F. 1993. Direct seeding: potential socio-economic and conservation benefits. - In: G.L. Holroyd, H.L. Dickson, M. Regnier, and H.C. Smith (eds.). Proceedings of the Third Prairie Conservation and Endangered Species Workshop. Curatorial Section. Provincial Museum of Alberta, Natural History Occasional Paper No. 19. Edmonton, Alberta. pp. 16-18.

Cowardin, L.M., D.S. Gilmer, and C.W. Shaffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildlife Monographs. 92. 37 pp

Creamer, R.E., D.L. Rimmer, and H.I.J. Black. 2007. Do elevated soil concentrations of metals affect the diversity and activity of soil invertebrates in the long-term? Soil Use and Management (Online Early Article). doi:10.1111/j.1475-2743.2007.00131.x.

Crist, T. and R. Ahern. 1999. Effects of habitat patch size and temperature on the distribution and abundance of ground beetles (Coleoptera: Carabidae) in an old field. Environmental Entomology. 28 (4): 681- 689.

Dale, B.C., P.A. Martin, and P.S. Taylor. 1997. Effects of hay management on grassland songbirds in Saskatchewan. Wildlife Society Bulletin. 25 (3): 616-626.

Darveau, M., P. Beauchesne, L. Bélanger, J. Huot, and P. Larue. 1995. Riparian forest strips as habitat for breeding birds in boreal forest. Journal of Wildlife Management. 59: 67-78.

Davis, S.K. and S.G. Sealy. 1998. Nesting biology of the Baird's sparrow in southwestern Manitoba. Wilson Bulletin. 110: 262-270.

Deibert, E.J., R.A. Utte, and D.P. Schwert. 1991. Tillage system influence on earthworms (Lumbricidae) in North Dakota. North Dakota Farm Research. 48: 10-12.

Delphey, P.J. and J.J. Dinsmore. 1993. Breeding bird communities of recently restored and natural prairie potholes. Wetlands. 13: 200-206.

Deschênes, M., L. Bélanger, and J.-F. Giroux. 2003. Use of farmland riparian strips by declining and crop damaging birds. Agriculture, Ecosystems and Environment. 95: 567-577.

Dimmick, R.W. and W.G. Minser. 1988. Wildlife Benefits from Conservation Tillage. - In: K. H Remy. Proceedings 1988: Southern Conservation Tillage Conference. Tupelo, Mississippi, August 10-12, 1988. Special Bulletin 88-1, August 1988. Mississippi Agricultural and Forestry Experiment Station, US. http://www.ag.auburn.edu/auxiliary/nsdl/sctcsa/Proceedings/1988/Dimmick.pdf. Downloaded on January 10, 2008. pp. 9-12.

Dmowski, K. and M. Kozakiewicz. 1990. Influence of a shrub corridor on movements of passerine birds to a lake littoral zone. Landscape Ecology. 4 (2/3): 99-108.

Dritschilo, W. and D. Wanner1980. Ground beetles abundance in organic and conventional corn fields. Environmental Entomology. 9 (5): 629-631.

Elfstrom, B. 1974. Tree Species Diversity and Forest Island Size on the Piedmont of New Jersey, Masters Thesis. Rutgers University, New Brunswick, New Jersey.

Environment Canada. 2007. Biodiversity. Environment Canada website. Date Modified: 2007-08-17. http://www.ec.gc.ca/default.asp?lang=En&n=CBCF3AB8-1. Downloaded on February 22, 2008.

Environmental Law Institute 2003. Conservation thresholds for land use planners. 56 p.

ERIN Consulting Ltd. 2006. Effects of Agricultural Beneficial Management Practices (BMPs) on Conservation and Restoration of Biodiversity in Agricultural Regions. National Agri-Environmental Standards Initiative Technical Series Report No. 2-27. 319 p.

Faanes, C.A. and G.R. Lingle. 1995. Breeding birds of the Platte River Valley of Nebraska. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/birds/platte/index.htm. Downloaded on January 3, 2008.

Farrand, D.T. and M.R. Ryan. 2005. Impact of the CRP on wildlife conservation in the Midwest. In: J. Haufler (ed.). Fish and Wildlife Benefits from Farm Bill Programs: update 2000-2005. The Wildlife Society, Washington, D.C., USA. pp. 41- 62.

Field, R.H., S. Benke, K. Ba´donyi, and R.B. Bradbury. 2007. Influence of conservation tillage on winter bird use of arable fields in Hungary. Agriculture, Ecosystems and Environment. 120: 399-404.

Flickinger, E.D. and G.W. Pendleton. 1994. Bird use of agricultural fields under reduced and conventional tillage in the Texas panhandle. Wildlife Society Bulletin. 22: 34-42.

Forman, R.T.T., A.F. Galli, and C.F. Leck.. 1976. Forest size and avian diversity in New Jersey woodlots with some land use implications. Oecologia. 26: 1-8.

Francis, G.S. and T.L. Knight. 1993. Long-term effects of conventional and no-tillage on selected soil properties and crop yields in Canterbury, New Zealand. Soil and Tillage Research. 26: 193-210.

Freemark, K.E. and D.A. Kirk. 2001. Birds on organic and conventional farms in Ontario: partitioning effects of habitat and practices on species composition and abundance. Biological Conservation. 101: 337-350.

Freemark, K.E. and H.G. Merriam. 1986. Importance of area and habitat heterogeneity to bird assemblages in temperate forest fragments. Biological Conservation. 36: 115-141.

Galli, A.E., C. Leck, and R. Forman 1976. Avian distribution patterns in forest islands of different sizes in central New Jersey. Auk. 93: 356-364

Gerard, B.M. and R.K.M. Hay. 1979. The effect on earthworms of ploughing, tined cultivation, direct drilling and nitrogen in a barley monoculture system. Journal of Agricultural Science. 93: 147-155.

Giuliano, W.M. and S.E. Daves. 2002. Avian response to warm-season grass use in pasture and hayfield management. Biological Conservation. 106: 1-9.

Good, E.E. and C.A. Dambach. 1943. Effect of land use practices on breeding bird populations in Ohio. Journal of Wildlife Management. 7: 291-297.

Greenwood, R.J., A.B. Sargeant, D.H. Johnson, L.M. Cowardin, and T.L. Shaffer. 1995. Factors associated with duck nest success in the Prairie Pothole Region of Canada. Wildlife Monographs 128. 57 p.

Haas, C.A. 1995. Dispersal and use of corridors by birds in wooded patches on an agricultural landscape. Conservation Biology. 9 (4): 845-854.

Haig, S.M., D.W. Mehlman, and L.W. Oring. 1998. Avian movements and wetland connectivity in landscape conservation. Conservation Biology. 12: 749-758.

Haines, P.J. and N.C. Uren. 1990. Effects of conservation tillage farming on soil microbial biomass, organic matter and earthworm population, in north-eastern Victoria. Australian Journal of Experimental Agriculture. 30: 365-371.

Hall, D.L. and M.R. Willig. 1994. Mammalian species composition, diversity and succession in Conservation Reserve Program grasslands. Southwestern Naturalist. 39: 1-10.

Hands, H.M., M.R. Ryan, and J.W. Smith. 1991. Migrant shorebird use of marsh, moist-soil, and flooded agricultural habitats. Wildlife Society Bulletin. 19: 457-464.

Hanowski, J.M., G.J. Niemi, and D.C. Christian. 1998. Influence of within-plantation heterogeneity and surrounding landscape composition on avian communities in hybrid poplar plantations. Biology Conservation. 11 (4): 936-944.

Hardcastle, P.D., I. Calder, C. Dingwall, W. Garrett, I. McChesney, C. Wiltshire, J. Mathews, and P. Savill. 2006. A review of the potential impacts of short rotation forestry. Final report on SRF-LTS International. 168p. http://www.forestry.gov.uk/pdf/SRFFinalreport27Feb.pdf/$FILE/SRFFinalreport27Feb.pdf. Downloaded on November 28, 2007.

Harris, L. 1984. The Fragmented Forest: Island Biogeography Theory and the Preservation of Biotic Diversity. University of Chicago Press, Chicago, Illinois.

Hanski, I. 1994. A practical model of metapopulation dynamics. Journal of Animal Ecology. 63: 151-162.

Henningsen, J.C. and L.B. Best. 2005. Grassland bird use of riparian filter strips in southeast Iowa. Journal of Wildlife Management. 69 (1): 198-210.

Herkert, J.R. 1997. Population trends of the Henslow's sparrow in relation to the Conservation Reserve Program in Illinois, 1975-1995. Journal of Field Ornithology. 68: 235-244.

Herkert, J.R., S.A. Simpson, R.L. Westemeier, T.L. Esker, and J.W. Walk. 1999. Response of Northern harriers and short-eared owls to grassland management in Illinois. The Journal of Wildlife Management. 63(2): 517-523.

Herkert, J. R., D.L. Reinking, D.A. Wiedenfeld, M. Winter, J.L. Zimmerman, W. Jensen, E.J. Finck, R.R. Koford, D.H. Wolfe, S.K. Sherrod, M.A. Jenkins, J. Faaborg, and S.K. Robinson. 2003. Effects of prairie fragmentation on the nest success of breeding birds in the Midcontinental United States. Conservation Biology. 17 (2): 587-594.

Herkert, J.R. 2007. Evidence for a recent Henslow's Sparrow population increase in Illinois. Journal of Wildlife Management. 71 (4): 1229-1233

Holland, J. and L. Fahrig. 2000. Effect of woody borders on insect density and diversity in crop fields: a landscape-scale analysis. Agriculture, Ecosystems and Environment. 78: 115-122.

Holland, J.M. 2004. The environmental consequences of adopting conservation tillage in Europe:

reviewing the evidence. Agriculture, Ecosystems and Environment. 103: 1-25.

Hoover, J., M. Brittingham, and L. Goodrich. 1995. Effects of forest patch size on nesting success of wood thrushes. Auk. 112 (1): 146-155.

House, G.J. 1985. Comparison of soil arthropods and earthworms from conventional and no-tillage agro-ecosystems. Soil and Tillage Research. 5: 351-360.

Hyvönen, T., E. Ketoja, J. Salonen, H. Jalli, and J. Tiainen. 2003. Weed species diversity and community composition in organic and conventional cropping of spring cereals. Agriculture, Ecosystems and Environment. 97: 131-149.

Jobin, B., L. Choinière, and L. Bélanger. 2001. Bird use of three types of field margins in relation to intensive agriculture in Québec, Canada. Agriculture, Ecosystems and Environment. 84: 131-143.

Johnson, D. H. and Igl, L. D. 1995. Contributions of the conservation reserve program to populations of breeding birds in North Dakota. Wilson bulletin. 107 (4): 709-718.

Johnson, D. H. and Schwartz, M. D. 1993. The Conservation Reserve Program and grassland birds. Conservation Biology. 7: 934-937.

Johnson, R .J. and Beck, M. M. 1988. Influences of shelterbelts on wildlife management and biology. Agriculture, Ecosystems and Environment. 22/23: 301-335.

Jones, G.A. and K.E. Sieving. 2006. Intercropping sunflower in organic vegetables to augment bird predators of arthropods. Agriculture, Ecosystems and Environment. 117 (2/3): 171-177.

Kantrud, H.A. 1981. Grazing intensity effects on the breeding avifauna of North Dakota native grasslands. Canadian Field Naturalist. 95: 404-417.

Kennedy, A.C. 1999. Bacterial diversity in agroecosystems. Agriculture, Ecosystems and Environment. 74 (1/3): 65-76.

Kielhorn, K.-H., B. Keplin, and R.F. Hüttl. 1999. Ground beetle communities on reclaimed mine spoil: Effects of organic matter application and revegetation. Plant and Soil. 213: 117-125.

King, J.W. and J.A. Savidge. 1995. Effects of the Conservation Reserve Program on wildlife in southeast Nebraska. Wildlife Society Bulletin. 23: 377-385.

Kladivko, E.J. 1.993. Earthworms and crop management. Agronomy 279. Purdue University Extension Service. http://www.agcom.purdue.edu/AgCom/Pubs/AY/AY-279.html. Downloaded on January 29, 2008.

Kladivko, E.J., N.M Akhouri, and G. Weesies 1997. Earthworm populations and species distribution under no-till and conventional tillage in Indiana and Illinois. Soil Biology and Biochemestry. 61 (3/4): 613-615.

Klett A.T., T.L. Shaffer, and D.H. Johnson. 1988. Duck nest success in the Prairie Pothole Region. Journal of Wildlife Management. 52: 431-440.

Knutson, M.G., W.B. Richardson, D.M. Reineke, B.R. Gray, J.R. Parmelee, and S.E. Weick. 2004. Agricultural ponds support amphibian populations. Ecological Applications. 14 (3): 669-684.

Kromp, B. 1989. Carabid beetle communities (Carabidae, Coleoptera) in biologically and conventionally farmed agroecosystems. Agriculture, Ecosystems and Environment. 27: 241-251.

Lacki, M.J., J.W. Hummer, and H.J. Webster. 1992. Mine-drainage treatment wetland as habitat for herptofaunal wildlife. Environmental Management. 16: 513-520.

LaGrange, T.G. and J.J. Dinsmore. 1989. Plant and animal community responses to restored Iowa wetlands. Prairie Naturalist. 21: 39-48.

Lapointe, S., J.-F. Giroux, L. Bélanger, and B. Filion, B. 2000. Benefits of rotational grazing and dense nesting cover for island-nesting waterfowl in southern Québec. Agriculture, Ecosystems & Environment. 78 (3): 261-272.

Larsen, K.J., F.F. Purrington, S.R. Brewer, and D.H. Taylor. 1996. Influence of sewage sludge and fertilizer on the ground beetle (Coleoptera: Carabidae) fauna of an old-field community. Environmental Entomology. 25: 452-459.

Lehtinen, R.M. and S.M. Galatowitsch. 2001. Colonization of restored wetlands by Amphibians in Minnesota. American Midland Naturalist. 145 (2): 388-396.

Lemen, C.A. and M.K. Clausen. 1884. The effects of mowing on the rodent community of a native tall grass prairie in Eastern Nebraska. Prairie Naturalist. 16 (1): 5-10.

Lokemoen, J.T. and J.A. Beiser. 1997. Bird use and nesting in conventional, minimum-tillage, and organic cropland. Journal of Wildlife Management. 61 (3): 644-655.

Mace, R., J. Waller, T. Manley, L. Lyon, and H. Zuuring. 1996. Relationships among grizzly bears, roads, and habitat in the Swan Mountains, Montana. Journal of Applied Ecology. 33: 1395-1404.

Maelfait, J-P and R. De Keer. 1990. The border zone of an intensively grazed pasture as a corridor for spiders Araneae. Biological Conservation. 54 (3): 223-238.

Maisonneuve, C. and S. Rioux. 2001. Importance of riparian habitats for small mammal and herpetofaunal communities in agricultural landscapes of southern Québec. Agriculture, Ecosystems and Environment. 83: 165-175.

Martin, P.A. and D.J. Forsyth. 2003. Occurrence and productivity of songbirds in prairie farmland under conventional vs. minimum tillage regimes. Agriculture, Ecosystems and Environment. 96: 107-117.

Mattson, D. 1990. Human impacts on bear habitat use. International Conference on Bear Research and Management. 6: 105-110.

McIntyre, N.E. 1995. Effects of forest patch size on avian diversity. Landscape Ecology. 10 (2): 85-99.

McMaster, D.G. and S.K. Davis. 2001. An evaluation of Canada's Permanent Cover Program:

Habitat for grassland birds? Journal of Field Ornithology. 72 (2): 195-210.

McMaster, D.G., J.H. Devries, and S.K. Davis. 2005. Grassland birds nesting in haylands of southern Saskatchewan: landscape influences and conservation priorities Journal of Wildlife Management. 69 (1): 211-221.

Minser, W.G. and R.W. Dimmick. 1988. Bobwhite quail use of no-till vs. conventionally planted crops in western Tennessee. Journal of Soil and Water Conservation. 43 (3): 270-272.

Moser, B.W., M.J. Pipas, G.W. Witmer, and R.M. Engeman. 2002. Small mammal use of hybrid poplar plantations relative to stand age. Northwest Science. 76 (2): 158-165.

Murray, L.D., L.B. Best, T.J. Jacobsen, and M.L. Braster. 2003. Potential effects on grassland birds of converting marginal cropland to switchgrass biomass production. Biomass and Bioenergy. 25: 167-175.

Naugle, D., K. Higgins, S. Nusser, and W. Johnson. 1999. Scale-dependent habitat use in three species of prairie wetland birds. Landscape Ecology. 14: 267-276.

Newton, I. and I. Wyllie. 1992. Recovery of a spparowhawk population in relation to declining pesticide contamination. Journal of Applied Ecology. 29: 476-484.

Nocera, J.J., G.J. Parsons, G.R. Milton, and A.H. Fredeen. 2005. Compatibility of delayed cutting regime with bird breeding and hay nutritional quality. Agriculture, Ecosystems and Environment. 107: 245-253.

Norris, D.R. and B.J.M. Stutchbury. 2001. Extraterritorial movements of a forest songbird in a fragmented landscape. Conservation Biology. 15 (3): 729-736.

O'Leary, C.H. and D.W. Nyberg. 2000. Treelines between fields reduce the density of grassland birds. Natural Areas Journal. 20 (3): 243-249.

Oliver, I., S. Pearce, P.J.M. Greenslade, and D.R. Britton. 2006. Contribution of paddock trees to the conservation of terrestrial invertebrate biodiversity within grazed native pastures. Austral Ecology. 31: 1-12.

Patterson, M.P. and L.B. Best. 1996. Bird abundance and productivity in Iowa CRP fields: The importance of vegetation structure and composition. American Midland Naturalist. 135: 153-167.

Pavel, V. 2004. The impact of grazing animals on nesting success of grassland passerines in farmland and natural habitats: A field experiment. Folia Zoologica. 53 (2): 171-178.

Payne, T. and W. Caire. 1999. Species diversity of small mammals in the tallgrass prairie preserve, Osage County, Oklahoma. Proc. Okla. Acad. Science. 79: 51-59.

Pimentel, D., U. Stachow D.A. Takacs, H.W. Brubaker, A.R. Dumas, J.J. Meaney, J.A.S. O'Neil, D.E. Onsi, and D.B. Corzilius. 1992. Conserving biological diversity in agricultural / forestry systems. BioScience. 42 (5): 354-362.

Ratti, J.T., A.M. Rocklage, J.H. Giudice, E.O. Garton, and D.P. Golner. 2001. Comparison of avian communities on restored and natural wetlands in North and South Dakota. Journal of Wildlife Management. 65: 676-684.

Reeleder, R.D., J.J. Miller, B.R. Ball Coelho, and R.C. Roy. 2006. Impacts of tillage, cover crop, and nitrogen on populations of earthworms, microarthropods, and soil fungi in a cultivated fragile soil. Applied Soil Ecology. 33: 243 -257.

Rewa, C.A. 2007. Fish and wildlife benefits associated with wetland establishment practices. In Fish and Wildlife Response to Farm Bill Conservation Practices. The Wildlife Society. Technical Review 07-1. pp. 71-82.

Reynolds, R.E., T.L. Shaffer, J.R. Sauer, and B.G. Peterjohn. 1994 Conservation Reserve Program: benefit for grassland birds in Northern Plains. Transaction of North American Wildlife Natural Resources conference. 59: 328-336.

Rieman, B. and J. McIntyre. 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society. 124: 285-296.

Robbins, C., D. Dawson, and B. Dowell. 1989. Habitat area requirements of breeding forest birds of the middle Atlantic states. Wildlife Monographs. 103: 1-34.

Robertson, L.N., B.A. Kettle, and G.B. Simpson. 1994. The influence of tillage practices on soil macrofauna in a semiarid agroecosystem in northeastern Australia. Agriculture, Ecosystems and Environment 48: 149-156.

Robinson, S.K. 1997. The case of the missing songbirds. Consequences 3: 3-15.

Rodenhouse, N.L. and L.B. Best. 1983. Breeding ecology of vesper sparrows in corn and soybean fields. American Midland Naturalist 110: 265-275.Rovira, A.D., K.R.J. Smettem, and K.E. Lee. 1987. Effect of rotation and conservation tillage on earthworms in a red-brown earth under wheat. Australian Journal of Agricultural Research. 38: 829-834.

Ryan, M.R. 2000. Impact of the Conservation Reserve Program on Wildlife Conservation in the Midwest. In: W. L. Hohman and D. J. Halloum (eds.). A comprehensive review of Farm Bill contributions to wildlife conservation. U.S. Department of Agriculture, Natural Resources Conservation Service, Wildlife Habitat Management Institute, Technical Report, USDA/NRCS/WHMI-2000. pp. 45-54. ftp://ftp-fc.sc.egov.usda.gov/WHMI/WEB/CompRev/Ryan45-54.pdf. Downloaded on January 6, 2008.

Ryan, M.R., L.W. Burger, and E.W. Kurzejeski. 1998. The impact of CRP on avian wildlife: A review. Journal of Production Agriculture. 11: 61-66.

Sage, R., M. Cunningham, and N. Boatman. 2006. Birds in willow short-rotation coppice compared to other arable crops in central England and a review of bird census data from energy crops in the UK. British Ornithologists' Union, Ibis. 148: 184–197.

Samson, F.B. 1980. Island biogeography and the conservation of prairie birds. In: C. L. Kucera (ed.). Proceeding of the seventh North America prairie conference. Southwest Missouri State University. Springfield. pp. 293-299.

Sauer, J.R., S. Schawtz, B.G. Peterjohn, and J.E. Hines. 1996. The North American Breeding Bird Survey home page (http:\\www.mbr.nbs.gov\). Version 94.3. Patuxent wildlife Resources Centre. Laurel. Md.

Schiller, A. and V.R. Tolbert. 1998 Hardwood energy crops and wildlife diversity: investigating potential benefits for breeding birds and small mammals. Oak Ridge National Laboratory 8p. http://bioenergy.ornl.gov/papers/bioen96/schiler1.html. Downloaded on November 28, 2007.

Schmidt, N.M., H. Olsen, M. Bildsøe, V. Sluydts, and H. Leirs. 2005. Effects of grazing intensity on small mammal population ecology in wet meadows. Basic and Applied Ecology. 6: 57-66.

Schroeder, R.L., T.T. Cable, and S.L. Haire. 1992. Wildlife Species Richness in Shelterbelts: Test of a Habitat Model Wildlife Society Bulletin. 20 (3): 264-273.

Semere, T. and F. Slater. 2004. The effects of energy grass plantations on biodiversity. 2nd Annual Report. 35 p.

Shalaway, S.D. 1985. Fencerow management of nesting birds in Michigan. Wildlife Society Bulletin. 13: 302–306.

Silva, M., L. Hartling, and S.B. Opps. 2005. Small mammals in agricultural landscapes of Prince Edward Island (Canada): Effects of habitat characteristics at three different spatial scales. Biological Conservation. 126: 556-568.

Smith, M.D., P.J. Barbour, L.W. Burger, Jr., and S.J. Dinsmore. 2005. Density and diversity of overwintering birds in managed field borders in Mississippi. Wilson Bulletin. 117: 258-269.

Soetaert, D. 2005. Winter Wheat Protects Duck Nests. Ducks Unlimited Canada. Subject: #137. http://www.innovationalberta.com/article.php?articleid=488. Download on May 16, 2008.

Soulé, M., A. Alberts, and D. Bolger. 1992. The effects of habitat fragmentation on chaparral plants and vertebrates. Oikos. 63: 39-47.

Springett, J.A. 1992. Distribution of lumbricid earthworms in New Zealand. Soil Biology and Biochemistry. 24: 1377-1381.

Stallman, H.R. and L.B. Best. 1996. Bird use of an experimental strip intercropping system in

Northeast Iowa. Journal of Wildlife Management. 60 (2): 354-362.

Stanczak, M. and J.B. Keiper. 2004. Benthic invertebrates in adjacent created and natural wetlands in northeastern Ohio, USA. Wetlands. 24 (1): 212-218.

Stavne, R.B., J.E. Thompson, and A.L. Foote. 2003. Effects of cattle grazing on wetland bird communities in the Aspen Parkland of Alberta. In: B. K. Calverley (ed.). 2004. Proceedings of the 2nd Alberta NAWMP Biodiversity Conference, Edmonton, Alberta. Alberta NAWMP, Edmonton, AB. NAWMP-053. pp. 35-37.

Stevens, C.E., T.S. Gabor, and A.W. Diamond. 2003. Use of restored small wetlands by breeding waterfowl in Prince Edward Island, Canada. Restoration Ecology. 11 (1): 3-12.

Trine, C. 1998. Wood thrush population sinks and implications for the scale of regional conservation strategies. Conservation Biology. 12 (3): 576-585.

United States Department of Agriculture. USDA. 2001. Agricultural management effects on earthworm populations. USDA. Soil Quality Institute. Auburn. Soil Quality-Agronomy Technical Note 11. 8 p. http://soils.usda.gov/sqi/management/files/sq_atn_11.pdf. Downloaded on January 30, 2008.

Verboom, B. and R. van Apeldoorn. 1990. Effects of habitat fragmentation on the red squirrel, Sciurus vulgaris L. Landscape Ecology. 4 (2/3): 171-176.

Walk, J.W. and R.E. Warner. 2000. Grassland management for the conservation of songbirds in the Midwestern USA. Biological Conservation. 94 165-172.

Warburton, D. and W. Klimstra. 1984. Wildlife use of no-till and conventionally tilled corn. Journal of Soil and Water Conservation. 39: 327–330.

Whitaker, D.M., A.L. Carroll, and W.A. Montevecchi. 2000. Elevated numbers of flying insects and insectivorous birds in riparian buffer strips. Canadian Journal of Zoology. 78: 740-747.

Whitaker, D.M. and W.A. Montevecchi. 1999. Breeding bird assemblages inhabiting riparian buffer strips in Newfoundland, Canada. Journal of Wildlife Management. 63 (1): 167-179.

White, J.S. and S.E. Bayley. 1999. Restoration of a Canadian prairie wetland with agricultural and municipal wastewater. Environmental Management. 24: 25-37.

Yahner, R.H. 1982. Avian nest densities and nest-site selection in farmstead shelterbelts. Wilson Bulletin. 94: 156-175.

Yahner, R.H. 1983. Small mammals in farmstead shelterbelts: Habitat correlates of seasonal abundance and community structure. Journal of Wildlife Management. 47 (1): 74-84.

Young, F.L. 2005. Weed and annual spring crop management in Pacific Northwest low-rainfall regions. Abstract. Washington State Weed Association. pp. 28-29.

Zampella, R.A. and J.F. Bunnell. 2000. The distribution of anurans in two river systems of a Coastal Plain watershed. Journal of Herpetology. 34: 210-221.