Effects of Agricultural Beneficial Management Practices (BMP's) on Conservation and Restoration of Biodiversity in Agricultural Regions

DRAFT REPORT

Submitted to:

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1.0 Introduction

Environment Canada (EC) has signed a Memorandum of Understanding (MOU) with Canada Agriculture and Agri-Food Canada (CAAFC) to develop Agri-environmental standards within a four year time period. The environmental goal under the National Agricultural Policy Framework is to decrease risk and increase benefits of agriculture to air, water, biodiversity and soil (environmental themes). The National Agri-environmental Standards Initiative (NAESI) is the Environment Canada program charged with setting performance standards for agriculture, that address each of the environmental themes. A working group has been established for each environmental theme with this particular project being part of the work plan for the Biodiversity Thematic Group.

NAESI standards will be established for ecologically ideal conditions and for achievable conditions. Achievable standards will be based on current landscape condition and available farm management practices. A checklist of indicators for species, landscape features, genetic and ecological function have been developed but measurable scientifically valid parameters for many of the hypothetical indicators are lacking. There is concern that some of the suggested indicators may not always work as indicators, depending upon geographic variation, societal complications and subtleties of ecological function. The goal of this project is to contribute additional information that is needed to design and implement achievable standards for structuring Beneficial Management Practices, (BMP's) so that benefits to biodiversity can be optimized.

CAAFC has identified a suite of BMP's intended to address a range of environmental themes. A BMP is defined as any agricultural management practices which:

1. Ensures the long-term health and sustainability of land related resources used for agricultural production;
2. Positively impacts the long-term economic and environmental viability of the agricultural industry; and
3. Minimizes negative impacts and risk to the environment.

This project will focus on BMP's that are believed to have a positive effect on components of biodiversity. These BMP's will include those in the national list, provincial lists and other agricultural guidelines intended to increase or conserve habitat for specific species (natural, semi-natural or cropland), re-create or conserve natural ecosystems, and/or reduce negative effects on species (mortality, reduction in reproduction or health of individuals).

Understanding the importance of BMP’s on biodiversity is important for legal reasons. The Canadian Environmental Assessment Act (CEAA) and Species At Risk Act, (SARA) require that any federally sponsored program must address environmental concerns including impacts on biodiversity. Federally sponsored BMP’s also must comply with provincial/territiorial legislation as well as municipal bylaws if environmental concerns, including biodiversity are implicated.

There has been some Canada-based work directed at determining values of some BMP’s to biodiversity. Other studies are being conducted or have been completed to assist with understanding the nature and scope of relationships between BMP’s and biodiversity. These include the Ontario program carried out in the St. Lawrence Lowlands eco-region titled “How Much Habitat is Enough”. This Ontario study has great relevance to the present study by its defining key aspects of habitat management that could be applied to standards for agricultural BMP’s. Agricultural practices impinge greatly upon habitat of species and communities of species of wild plants and animals. These key aspects of understanding habitat included:

- Defining habitat patch size for a variety of ecosystem types within broad land cover types based on a broad range of species representing ecosystem structure, function and composition
- Defining amount of each habitat type based on habitat required to support target population levels for indicator species.
- Integrating the dynamic nature of landscapes within the process for determining land cover standards.

Another program called Watershed Evaluation of BMP’s (WEBs) is a four-year program to evaluate the effects of BMP’s on water quality from both the environmental and economic stand point at study sites scattered across Canada. At each study site, the benefits of certain BMP’s are being monitored over the four year period.

As part of the National Agricultural Policy Framework under the National Environmental Farm Planning Initiative, each province has a program in place to encourage farmers to develop environmental farm plans. These farm plans that identify various management practices beneficial to the environment sometimes, but not always, take implications to biodiversity into account. Canada has identified that a system of parks, protected areas and specifically managed areas for wildlife is insufficient to fully protect our natural heritage. Accordingly, the additional contribution of farm land to conservation of Canada’s biodiversity becomes of paramount importance.

.In the USA, federal programs such as the Conservation Reserve Program (CRP) have, for over a decade, been reporting on the biodiversity benefits of retiring thousands of acres of crop land and planting to perennial grasses. A bibliography of effects of the CRP program and other BMP's, compiled by the United States Department of Agriculture, will serve as a starting point for this project.

The scope of this study is to develop from literature citings and expert opinions, a scientific background for developing standards for BMP's to ensure that they enhance or preserve the various components and levels of biodiversity.

1.1 Objectives

- To provide an assessment of the effectiveness of BMP's and agricultural guidelines for conserving and restoring biodiversity and ecosystem health by reviewing results of completed and ongoing studies
- To develop a catalogue of study sites where BMP's have been assessed or continue to be assessed.

1.2 Tasks

- Review all background material for NAESI and the Biodiversity Theme
- Identify general risks of agricultural practices to biodiversity
- Identify BMP's (agricultural best management practices) that effect biodiversity
- Identify literature and expert opinions that relate to BMP's and conservation and protection of biodiversity
- Assess and provide recommendations for guidelines and potential standards for BMP's to positively effect biodiversity referenced to ecological zones and agricultural regions and commodities.
- Identify major gaps in information and recommendations for future work

1.3 Results

Biodiversity is expressed at various levels within the biosphere. For the purposes of this study, it is important to recognize those parameters and actions that impact at the landscape level. Thus, management practices that alter watersheds or overall terrestrial landscapes have a significant influence on biodiversity. Landscapes have been significantly altered by agriculture such that habitat for wild plants and animals that existed there before agriculture no longer supports those species. Other species have occupied the new habitats resulting in a completely changed landscape.

Measures of biodiversity invariably involve an assessment of species richness, distribution and numbers. Agriculture has greatly modified species diversity at the broad regional scale as dictated by landscape changes and also at the more local scale such as at each individual land holding. For purposes of this study, the assessment of species diversity will have to address the phenomenon of changed groupings of wild plant and animal species as a result of farming practices. Thus instead of oven birds and red-eyed vireos being representatives of the landscape, the common species now may be house finches and American robins; native species groups that existed before agriculture. Measures of species diversity will therefore, have to deal not just with effects on numbers of different species but also whether those species are representative of natural ecosystems.

Genetic diversity is impacted by farming policies and practices such as use of genetically modified crops and loss of genetic diversity in species as the result of low numbers or isolated populations. This study will examine the farming practices that effect genetic diversity in wild populations and evaluate how BMP’s can contribute to this aspect of biodiversity.

Preserving essential ecological functions and processes are perhaps the most important consideration when conserving biological diversity. Each living organism requires food, water, shelter and space in the right amounts and properly distributed on the landscape. Predators, parasites, diseases and other regulators of life and death are ecological functions that determine the health of biodiversity. For example some agricultural BMPs’ will contribute to ensuring that critical relationships between taxa and with various features of the landscape are maintained or enhanced. Because ecological function is not only essential to retain wild taxa on the landscape but also to retain agricultural productivity, the maintenance of ecological integrity is of primary importance to both farmers and other members of society concerned about conservation of nature.

2.0 General Risks of Agricultural Practices to Biodiversity

Neave, 2005 provided an overview of the farm activities that potentially impact biodiversity across Canada. Neave provides a useful reference to the size and scope of agricultural impacts both for crop and livestock production. It must be noted that by far and away the greatest impact from agriculture has been extensive conversion of native vegetation to agricultural production in areas where climate and soils provide suitable growing conditions for agricultural crops. This action has resulted in large areas of the major agricultural areas having little of the native landscape remaining. The native biodiversity has been significantly altered and in many cases destroyed. Often biodiversity in these areas of intensive agriculture has been so compromised that the most basic of ecological functions such as microbial decomposition of organic matter in soils has been greatly slowed. Agricultural BMP’s in these areas will face significant challenges when attempting to substantially influence biodiversity at the landscape level.

Other areas of less intensive agricultural activity have varying amounts of natural vegetation remaining. These “islands of remaining biodiversity” can be protected and enhanced to maintain their ecological integrity. Their value for protecting biodiversity can be influenced by the way the surrounding area is managed such that biodiversity can be enhanced in the region as a whole.

Finally, on areas of extensive rangeland or forest fringe where crop production is relatively small scale, agricultural production may actually enhance overall biodiversity by increasing potential food, water or shelter for wild species. This "improved situation" depends upon the remaining natural ecosystems being suitably managed to support conservation of biodiversity while areas devoted to agriculture are incorporated into the ecosystem using various ecologically beneficial practices.

The assessment of risk posed by agricultural practices to biodiversity is complex and is dependent upon many factors related to geography, geomorphology, soils and water, climate and past history of land use practices. These broad level risks posed by agriculture can be grouped for analysis into the following categories:

- Large scale conversion of naturally vegetated lands to cultivation
- Intensification and specialization of agricultural activities resulting in monoculture
- Removal and degradation of small wetlands and watercourses
- Pollution and poisoning of water and soils by organic and inorganic compounds
- Introduction of exotic invasive plants, animals, and diseases

A general discussion of each broad risk follows.

2.1 Conversion from Native Habitats to Agricultural Cropping

This practice has and continues to result in major loss of landscape diversity and habitat for many plant and animal species. On the prairies this wholesale conversion of the native grassland to annual crop and summerfallow was a major contributor to elimination of dominant species such as bison, grizzly bear and plains wolf shortly after the conversion was initiated. These species require large home ranges and were incompatible with agriculture. Whereas the native prairie presented a diverse assemblage of plants and micro-habitats, that extended across thousands of square hectares, the agricultural mosaic reduced the landscape diversity to a monocultural cropping system involving a few plants to the exclusion of others. The individual fields were dissected and intersected by roads, rail lines and fences that further compromised the integrity of the natural ecosystem.

After initial European settlement, many sub-dominant wildlife species of the open prairie were temporarily sustained on remnant parcels of natural grasslands. Certain species such as white-tailed deer and some species of ducks benefited through increased production of grains, a high energy food source for these opportunistic feeders. Other remnant populations of species that require native habitat continue to decline as more of the remnant parcels are destroyed or degraded. Many of these native plants and animals are now listed by COSEWIC as species at risk because both their populations and habitats continue a long term decline.

Similar loss of landscape diversity occurred in southern Ontario, Prince Edward Island the lower mainland of British Columbia and parts of the Maritimes where extensive agriculture replaced hardwood or mixed forest and remnant tall grass savanna habitats. The reduction of natural wooded and parkland habitats to small parcels of woodland has not only greatly reduced the amounts of wildlife habitat available but has compromised the balance of ecological functions such as parasite-predator prey relationships. Workers such as Robinson et al.(1995) and many others have found that these fragmented landscapes result in the habitat becoming a population sink for many species. The capability of soil and water to sustain viable wildlife populations and to carry out vital ecological functions such as decomposition and primary production have all been compromised. The loss of soil carbon and deteriorating water quality problems are symptoms of this loss of ecological function. Thus for the major agricultural areas of Canada, complex, multi-dimensional landscapes have been replaced by much simpler monocultures or severely fragmented landscapes with biodiversity at all levels significantly reduced.

The most significant impact of this large-scale land conversion to a monocultural ecosystem is at the landscape diversity level. Conservation ecology generally identifies loss and degradation of wildlife habitat as the primary cause of wildlife population problems. While individual populations of many wildlife species have been put in jeopardy, others, some of which are introduced exotics, have become so abundant that they compete with other wildlife species or become pests to humans. Where natural landscapes have been reduced and fragmented to the extent that connectivity is lost for certain species, the species become isolated causing genetic problems and long term and often permanent decline. The loss of genetic diversity resulting from large scale landscape conversion and degradation may be a camouflaged time bomb that will ultimately destroy the natural biodiversity of agricultural Canada.

Landscape diversity contributes heavily to perpetuating the ecological functions that provide the essential processes of all life. If landscape diversity is significantly compromised and these ecological services are lost, life on earth as we know it will fail. Primary production and decomposition are dependent upon vast arrays of biological organisms that may be insignificant individually but, when working in concert together, perform services that ensure the earth continues to sustain life. Loss of landscape diversity jeopardizes those processes that govern the ability of soils to grow plants (primary agricultural and native plant production). Conversely, waste material has to be decomposed and returned as essential elements for growth in the biosphere. These biological services must occur at a large scale to prevent their function being overwhelmed by local accumulation of wastes and/or catastrophic events at all levels. So loss or reduction of landscape diversity must be viewed as one of the great risks facing the agricultural sector and indeed all of human society in the 21st century.

Wilson, (1992) and many others have decried the wholesale fragmentation of landscapes and their devastating effects on biological diversity. It follows that BMP's that reduce or mitigate for large-scale land conversion will have the greatest impact on overall conservation of biodiversity. These benefits will be facilitated greatly through large scale land use policies at various levels of government that change land use perceptions, values and actions across a broad geographic area. Implementation of these changing attitudes will, however, have to happen at the local farm level in the form of BMP's that benefit biodiversity.

2.2 Intensification of Agricultural Practices

In the past half-century, agricultural practices in Canada have changed radically. Farm size has greatly increased after the termination of World War II. For example, in Saskatchewan, the average farm size of 160 ha. in 1931 increased to 460 ha.in 1996; (Fung et al.,1999). Instead of mixed farms that had small fields growing a variety of perennial and annual crops, as well as areas of remnant native vegetation, many of the farms have become much more specialized into either large livestock production facilities or large fields of annual crops. In Saskatchewan, between 1971 and 1996, an additional 1.4 million ha. of marginal agricultural land was "improved". Thus many of the remnant parcels of natural vegetation have been degraded or converted from native to exotic cover or summerfallow. In the 1970's soil scientists such as Don Rennie at University of Saskatchewan (Sparrow, 1984), identified that because of intensive cropping and summer fallowing, the prairie soils were being rapidly mined of their available carbon (their fertility that is generated by microbial activity in the soil).

Use of agricultural chemicals such as chemical fertilizers and pesticides are additional symptoms of agricultural intensification. These chemicals, part of the green revolution, have completely changed the flora and fauna to a few agricultural crop species to the exclusion of other species that do not generate immediate economic wealth. Eventually opportunistic species that can tolerate the chemicals or develop resistance to the chemical action have replaced those that are less resistant or hardy. Even fertilizers designed to promote growth, favour only certain crop species or weeds to the detriment of native plants and animals that fare more poorly under high nutrient loads. Because residual chemicals and other intensive farming practices impacting on soil and water weaken and kill any attempts by native species to re-inhabit these intensively farmed lands, the biodiversity of natural biota is largely permanently eliminated. Once the native seed bank has been decimated, restoration becomes totally dependent on artificial propogation.

The all pervasive drive to simplify ecosystems to maximize commercial crop production is moving the agricultural sector into genetically modified organisms (GMO's). The intent is to totally eliminate weeds and herbivory on crops. Among other problems associated with this philosophy, use of GMO's combined with pesticides on a major scale will serve to remove all weeds and invertebrates on agricultural fields and even around field edges. Common weeds that have been a part of the agricultural landscape since settlement days, have provided food and cover for some species of plants and animals such as butterflies, bees, certain sparrows, pheasants, ground squirrels and even deer. With clean farming, even these opportunistic and adaptable species are removed from the landscape.

When some small dispersed parcels of natural habitat are left, intensive agriculture on the rest of the landscape plays havoc with genetic diversity by creating many small islands of populations that become increasingly removed from each other. This isolation can result in genetic drift and loss of genetic richness in certain taxa. Those species then become susceptible to such environmental hazards as disease or changing environmental conditions due to climate change.

So intensification of agriculture takes the wholesale conversion of natural ecosystems to the next step of biodiversity reduction by removing what natural habitat was left or reduces its capability to perform vital ecological functions. Recovering native biodiversity under these conditions becomes very difficult. Ecological functions and processes such as herbivory and predator/prey relationships are seriously jeopardized, be it at the level of deer and leaves of native shrubs, badgers and ground squirrels or wild bees and flowering plants. Natural balance between pest species and their controlling influences over the landscape is lost and human society must use increasingly costly pesticides, genetic engineering and other artificial means to manage and control the agricultural environment.

2.3 Removal of and Degradation of Small Wetlands and Watercourses from the Landscape

Ducks Unlimited biologists and other conservation ecologists have long described wetlands as being the kidneys and liver of our natural environment. More than that, because they are an interface between land and water, they are the most biologically productive part of the landscape and thus are the heart and lungs for most ecosystems. Unfortunately, a large percentage of the wetlands in all agricultural parts of Canada are either eliminated or severely degraded to the extent that their natural biodiversity has been severely compromised.

From the standpoint of importance to life processes, the presence of water cannot be overstated. Wet and mesic areas on the landscape contribute greatly to the variability of habitat resulting in many micro-habitats as well as major ecological communities such as individual forest stands. On arid prairies and in mountainous regions the wetlands and water courses support their own ecosystems that differ greatly from the surrounding uplands. The riparian areas draw species from these uplands and from the water bodies themselves and, combined with those species that commonly reside in the more luxuriant vegetative growth, supplement the biodiversity of the entire region. Further, this influence of the riparian areas far exceeds their actual physical space in the local area. When wetlands are destroyed or altered, whole ecosystems are compromised downstream resulting in a cascading sequence of detrimental effects.

The riparian areas of small wetlands and watercourses of all sizes provide the environment for many important taxa including species at risk. Yet these high ecological values are eliminated when wetlands are drained and/or filled. Agricultural practices that invade into the riparian area either remove vital components of the different species habitat requirements or cause crowding and ultimate lowering of carrying capacity for the immediate area. When the water quality is reduced by siltation, leaching of chemicals or pollutants some taxa may perish while others are sickened or weakened resulting in long term decline or extirpation at the local level.

Water courses and wetlands often function as dispersal pathways and connect different subpopulations of taxa. When the vital pathway is disrupted or severed by drainage or degradation, cross dissemination of genetic codes is also lost or compromised. This is of particular concern for sedentary species such as amphibians or invertebrates that have limited capability to bridge gaps in dispersal pathways.

The ecological functions of wetlands and water courses are the most important part of their value for conservation of biodiversity. Agricultural practices often conspire to reduce their ecological roles and clog and otherwise reduce their capability to carry out their essential functions. Once a certain percentage of the wetlands and their riparian habitat are removed, services such as moderation of micro and macro habitats are eliminated or much reduced. Instead of a shady, cool, moist environment that supports many species at different times of their life cycle, the remaining environment becomes sterile, single-dimensional and subject to harsh and extreme living conditions.

Many wetlands provide key stop over and restoration stations for migrating wildlife. Passerine and water birds would not be able to make their long trips between their breeding grounds and wintering habitat in the south without these stop-overs. The luxuriant vegetation harbours high populations of insects and seeds for food and provides thermal and visual cover as well as water. Because space is also essential to all living organisms, even minor reductions in the size of riparian habitats can be problematic for some ecological functions. Even after many wetlands are drained or filled, agricultural practices tend to infringe on the edges of riparian habitats tillage practices, sheet erosion and concentration of livestock.

2.4 Nutrient Management

Agricultural crops require high soil nutrient levels to support their rapid and vigorous growth. Also, the practice of confining livestock in farm facilities tends to concentrate animal wastes such as manure and other animal by-products. The results on biodiversity may be subtle but can be serious.

From a landscape perspective, over-application of manure and chemical fertilizers can result in poisonous concentrations of chemicals such as nitrates, sodium chloride, and pathogenic organisms in soils and water. Where water bodies or ground water deposits are affected by poor nutrient management, the results can be serious disease and illness in both wildlife and humans.

Sensitive species like amphibians are particularly sensitive to pollutants such as medicines and hormones that escape into the environment from inadequate septic systems. Other wildlife are attracted to manure piles and other agricultural waste repositories on the farm and in turn become nuisances or transmit disease and dependencies on others of their species. The common practice in days gone by of using the slough or wooded grove at the back of the farm as a waste dump site created a refuge for pestiferous species that by preying on or contaminating other species, limited their ability to maintain viable populations.

The spread of genetically altering compounds in wastewater and manure may be a risk of increasing importance. These compounds have been found to reduce reproductive capacity of some organisms and/or alter the genetic codes of others. Because these phenomenon are often delayed and long lasting in their expression, little is known about the genetic implications to resident taxa around agricultural facilities where these drugs and chemicals are used to enhance agricultural production.

2.5 Wild Species of Plants and Animals

The very essence of agricultural production is to focus the soil, water, and sun's energy capability for biological production into products that are useful for humans. This focus on a very few plants and animals dictates that ecosystems have to be simplified in order to use all of the agricultural inputs for a "useful" purpose. Further, unless other political or societal objective dictates differently, where soils are capable of growing agricultural crops, every available acre has tended to be devoted to agricultural production. Plants and animals that do not contribute to this production of agriculture commodities have become *personna non grata.*

Changes to native flora and fauna have been documented at great length. Animal populations have been monitored using various surveys and inventories for some game species for more than a century. Most of these species inhabiting agricultural landscapes are stable or increasing as the result of stronger game management programs, decreasing hunting and predator pressure and, in some cases, improved habitat. Song bird populations have also been monitored for several decades; many of these associated with agricultural lands are on longterm declines. Continuing breeding and wintering habitat loss, continued habitat fragmentation and compounding causes of mortality along migration routes has jeopardized these species. Native plants have not been measured with the same intensity as have animals but an increasing number of species are being classified as rare, threatened or endangered. Many of these rare plants are jeopardized by invasive weeds or escaped agricultural cultivars.

Similarly, the introduction of various diseases of agricultural plants and animals into wild plant and animal populations is a continual cause for concern and friction between agricultural producers and wildlife managers. If a wild species population is already reduced or the species is vulnerable in some way, the introduction of a new stressor into the population can seriously jeopardize the future of that organism. A recent case in point is the introduction of West Nile Virus, a highly contagious disease of homeotherms, and particularly birds, into the endangered sage grouse. The increased mortality of young birds at a time when reproduction appears to be inadequate to sustain the Canadian population (Aldridge 2002) further jeopardizes survival of this large grouse in Canada.

The continued reduction of space for wild plants and animals has been further exacerbated by introduction of aggressive opportunistic and weedy species. Out competing or preying upon native species, the impacts of agricultural pests are sometimes felt equally strongly on native taxa as on agricultural production. On the other hand, where weedy species are the only source of food and cover for remnant wildlife populations, control of these weeds and final simplification of agricultural ecosystems can reduce or eliminate even the opportunistic and most adaptive species. In other cases, species that are much valued by humans and serve a purpose as game species or fur producers can become unwanted when occurring in large concentrations.

2.6 Regional Importance and Application of BMPs

The adoption of different BMP's varies considerably across the country. An analysis presented at the CNC Symposium in April, 2006, (Hewitt, 2006), showed the considerable regional difference across Canada regarding current application of BMP's. The following table is an attempt to analyze the patterns of adoption of the different groups of BMP's according to geographic region.

Table 1: Adoption of groups of BMPs by geographic region

BMP Group	BC	Prairies	Ontario	PQ	Atlantic	Total
Terrestrial Habitat	/38*	/44*	/33*	19	/32*	/33*
Riparian Habitat	10	5	/33*	38	/32*	/23*
Soil Management	/38*	43	9	9	/32*	/26*
Nutrient Management	21	7	58	31	55	34
Species Management	12	-	/33*	/3*	/32*	16

**These BMP's were assumed to be classed along with other BMP's as "others" so would have made up varying amounts of the class in the Overview of the National EFP Initiative document.*

In the above analysis, the only group of BMP's consistently adopted in measurable terms across the country was nutrient management. Other BMP's are considered important in some parts of the country but of limited concern by agricultural producers in other regions. Because biodiversity has not been a priority for application of BMP's, the likely reason for uptake of different BMP's in different regions likely relates largely to agronomic factors. For example, improved cropping systems make up 43 percent of the prairie BMP's that have been adopted while this group of BMP's are not specifically identified elsewhere.

Nutrient and waste management BMP's were found to be adopted by a large percentage of producers in Ontario, Atlantic provinces, Quebec and to a lesser extent, BC, but were adopted by only seven percent of prairie farmers sampled. Thus the efficacy of BMP's currently being used by the agricultural sector is complicated not only by the ecological implications of different ecoregions and landscapes but also by the apparent readiness of agricultural producers to employ BMP's that have relevance to their own unique farming/ranching situation. Therefore the proven effects of different BMP's on protection of biodiversity at the national level will be spotty because in some cases there may be few if any case studies on which to base conclusions.

3.0 Reducing Risks of Agriculture to Biodiversity

Management practices that reduce the negative effects and create favourable conditions for protection and enhancement of biodiversity will have to address the risks at all levels of biodiversity to be effective. This fact dictates that all programs and individuals that are involved in the agricultural sector have to play a role. Government action that benefits biodiversity will be needed to entice and regulate broad scale actions. Policies and regulations that are perpetuated by different levels of government can either exacerbate loss of biodiversity or can provide strong incentives for agricultural producers to use agricultural practices that benefit biodiversity. Conflicting policies and incentives between different departments and levels of government have historically served to confuse and confound meaningful initiatives to preserve natural ecosystems in the past. Effective BMP's for preserving biodiversity will therefore have to be recognized and incorporated into future government programming.

Universities and technical schools will need to assist with research and technology transfer to agricultural producers the correct approaches to maximizing beneficial practices. In addition, academic classes and training courses related to agricultural production will have to recognize the importance of protecting biological diversity and ways to enhance it while showing how to be successful as a farm business.

The support and cooperation of chemical and farm supply companies will be important to provide technology and supplies to implement biodiversity friendly practices. The present overwhelming tendency of chemical and farm equipment companies to bombard agricultural producers with information that promotes "clean farming" at the expense of all else, is a persuasive message that is detrimental to long range preservation of biodiversity on the landscape.

Ultimately the actions of farmers and ranchers to implement biodiversity friendly practices at the local level will be key to determining how effective any program is. Each farmer can do his/her part but for most BMP's to be effective, it will be essential that a certain percentage of land managers, controlling a critical mass of land acreage, be implementing a particular BMP or group of BMP's in concert. An obvious example would be if one landowner failed to protect the riparian habitat upstream and the stream becomes degraded or polluted, the best efforts of those landowners downstream will be nullified.

All of these groups and individuals will be needed as part of a team working toward the common goal of benefiting biodiversity while recognizing the needs for viable agricultural production.

In reality however, the critical part of the biodiversity conservation program is at the individual farm level. Unless a critical mass of landholders in a particular region implement an effective package of best management practices results of the goal will be negligible. Part of any BMP program will have to be to change the paradigm of farm management from wholesale specialization of crops and farming practices to diversity of crops and farming systems. From this perspective the contributions of ecological farming, organic farming, holistic farming and other sustainable agricultural systems should be recognized.

Analysis of a Package of BMP's for Their Benefits to Conserving and Enhancing Biodiversity

For purposes of analysis we have grouped a long list of potential or recognized farming BMP's into five categories that have similarities in their target and mode of application. These general categories and their specific BMP's are:

- **Terrestrial Habitat Management**
    - Conversion to permanent vegetation
    - Cover crops
    - Improved cropping systems
    - Grassland management
    - Enhancing wildlife habitat and biodiversity
    - Shelterbelt establishment
    - Biodiversity enhancement planning
    - Relocation of livestock confinement and horticultural facilities
    - Wintering site management
    - Woodlot management

- **Riparian and Water Management**
    - Erosion control structures
    - Riparian area management
    - Riparian health assessment
    - Irrigation management
    - Irrigation management planning
    - Farmyard runoff management
    - Watering system management

- **Soil Management**
    - Erosion control structures (non-riparian)
    - Land management for soils at risk
    - Soil erosion and salinity control planning
    - Manure land application

- **Nutrient Management**
    - Nutrient recovery from wastewater
    - Nutrient management planning
    - Manure management
    - Improved Manure storage and handling
    - Product and waste management

- **Species Management**
    - Improved pest management
    - Invasive alien plant species control
    - Preventing wildlife damage
    - Integrated pest management planning
    - Protecting species at risk

A detailed analysis of the BMP's follows.

4.0 Terrestrial Habitat Management

4.1 Strategies to Enhance Perennial Agroecosystem Management for Biodiversity

4.1.1 Introduction

There are considerable ecological advantages and biodiversity gains that could be realized through the increased use of perennial crops and agroforestry systems on farms in Canada. The main ecological benefits of perennials are that they tend to have greatly reduced rates of erosion, reduced level of nitrate pollution to groundwater and phosphorus loss to surface water and reduced pesticide use. From a greenhouse gas abatement standpoint, they store significantly larger volumes of soil carbon and the root systems and above ground biomass of perennial species are superior to annual systems. Perennials consume less energy inputs in their cultivation compared to annual crops (Samson et al. 2005). Additionally, less soil disturbance makes them generally more favorable to soil organisms and they provide habitat throughout a greater part of the year. It has been recognized that conversion of perennial landscapes into more intensive managed annual cropland has been a major source of loss of biodiversity. However, intensification of grassland production by using monoculture plantings and frequent cuttings can also be detrimental to biodiversity, particularly to birds on their nesting territory.

New efforts are required to incorporate more perennial species into agricultural landscapes. This can be done by putting land into permanent cover programs to protect fragile soils; land set aside programs to reduce surplus farm production; perennial biofuel production systems to replace the use of fossil fuels; and through short rotation tree plantations for fibre and fuel. There also is some scope for greater use of perennial forages to replace grains in animal production systems such as expanded use of intensive grazing and seasonal dairying to replace the use of concentrate feeds in dairy and beef production.

Biologists consistently report major advantages of perennial landscapes for wildlife populations. This review will overview the potential of various forms of perennial production systems and conservation plantings to be incorporated into farming landscapes of Canada and strategies for enhancing their potential to encourage biodiversity. Perennial farming and agroforestry systems appear to be one of the best solutions to reduce the intensification of agricultural landscapes that has occurred under evolving crop production systems. However, best management strategies need to be identified and further developed to maximize these benefits. With the warming climate trend that has been experienced in recent decades and future predicted increases of several degrees celsius it is likely the expansion of savannah and grassland habitat will occur in Canada. For example, the prairie peninsula that juts from the Midwest into Michigan, Ohio and the south western corner of Ontario was known to have expanded in a northeast direction during previous xerothermic intervals (Stuckey 1981).

4.1.2 Permanent Cover and Conservation Reserve Plantings

Areas established as permanent cover or conservation reserves should be large and continuous, rather than small and fragmented. Grasslands need some degree of disturbance management to maximize biodiversity benefits. Effective disturbance methods can be periodic mowing after mid-July, discing in the fall or spring burning depending on the situation. Maintain heterogeneity in both sward height and planting mixture between different fields. Mixed seedings are better than monoculture seedings of either cool- or warm-grass species.

In North America there has been considerable effort to utilize perennial grass plantings to protect fragile lands, enhance biodiversity and reduce the oversupply of grain in North America. In the US a major program was initiated in the 1980's to set aside 14.5 million ha. into the Conservation Reserve Program (CRP) and the more recent Conservation Reserve Enhancement Program (CREP). In Canada, a much smaller program of 450,000 ha. was developed called the Permanent Cover Program (PCP) and farmers were allowed to utilize the grassland seedings for their livestock operations. The US program has been a more expensive program to implement as farmers receive no income from the crop.

There has been considerable analysis of the CRP plantings in the US on wildlife populations and in particular on declining grassland bird populations. The main findings have been that the overall program has helped significantly to stabilize many grassland bird populations. Johnson and Shwartz (1993) found in CRP, 16 species of birds to have 7 times the median density of birds compared to cropland sites. Patterson and Best (1996) found 16 species of birds nesting in CRP fields and 2 species nesting in row crop fields. In total there were 10 times more nests in CRP fields than cropland fields. As well, nest losses were 52% in CRP fields while they were 65% in cropland fields. In the case of the one declining grassland bird (Patterson & Best 1996), there was 20 times the nesting success in CRP fields than in alfalfa hayfields.

It is important however that CRP plantings cover an extended area. Grassland waterways in the study were also identified to be bird sinks with only 8% successful nesting because of high predation (Patterson & Best 1996). For winter habitat, Best et al. (1998) found CRP fields provided winter habitat for several declining grassland birds not generally abundant in row crop habitats replaced by CRP.

CRP plantings however haven't contributed to stabilizing or restoring all grassland bird populations. There has been considerable loss of other permanent vegetation land to annual cropping which has helped reduce the overall impact of the program (Johnson D.H 2000). As well it has been identified that certain declining grassland birds have not responded to the CRP plantings because the size of the plantings were too small (Johnson D.H 2000). Certain specialist grassland birds require large areas of grassland, and most of the CRP contracts have been small fields.

Another concern is that the quality of CRP plantings, when left unmanaged without disturbance, deteriorates as litter accumulates. Lack of disturbance is likely leading to a decline in food abundance and availability and cover resource quantity and quality (Best et al. 1998). Best et al (1998) suggested periodic disturbance such as spring burning or autumn discing to reduce litter, stimulate seed production, and increase grass cover to provide better quality winter habitat. Johnson & Schwartz (1993) assessed densities of birds in hayed versus idled CRP lands in the year following a disturbance and found species that preferred short and sparse vegetation were favoured while many other species responded with reduced densities.

There also has been inconsistent findings related to the relative advantages of CRP 1 (cool season) vs CRP 2 (warm season) plantings (McCoy et al. 2001; Johnson D.H 2000) (Giuliano & Daves 2002). The overall findings indicate that mixed seedings are preferable to monoculture seedings of both CRP 1 and CRP 2. However if harvesting occurs, CRP 1 fields create significant interference with bird nesting (Giuliano & Daves 2002). Mowings on CRP lands are not recommended until after mid July. The other findings have been that for some specialist grassland bird species, keeping shrub cover below a certain height may be helpful in improving bird habitat by reducing perching sites for brown headed cowbirds (Shaffer et al. 2001)

Even when fields go unharvested, CRP-2 seedings appear to have an overall higher nesting success than CRP 1 plantings (McCoy et al. 2001). Lower incidence of parasitism might be expected in warm season versus cool season grass sites because of higher vertical vegetation density and the greater nest concealment it provides (Murray et al. 2003). This may be a significant advantage of warm season tallgrass plantings. Nest predation is the primary factor influencing grassland songbird reproductive success (Davis 2003)

In general, CRP 2 plantings have more potential benefit for bird species that prefer tallgrass while CRP 1 plantings tend to be more utilized by birds preferring shorter habitat (McCoy et al. 2001). However, the use of adapted species mixtures of shorter-statured moderately productive native warm season grasses such as little bluestem and sideoats grama (Jacobson et al. 1986) could also likely contribute to creating habitat for bird species requiring shorter grass habitats.

There are some key advantages of warm season species for biodiversity over cool season grasses. Warm-season grass plantings tend to have more vertical density and greater forb coverage and plant species richness, because young warm-season grasses grow in clumps leaving openings for opportunistic species (Grimsbo Jewett et al. 1996) (Henningsen & Best 2005). Warm-season grass stands tend to include a greater proportion of forbs (5-40%) compared to stands of cool-season grasses (1-25%) (Walk & Warner 2000).

Cool season grasses tend to be more sod forming, early in growth and increase competition by utilizing early season soil moisture. The increased forb content of warm season plantings makes them valuable insect and pollinator attractors. High quality tallgrass habitat can support significantly higher butterfly species diversity than shortgrass habitat (Collinge et al. 2003). Forbs are also the preferred habitat for building nests for some important declining grassland birds including dickcissels (Walk & Warner 2000). The stiff stems of forbs and thick stalked warm-season grasses can support the large nests of field sparrows and dickcissels (Walk & Warner 2000).

Haying as a management tool for maintaining tallgrass plantings is more favourable to avian abundances than burning, including species in decline such as Henslow's Sparrow *Ammodramus henslowii*, Grasshopper Sparrow *A. savannarum*, and Dickcissel *Spiza Americana* (Walk & Warner 2000; Swengel & Swengel 2001). Insects decline in number after a mowing event, but declines are smaller and shorter than after fire (Bulan & Barrett 1971; Chambers & Samways 1998) (Swengel & Swengel 2001). While no declines are seen in unmowed areas, successional changes in vegetation composition can impact insect communities (Feber et al. 1996; Schwarzwälder et al. 1997; Swengel & Swengel 2001). Thus, a mosaic of mowed and unmowed areas would increase insect species diversity.

A matrix of cut and uncut fields would also increase avian diversity. In terms of bird foraging, having shorter vegetation enhances foraging efficiency and reduces risk of predation (because birds can see approaching predators) for 75% of ground-foraging species studied (Whittingham & Evans 2004). Some species (eg., horned lark, vesper sparrow) prefer even more open surroundings such as those found in row crops (Murray & Best 2001). At the same time, longer vegetation harbours more insects and small mammals such as voles and mice. This can also provide food for hunting birds, often in greater abundance than in shorter fields (Atkinson et al. 2004; Whittingham & Evans 2004). A similar trade-off occurs for nesting birds, where nests in dense vegetation are less likely to be found by predators but the parents have less ability to detect them (Götmark et al. 1995; Whittingham & Evans 2004).

Some experiments have been done with strip-harvesting, where the field is mown in alternating strips so that only 60% of the field is harvested at one time. This leaves a medium litter depth and some residual vegetation within the cut strips for foraging and escaping. However, there is greater success for both dense-vegetation species and sparse-vegetation species when some fields were entirely cut and other whole fields were left uncut (Murray & Best 2001). Having a matrix of both short and long vegetation can both enhance insect and vole populations along with bird species that depend on these (barn owls, etc.), as well as providing shorter cover for the preferences of other species. Thus both the food and the access to food are enhanced.

In the Canadian Permanent Cover Program (PCP) initiated by Agriculture Canada in the early 1990's, over 445,000 ha of cropland was converted to permanent cover. Compared to the CRP program, limited analysis has been completed on the nesting success on these lands. An evaluation by McMaster and Davis (2001) suggested the PCP could help create habitat for grasslands birds and that 9 of 10 commonly detected grassland birds occurred at higher frequencies in PCP than cropland. Based on other research studies they suggested haying of PCP sites likely represents a major source of mortality in some years, and may create local sink populations. They found species richness and evenness did not differ between hayland and grazed sites. Species which preferred taller grass habitat were more commonly associated with hay crop land while those preferring shorter habitat were more commonly found on pastures. They suggested that their study join the body of evidence that indicates that habitat maintained in a mosaic of successional stages will provide habitat for the richest diversity of grassland species.

McMaster et al (2005) surveyed haylands in Saskatchewan associated with semi-permanent or permanent wetlands and found that habitat conversion significantly improved habitat for grassland birds and waterfowl compared to cropland use. However, they identified that significant potential exists for nest mortality and recommended delayed hay cut agreements and flushing bar use be negotiated with farmers.

4.1.3 Perennial Energy Crops

There is a strong possibility that significant amounts of Canadian farmland could be converted into biofuel production systems. Samson (1991) suggested that perennial grasses could be used on 14 million ha in Canada to become a major strategy for Canada to mitigate greenhouse gases by increasing carbon storage in landscapes and through biofuel displacement of fossil fuels. Several recent reports indicated that 17% (Etcheverry et al. 2004) and 65% (Layzell et al. 2006) of Ontario's agricultural landscape could be dedicated to energy crop production to produce fuel to replace imported natural gas, oil and coal for space heating and power generation.

A target of 1 billion tons of biomass production has been set in the US. (Perlack et al. 2005) found a total resource potential of 1239 tonnes in the US and that agricultural could provide 73% of this total or 906 million tonnes. No specific target has been made in Canada, but given Canada's agricultural land area, 100 million tonnes of total resource potential from the agriculture sector would represent a similar target in Canada based on our current farmland area. In Europe a number of initiatives have recently been developed with 17,000 ha of short rotation willow under cultivation in Sweden (Keoleian & Volk 2005) and 5,000 ha of reed canarygrass under cultivation in Finland (Pahkala et al. 2005).

Warm season grasses in Canada are now being produced by farmers for use in the production of biofuel pellets as there is an expanding market for agri-fibre pellets in commercial space heating applications such as greenhouse heating. Other applications for warm season grasses include straw bale housing, livestock bedding and use as a replacement for wheat straw in mushroom cultivation. The main biofuel production systems that have been researched in the US and Canada are warm season grasses and short rotation forestry. The biodiversity issues associated with these crops have some similarities but need special attention to address particular issues.

4.1.3.1 Perennial grasses as biofuels

Plant adapted mixtures of varieties of warm-season grasses where possible and harvest in late fall. Plant perennial biomass crops near natural areas to maximize their biodiversity potential. Include 'skylark patches' of unsown field areas on productive field sites.

Warm season grasses are generally favored for biofuel application because of their low cost of production adaptability to marginal soils, stand longevity and low nutrient requirements (Girouard et al. 1999; Samson et al. 2005). They have more favourable water relations which make them better adapted to landscapes with rainfall-to-evaporation ratios below one which are typical of grassland or savannah regions (Samson et al. 1993). They also have significant fuel quality advantages over cool season grasses because of their lower silica and mineral contents (Samson et al. 2005). However, cool season species are more productive than warm season species in cooler agricultural zones in Canada and can also be developed as biofuel crops.

The overall indication is that late season harvested biofuel crops have significant wildlife habitat potential compared to annual cropping systems. They provide much of the soil conservation and wildlife benefit of traditional CRP plantings while providing farmers with an economic return (Murray et al. 2003; Giuliano & Daves 2002; Samson et al. 2005). They are particularly valuable when they are utilized near natural landscapes where they can increase protection from predation and provide suitable habitat. A main advantage of perennial grasses for biofuel production is that mowing/harvesting is generally optimized in the late fall period following several hard frosts (Samson et al. 2005) and is avoided during the period of nesting or fledging (up until about early July in most of the agricultural regions of Canada). Since alfalfa fields in Canada are generally harvested in June this causes significant management concerns for grassland bird populations.

The main concern expressed with species such as switchgrass is that high yielding production systems will have limited potential for wildlife due to a number of problems associated with changing crop structure compared to native prairie. When grown in a monoculture, tall grasses such as big bluestem and switchgrass can be too tall and dense for many species (Norment 2002). Switchgrass cultivars in Quebec were found to have 485-956 tillers per square meter when managed for biofuel production (Madakadze et al. 1998).

The general concerns with intensification of switchgrass production are the same as with cereals and other grassland species. These include: increased density (i.e. mass of vegetation per unit area prior to any grazing or harvesting impacts), simplified and homogenized sward structure and architecture, both directly and by reduction in the species diversity of swards (Hole et al. 2005). This has been reported to be a problem in New York state where few birds were found in dense stands of switchgrass CRP fields (Norment et al. 1999). However, CRP fields of warm season grasses are known to become less productive because of the thick mulch that builds up on these fields and periodic mowing or burning is now recommended to improve the biodiversity potential of these conservation plantings (Giuliano & Daves 2002).

Wildlife biologists are now recommending the establishment of warm season grasses over cool season grasses as an avian conservation and management priority in permanent cover programs where hay harvesting occurs (Giuliano & Daves 2002). In the seeding year, warm season grass plantings are also known to be quite weedy and this provides a major source of weed seeds. Many grassland birds depend on a source of seed over the winter. Annual weeds are preferred by grasshopper sparrows (Walk & Warner 2000). In addition, some weeds go to seed in the fall and can provide a source of food over the winter when other seeds are scarce (Moorcroft et al. 2002; Henderson et al. 2004).

Winter bird crops (WBC's) have been tested in England for their value on a range of bird species (Vickery et al. 2004). Birds had a great preference for weedy stubble in winter, but most preferred specifically planted WBC's such as kale, quinoa, and a maize and millet combination (Vickery et al. 2004). Some warm season grasses such as switchgrass and prairie sandreed are heavy seed producers and could provide a significant source of food for birds and small rodents in the winter when other seeds are scarce.

Switchgrass and other warm season grass biomass crops are beneficial for biodiversity, as they require only a single fall or winter cut and do not disturb nesting birds (Murray et al. 2003). Switchgrass, a C4 plant, is much more effective than a cool-season species, as it has long fibrous, deep perennial root systems up to 330cm below soil surface, below those of most crop species (Ma Z et al. 2000). Tests have revealed that switchgrass can remove up to 20kg/ha of nitrogen as nitrate below 120 cm in the soil profile. Switchgrass has also been shown to have significant potential to sequester soil organic carbon (Frank et al. 2004; Liebig et al. 2005; Ma Z. et al. 2000; Tufekcioglu1 et al. 2003) and improve soil quality compared with row crops (Tolbert et al. Unknown Date), particularly at deeper soil depths (below 30 cm) where the roots extend into the soil column (Liebig et al. 2005). The roots (including crown) of switchgrass can account for as much as 84% of total plant biomass (Frank et al. 2004; Liebig et al. 2005).

Multi-species riparian buffers that include switchgrass can also be used to effectively protect surface and sub-surface waters from nutrient enrichment (Ma Z. et al. 2000). However, these crops do not leave enough residual dense cover in a field for all birds. Some grassland birds, such as the northern harrier, sedge wren, Henslow's sparrows and field sparrows, have increased densities when litter is present (Walk & Warner 2000) (Murray et al. 2003) (Swengel & Swengel 2001). Red-winged blackbirds also experience higher nesting success in such environments, while some declining species such as grasshopper sparrow preferred harvested CRP fields (Murray et al. 2003).

While strip harvesting fields may be an option to integrate more species in a field, the overall populations may benefit more if entire fields in an area are managed either as harvested or unharvested (Murray et al. 2003). Varying the cuts temporally from field-to-field rather than within the same field (eg. strip-cutting) maintains the farm habitat in a mosaic of successional stages which provides for greater avian diversity.

Other options that need to be further tested are to raise cutter bar heights in sections of harvested fields to provide adequate cover for early nesting species such as pheasants and to manage centres of harvested fields as CRP. Overall, the study by Murray et al (2003) demonstrated that harvesting warm season grass fields for biomass will create a marked improvement for grassland bird ecology.

This is in stark contrast to bioenergy production from corn ethanol. Corn production is considered a grassland bird nesting sink (Best et al. 1998; Best 1986), and fields have low biodiversity benefits because of increased rates of soil erosion and nutrient off loading. When genetically modified herbicide tolerant (GMHT) crops are planted low food resources are available to butterflies, wild pollinators and birds due to low weed biomass, impacts on field borders and low nectar production (Heard et al. 2003a; Roy et al. 2003). This problem of low non-crop bioresources may worsen in time with continued use of GMHT crops, as weed seed bank populations have also been reported to decline by 7%/yr when genetically modified herbicide tolerant crops are grown because of low return of weed seed rain (Heard et al. 2003a; Heard et al. 2003b).

A major advantage of switchgrass for biofuel production is that cellulosic ethanol and combustion applications are not highly sensitive to species contamination unlike livestock feeding (where noxious weeds and unpalatable species can occur in stands). Observations of stands by REAP-Canada in eastern Ontario and Quebec indicates significant diversity is achieved in monoculture seedlings on former hayfields through invasion by species such as red clover, vetch, brome grass, Canada thistle and fleabane. This species diversity makes these stands much more suitable for birds, butterflies and wild pollinators. The older the stand, the less it tends to be a monoculture.

As well, in many instances biofuels will be established on marginal farmlands. On low fertility farmland sites, weeds tend to make a higher proportion of the total biomass produced on sites compared to high fertility sites where crops predominate (Patriquin 1989). In native prairie landscapes, warm season tallgrasses tend to predominate on productive lowland soils while a greater diversity of grasses, forbs and legumes are found on less productive upland soils (Weaver 1968). Overall, if longer term stands are planted on marginal farmlands there is likely going to be less concerns for biodiversity than for short term stands (<5 years) on productive fields.

The main strategies that could be used to augment the biodiversity value of the plantings would be increased use of mixtures. The North American tallgrass prairie was largely dominated by three tallgrass warm season grass species: switchgrass, big bluestem and Indiangrass (Weaver 1968). In CRP1 and CRP2 planting in the US mixtures of cool season and warm season grasses are recommended.

In eastern Canada it is likely a portfolio of species could be developed and that species mixtures could be utilized. Prairie cordgrass, switchgrass and big bluestem are promising species that could be sown in fields in eastern Canada(Samson et al. 2005). Based on experience in western Canada and the northern great plains, the major warm season species that could be developed in the southern Canadian prairies are prairie sandreed, switchgrass, little bluestem, big bluestem and sand bluestem (Samson et al. 2005; Jacobson et al. 1986; Jefferson et al. 2004; Jefferson et al. 2002).

In addition to the use of mixtures of prairie grasses, another strategy to improve the wildlife potential of tallgrass monoculture switchgrass stands would be to introduce the "skylark patch" concept developed in Britain and introduced into the new environmental Stewardship Scheme in England (Morris et al. 2004; Wilson et al. 2005). These are 4 m x 4 m unsown areas that provide high quality habitat for species requiring short-statured open areas. This is a promising example of the emphasis the British ecology community is placing on re-creating heterogeneity in temperate agricultural systems. Rather than creating it through outcropped fields, their emphasis is on strategic zones in field or in surrounding fields, zones between cropped and uncropped areas, and post harvest strategies.

Warm season grasses biofuel crops appear to be most suitable habitat for large game birds such as ducks and pheasants. In Saskatchewan, McMaster et al. (2005) found haylands especially suitable for ducks including species of conservation priority such as the pin tail duck. The relatively dense nesting cover provided through the nesting season make taller vegetation preferred by waterfowl (Klett et al. 1986; Greenwood et al. 1995). Overall, the introduction of fall harvested warm season grasses into the southern Canadian prairies as biofuel crops appears to be a highly promising strategy to strengthen grassland bird and waterfowl populations.

4.1.3.2 Short rotation forestry

There is increasing potential for short rotation forestry (SRF) to become a significant new land use option for Canadian farmers that, like warm season grasses, could have some benefit to biodiversity compared to conventional land use. The main rationale for this industry is increasing demand for biofuels and biofibres, and for Canadian farmers to benefit from a land conversion program which would enhance demand for Canadian farm products.

The two most likely production systems are short rotation willow planted for energy and hybrid poplar or aspen planted for fibre applications. Typically the willows are planted at 12-15,000 spear per ha and harvested on a 3-4 year cutting cycle for a period of 25 years. Hybird poplars (or potentially aspen) are planted at 1100-1500 spears per ha and harvested in Canada on rotations of 10-20 years (Samson et al. 1999).

In Europe, the recent change in farm support programs should favour the development of short rotation willow as their subsidies for commodity production have been redirected to a general farm support program. In Sweden, the industry is in its most advanced development with 17,000 ha of short rotation willow under cultivation for energy production (Keoleian & Volk 2005). In Canada, longer rotation poplar cultivation for solid wood products and SRF willow for energy use have been identified as potentially valuable new economic options for farmers that have significant potential for carbon sequestration compared to current land uses (Samson et al. 1999).

Biodiversity under SRF is generally at least as favourable as conventional cropland use (Christian et al. 1998). SR plantations in Canada are generally not intensively cultivated with herbicides, irrigation or insecticides. In the US, researchers have found that wildlife can either be positively or negatively affected by SR plantations depending on the way the crop is managed, the location of the plantation with respect to other land uses, and which land use it displaces (Christian et al. 1998; Wolfe 1993). If properly designed and established, such plantations can provide a favourable habitat for wildlife and serve as effective travel corridors (Wolfe 1993).

For example, a number of studies have demonstrated that SR systems provide useful habitat for wildlife (Christian et al. 1994; Crawford 1995; Sage & Robertson 1996; Tolbert et al. 1997; Christian et al. 1998). In studies conducted in the Pacific Northwest and upper Midwest, hybrid poplar plantations did provide habitat for breeding and migrant birds (Tolbert et al. 1997). Bird species were found to use hybrid poplar plantations to a greater extent than agricultural crops, but to a lesser extent than natural forests (Tolbert et al. 1997).

Several factors can affect biological diversity in SRF systems. Major factors include the structural complexity of the plantation system, plantation age, rotation cycles, harvesting activities, adjacent land use, and the time scale within which the plantations are managed (Wolfe 1993).

In general, the more complex the vegetation structure within a system, the more diverse the community of animals associated with it. Therefore, as vegetative structure becomes simplified, so does the community it supports (Wolfe 1993). Vegetative diversity therefore plays a critical role in increasing biodiversity within SR plantations. Short-rotation systems that are intensively managed have little ground vegetation due to chemical and mechanical weed control early in the rotation, and shading later on. Such systems may therefore offer little to increase biodiversity. These plantations lack the structural complexity that is required for increasing biodiversity, such as the presence of canopy gaps to encourage other plant growth and dead trees (Christian et al. 1997b).

Conversely, in less intensely managed systems where vegetative diversity usually occurs because of incomplete weed control, increased biodiversity ultimately takes place. For example, in a midwestern U.S. poplar plantation, a high proportion of small-mammals were found to occur in portions of the plantation that were poorly established (i.e. other vegetation/weeds present) whereas mammal communities in the well-maintained portions had fewer and less diverse species (Christian et al. 1997a). In the midwestern U.S., well-maintained poplar plantations had only 0 to 49% of the plantation being utilized by birds and mammals (Crawford 1995). Therefore, in areas where weed control is very effective, and thus little vegetative diversity present, the possibility to increase biodiversity is lost (Christian et al. 1998). Hence, the use of genetically engineered trees to enable broad-spectrum herbicide use would be expected to provide extremely clean plantations and low biodiversity potential. This is of particular concern with the introduction of genetically engineered poplars, which may outcross native poplar species (Tolbert 1999).

The use of SRF systems for wildlife is also affected by plantation age since the habitat offered within a plantation will change with time (Wolfe 1993; Sage & Robertson 1996). In a Minnesota study, the amount and diversity of breeding birds utilizing young hybrid poplar plantations was initially similar to those utilizing grasslands and row crops. However, as the plantations approached canopy closure, successional species became predominant (Tolbert et al. 1997). Another midwestern U.S. study also demonstrated that shortly after planting poplars, the bird species frequently observed within the plantations were typically associated with those observed in open fields. However, between ages 2 and 4 years, a change in bird species composition had occurred (Hanowski et al. 1997). In a British study, more migrant bird species were recorded from a 2-year old than a 1-year old willow plantation after coppice and most resident species selected older willow or poplar coppice growth (Sage & Robertson 1996). Both poplars and willow have also been reported by other scientists as having a great diversity of insects in their canopies (Sage & Tucker 1997). However, SRF willow has an increased avian fauna diversity compared to poplar plantations which may be due to larger population of insects (Sage 1998).

Species composition of small mammals also changes with plantation age. For instance, shrews were found to be absent from young, well-maintained poplar plantations, but appeared in well-vegetated patches on both young and older plantations (Christian et al. 1997b). In addition, mammal communities in young plantations were dominated by a single species generally found in open habitats (Christian et al. 1997a). In older plantations however, a more diverse array of species was present, including species generally associated with more complex vegetation structures and forest habitats. However, mammals requiring forest habitats were almost completely absent from older plantations (Christian et al. 1997a; Christian et al. 1997b). Therefore, plantations even late in the rotation will likely harbour species primarily seen in open habitat but not those associated with forest (Christian et al. 1997a; Christian et al. 1997b; Christian et al. 1994).

Harvesting activities and rotation cycles may also negatively impact biodiversity. For instance, in the case where a winter harvest will remove all or most vegetative cover, this will ultimately leave wildlife with no adequate cover for winter, no protection from predators, and destroy their nesting ground thus disrupting nesting activities the following spring.

Biodiversity within biomass plantations is greatly affected by the surrounding landscape (Christian et al. 1998). As observed in a study conducted in Ontario poplar plantations, bird communities were influenced by the surrounding landscape. Forest birds were more abundant in plantations that were surrounded by natural forest than by those that were not (Christian et al. 1998). In addition, more species occurred on plantations located adjacent to both forested and open habitats than on those located in a less diverse area. In the U.S.

Midwest, bird species associated with forest habitat were also found on plantations in close proximity to forest (Hanowski et al. 1997). Similarly, species associated with open habitats were more commonly observed on plantations surrounded by open and agricultural landscapes (Christian et al. 1998).

4.1.4 Grassland Management Systems

Both hayland and pastureland represent a type of grassland that can house many species if managed properly. The act of haying or grazing can be beneficial to grassland habitat, as it resets the successional stage of the ecosystem and prevents the ascendance of shrubs and woody material. Overall, grasslands are prime habitat for many avian species, butterflies, other invertebrates, and some prairie mammals.

Many of the grassland birds are species of concern across North America. Reasons for their decline can be found in many traditional farming practices: decreased field area; denser, more uniform swards; more intensive grazing; increased frequency and earlier timing of hay mowing; and the abandonment of farmland and succession to woodland habitat (Bollinger et al. 1990; Herkert 1994; Vickery et al. 1994; Norment 2002).

Threats to biodiversity can be physical (crop structure, agricultural operations), chemical (pesticides and herbicides), and biological (increased predation by species that thrive in anthropogenic habitats).

Grassland vegetation structure is a more important determinant of avian habitat than the plant species composition (Weins 1974; King & Savidge 1995) (Sutter et al. 1995; Davis & Duncan 1999; McMaster & Davis 2001). However, vegetation type does matter for butterflies, whose species diversity increases with an increased proportion of native plants (Swengel & Swengel 2001; Collinge et al. 2003). For butterflies, the most important factors are the presence of host plants and nectar. Grassland species are adapted to great interannual variability in grassland structure, having evolved with unpredictable weather and frequent disturbances by fire and grazing (Blackshaw et al. 2005). However, different species respond in different ways to vegetation changes between years and between regions (Blackshaw et al. 2005). Maintaining grasslands with different types of vegetation structure at all times is critical.

The needs of species are unique, and often management goals are made with a particular species in mind. Bird species have many different food requirements, antipredator behaviours, microclimate preferences and breeding seasons and lengths (Hole et al. 2005). However, some general recommendations can be made that benefit a diversity of species. For both haylands and rangelands, a common theme in the literature is heterogeneity. Many environmental farming schemes to date have focused on landscape-scale solutions, such as shelterbelts. In addition to these schemes, however, maintaining heterogeneity within a single field can benefit a wide variety of species.

4.1.4.1 Haylands

Hayfields are unfortunately often a sink habitat for birds, given current management schemes. Fields can appear to be good habitat with abundant food and nesting resources, and many birds will nest there only to have their broods destroyed by haying operations come June.

The intensification of hay production simplifies crop structure and creates a dense, homogeneous stand. The intensification of forage production promotes fast-growing grass species which outcompete others, decreasing the plant diversity, the structural diversity, and the food and nesting opportunities for wildlife (Vickery & Herkertc ; Vickery et al. 2004). Pure alfalfa stands and alfalfa grass mixtures are common throughout Canada and are regularly resown in rotation with other field crops. In the past 30 years in Canada, livestock farmers have been encouraged to harvest early and frequently to optimize forage quality. This is especially the case in dairy production where most farmers in Canada largely have completed their haying well before the time of peak fledging for most birds in early July.

Species nesting within hayfields are often harmed by frequent agricultural operations (Rodenhouse & Best 1983; Johnson 2001). Haylands can therefore create local sink populations if improperly managed (Pulliam 1988; Bollinger et al. 1990; Frawley & Best 1991; Dale et al. 1997; McMaster & Davis 2001). In managed grasslands in Illinois, fields are left idle from April to late July to accommodate the local nesting season (Walk & Warner 2000). The long-term average cutting date for Saskatchewan, for example, is 7 July; this haying date left 25-30% of nests vulnerable to destruction in one study over 1999-2000 (McMaster et al. 2005). Harvesting forage in mid-summer can be beneficial for field curing, but the quality of forage may be poor (Kunelius et al. 2000) as the lower protein and higher ADF content of forages make them more suited to small beef cattle breeds and not well suited to dairy cattle (Nocera et al. 2005).

Grassland birds feed on invertebrates (foliar or soil invertebrates) or seeds and grains. According to recent literature, the abundance of food has less of an effect on bird habitat choice than the accessibility of that food and ease of predator detection while eating it (Atkinson et al. 2004). Foraging is increased where the grass swards are sparser and where gaps in the grass exist (eg., tractor wheelings, unsown plots within the field) (Odderskaer et al. 1997; Moorcroft et al. 2002; Perkins et al. 2002; Atkinson et al. 2004; Barnett et al. 2004; Wilson et al. 2005).

Native prairie is still the most beneficial habitat for grassland birds (Johnson D.H 2000), yet hayland can provide important habitat for many species. Hayfields provide more benefits than croplands to grassland birds, especially to waterfowl (eg., gadwall, northern pintail) in the Prairie Pothole Area (McMaster et al. 2005). Directing conservation efforts towards hayfields targets a typically low-diversity system and therefore avoids the problem of trying to achieve gains in grassland bird numbers at the expense of other species such as forest-dependent birds (Norment 2002). Hayfields can also host a great number of butterflies and small mammals.

4.1.4.2 Planting

Utilize mixtures of late maturing legumes and grasses for forage production that retain their quality when harvested after July 15.

The choice of plants for a hay mixture will be determined by the farmers' forage plan for their livestock operation. Typically, dairy farmers are most concerned with maximizing forage quality to increase intake and milk production while beef producers are more concerned with optimizing the yield of forages while accepting a lower forage quality than dairy producers. The choice of plants is also affected by the winterhardiness zone, field drainage and soil acidity. To promote biodiversity in hayfields, the following characteristics can be encouraged:

a) include mixtures or species which can maintain nutritional quality under a later-cutting scenario;
b) grow mixtures which are well adapted to the site and that grow well with minimal inputs of inorganic fertilizers or herbicides;
c) use mixtures which produce seeds;
d) use mixtures which attract a diversity of invertebrates.

4.1.4.3 Options for Delayed Hay Harvesting

The many studies which identified high nest mortality under cool season grass and alfalfa hay management have enabled some strategies to be identified to better conserve grassland birds. In Atlantic Canada, peak fledging activity occurred in the first week of July for savannah sparrow, bobolink and Nelson's sharp tailed sparrow (Nocera et al. 2005). In western Canada, fledging also occurs generally in the first two weeks of July depending on the latitude and year.

In Western Canada, the cool season species that would be most suited for plantings for a mid-July cut would be intermediate wheatgrass, and cicer milkvetch and intermediate wheatgrass mixtures. Cicer milkvetch tends to hold its forage quality as it tends to be thinner stemmed and does not lignify as quickly as alfalfa (Coulman 2006). Another option might be the introduction of improved warm season species for forage production especially big bluestem and switchgrass. In the prairie provinces, cool-season grasses are best adapted to the northern areas while both warm-season and cool season grasses are productive in the southern prairies (Jefferson et al. 2002).

Warm-season grasses mature later, producing 70% of their biomass after June 1 and reaching peak biomass during July and August (Giuliano & Daves 2002; Jefferson et al. 2002). Most of the cool-season grass biomass is produced by June (Jefferson et al. 2002; Giuliano & Daves 2002). In particular, the introduction of mixtures of improved forage varieties of big bluestem and switchgrass could enable native grasses to produce forage of acceptable quality for beef cows and reduce the risks of drought on forage/livestock producers. Cultivar studies of switchgrass in North Dakota identified varieties that had no winter mortality problems when a 15 cm cutting height was used in July or August (Berdahl et al. 2005).

In eastern Canada there are several options for forage mixtures which facilitate a delayed harvest management. Birdsfoot trefoil typically flowers 2-3 weeks later than alfalfa (Robinson & Winch 1986) and is best suited to poorly drained or marginal soils and for use in mixtures with late maturing timothy. It is more competitive in yield with alfalfa in northern locations in Ontario and Quebec, and first flowering on some varieties occurs as late as July 7 (Ontario Forage Crops Committee 2006). Red clover and timothy are commonly grown for silage and hay in Atlantic Canada (Kunelius et al. 2000). Typically, the red clover used is of the early-maturing or double-cut type. Single-cut red clover has a later maturity date, and is hardy and persistent especially in harsh overwintering conditions. Grown in combination with a late-maturing timothy, both reach optimal maturity about two weeks later than the traditionally grown red clover varieties (Kunelius et al. 2000). Harvesting on July 11 rather than June 27 led to a 39% yield increase to 7.68 t/ha (Kunelius et al. 2000). This is out of the range of peak nesting for most grassland species (approximately May 15 to July 10). The combination of single-cut red clover and timothy can be grown as a valuable rotation crop with potatoes, as they are short-term, low-input forage crops (Kunelius et al. 2000).

From a practical standpoint for farmers, including some fields in late maturing mixtures may well suit their farming operations as a portfolio of hay mixtures of different maturities may enable them to use their available labour and machinery more efficiently and will reduce the risks of wet weather impacting on their forage harvesting operations and forage quality.

On most forage farms in western Canada, alfalfa is often mixed with other cool-season grasses such as crested wheatgrass (*Agropryon cristatum*), smooth brome (*Bromus inermis*) or Russian wildrye (*Elymus junceus*) (McMaster et al. 2005). In eastern Canada, haylands are most commonly sown to alfalfa and timothy mixtures. Mowed cool-season grasses provide good habitat for such species as short-eared owls, while areas of bare ground also provide for foraging of upland sandpipers, prairie chickens and northern harriers (Herkert et al. 1999; Walk & Warner 2000). In Colorado, hayfields of alfalfa and a mixture of cool-season grasses harboured the greatest abundance of butterflies when compared to shortgrass, mixed-grass and tallgrass prairie patches; however, tallgrass prairie (warm-season grasses and forbs) exhibited the greatest butterfly species richness and most uncommon species (Collinge et al. 2003).

4.1.4.4 Cutting Time and Pattern

Harvest first cut in mid July. Cut from the inside (around the inner 'prairie') outwards. Vary the cutting times of neighbouring fields; spatial heterogeneity is important.

Besides implementing a later harvesting date, having an inside-to-outside mowing pattern can greatly help in the survival of many young birds. Chicks can move away from mowers quickly enough to avoid the cutter, provided they have an escape route to a refuge area as they will not leave the shelter of tall grass (Tyler et al. 1998). Maintaining an inside-to-outside cutting path and orienting harvesting routes towards safe cover can greatly aid the survival of both hens and their chicks (Green 2004; Wilson et al. 2005). The later harvesting date will also aid chick dispersal, as older chicks have a higher probability of escape (Tyler et al. 1998).

Hayland adjacent to cropland, or with cropland available at the landscape scale, had greater waterfowl and nest abundance, although for other birds the greater landscape had no significant effect (McMaster et al. 2005). Green (Green 2004) recommends harvesting fields adjacent to wetlands last in a sequence, as this is preferred habitat for nesting birds.

4.1.4.5 Haying Method

Use flushing bars or enhanced flushing bars for dense vegetation. Raise or angle the cutter bar and drive at reduced speeds.

Not only birds are harmed by haying operations, but small mammals and deer as well. Fawn mortality caused by mowing was estimated at 25-44% of young in one study in Sweden (Jarnemo 2002); this problem was described by farmers in western Canada as well. Placing black plastic bags in the field prior to haying was shown to be an effective method to reduce this problem (Jarnemo 2002). Black plastic bags can be attached to approximately 2-m long poles and placed at regular intervals in hay fields prior to harvesting. This causes female deer to remove their fawns hiding in the grass to another field or habitat patch within one to two days of setting out the bags (Jarnemo 2002). If fields are maintained in a matrix of cut and uncut fields, there should be adequate refuge for the fawns.

The use of flushing bars is strongly promoted across Canada by Ducks Unlimited. Considerable research was done on the effectiveness of these bars in the 1950s, and interest is being revived today. These bars are targeted at flushing out roosting hens from the field before it is cut, as their instincts are to ‘freeze’ and stay on the nest. The flushing device is frame of steel tubing mounted to the tractor or haybine with chains penetrating down into the vegetation at given intervals. These devices cost about $700 US to fabricate and custom-mount (Green 2004). A design is available from Ducks Unlimited. Use of flushing bars appears to be most effective between 7 and 10 am, and 3 to 6 pm (Klonglan et al. 1959; Green 2004). Calverley and Sankowski (Calverley & Sankowski 1995)found the use of flushing bars to be 100% effective in flushing out nesting ducks in Alberta.

However, in growing seasons with above-average hay crop density, hens are more difficult to flush as they feel safer in the dense cover. An enhanced flushing bar can be used for these years, by splicing double chains or weights onto existing chains on the flushing bar. This will add weight for better penetration and greater noise (Green 2004). Auditory stimulation has no effect on flushing birds from a field (Stewart & Dustman 1955; Green 2004).

Reductions in wildlife mortality during hay cuts can also occur by altering the cutting head. Raising the cutter bar by at least 3 inches above the ground can help avoid any unflushed grassland birds, who often nest in small depressions in the field (Green 2004). This might reduce hay volume, but less stem would be harvested and the practice could also reduce machine maintenance costs as the cutter would hit the dirt less frequently (Green 2004). This leftover stubble can also be beneficial to re-colonizing birds in terms of residual cover and food (Giuliano & Daves 2002). Many species, including Henslow's sparrow, upland waterfowl, northern bobwhite, ring-necked pheasant and upland sandpipers prefer fields with dead residual cover (Giuliano & Daves 2002). Angling the cutter bar slightly upward can also minimize injuries from the cutter.

4.1.4.6 Field Layout

Keep large, block-shaped hayfields. If you are planting both warm- and cool-season grasses, plant the inner fields in cool-season grasses and put warm-season grass fields towards the outside. For each field, consider an inner square of uncut 'prairie'. Leave an uncut/rough grass field margin around each field.

Block-shaped fields that minimize edge are generally better habitat for grassland birds. In narrow, strip-cover habitats, nest success of all bird species is relatively low compared to block-shaped grasslands of similar planting mixture because of the high rates of predation from mammals that also use strip-cover as travel lanes (Patterson & Best 1996; Henningsen & Best 2005). Large, square field size minimizes edge effects and accommodates species with large home ranges.

More edge habitat and woody vegetation will actually cause greater numbers of bird species to be present (Arnold & Higgins 1986; Johnson D.H 2000). However, these edge species are typically generalists with stable populations and plenty of habitats from which to choose (Johnson D.H 2000). Obligate grassland species are the ones whose diversity is at risk on the larger scale. One of these is Sprague's Pipit (*Anthus spragueii*), a native grassland specialist that may benefit from seeded grassland (Wilson & Belcher 1989; Dale et al. 1997; Sutter & Brigham 1998; Davis & Duncan 1999; McMaster & Davis 2001).

One farm-scale pattern that may be used is to put fields with taller, denser grasses such as biomass crops and warm-season grasses near the outside/edges of the farm. These areas are usually more marginal so the grass won't form quite as dense a monoculture. These areas are usually the most open to predation, which the tall stands might protect against more strongly than the cool-season grasses being cut more often.

Within individual fields, leaving small unsown patches can provide for nesting sites. Leaving a centre square uncut in the middle of each field can also be beneficial for cover-loving birds when harvest time comes. These patches can provide seeds and an abundance of invertebrates, as well as a refuge for birds and butterflies during the cut.

Leaving uncut and/or rough grass field margins around the border of each field is also critical (Green 2004; Wilson et al. 2005). Chicks and other animals escaping the harvest can take refuge in uncut field margins, especially when fields are harvested in an inside-to-outside pattern.

Riparian filter strips along the edges of fields and streams are advocated for many reasons, including wildlife benefit and protection of soil and water resources (Henningsen & Best 2005). These filter strips can vary in planting mixture (McCoy et al. 2001) and adjacent vegetation (wooded vs. non-wooded), and these variables impact on the wildlife using the filter strips as well as nesting success of birds and predation rates. Planting warm-season grasses in filter strips is often preferred because of their greater ability to intercept runoff (Lee et al. 1999; Henningsen & Best 2005). The planting mixture in filter strips did not affect mean avian species richness or bird and nest abundances (Henningsen & Best 2005). However, nest success in strip-cover is likely too low to maintain stable avian populations (McCoy et al. 1999; Henningsen & Best 2005).

Trees and shrubs in shelterbelts and other arrangements provide other aspects of farm diversity, including perches for raptors and pathways for mammals (Johnson D.H 2000). Opossums and raccoons are more abundant in woody vegetation, while grassed strips are more frequented by skunks, snakes, and rodents. Some grassland birds such as vesper sparrows use perches, and other species associated with edge habitats include common yellowthroats, song sparrows and ring-necked pheasants (Herkert 1994; Norment et al. 1999; Henningsen & Best 2005). Other species such as dickcissels and sedge wrens avoid wooded edges.

Wooded strips can be detrimental to the grassland bird species as they harbour predators (cowbirds, other avian and mammalian predators) and competitors for food in the adjacent fields (Gates & Gysel 1978; Winter & Faaborg 1999; Winter et al. 2000; Henningsen & Best 2005). Some studies have found that the presence of woody vegetation has no significant effect on bird densities and nest success where the amount of ground covered by woody vegetation is very low (2.4%) (Blackshaw et al. 2005).

Another problem with having vulnerable grassland nests close to woody vegetation is nest predation by catbirds. These birds prefer roosting in forest, riparian woodland, or cattail marshes (Curson et al. 2000). Catbirds usually require a tree or shrub or other structure higher than the surrounding vegetation for perch sites.

4.1.4.7 Pasture and Rangeland Management

In a study measuring avian species richness among fields enrolled in Canada's Permanent Cover Program, there was no difference between fields used for haying and those used for grazing (McMaster & Davis 2001). However, the mean difference in patches of bare ground between these sites was quite small. Grazed sites had shorter vegetation and a greater proportion of bare ground. Some avian species (eg., Baird's sparrow, Sprague's pipit) nest primarily in native pasture rather than haylands, and some do not nest in hayed lands at all (McMaster et al. 2005). Both abandonment of grazing lands and grazing intensification have been cited as causes for the decline of grassland birds (Söderström et al. 2001).

Fleischner (Fleischner 1994) cited the ecological costs of western North American grazing systems as loss of biodiversity; lower population densities for many taxa; disruption of ecosystem functions; and changes to community organization and physical habitat structure. There is typically reduced species richness, and fewer individuals. In vegetation, this occurs by two different means: active selection by herbivores for or against a plant species, and by differing hardiness of plant species to grazing (Fleischner 1994). Animal populations are also affected due to indirect effects on habitat structure and food availability (Quinn & Walgenbach 1990; Fleischner 1994). A more varied sward composition is achieved in low-intensity cattle-grazed pasturelands, versus high-intensity cattle or sheep grazing (Vickery et al. 2004).

Like haylands, the key to biodiversity in pasture is habitat heterogeneity. Birds, butterflies, mammals, and even aquatic creatures can be affected by pasture and grazing management. Soil-invertebrate-eating birds like short, grazed swards with some bare patches, ideally not far from longer grassed areas from which invertebrates can disperse. For these birds, one of the benefits of grazing is the presence of dung on the field. Dung attracts soil invertebrates to the surface, making them more accessible to birds (Tucker 1992; Atkinson et al. 2004).

On the other hand, foliar-invertebrate-eating birds prefer taller, dense swards with abundant food. Some gaps still helps them maintain vigilance against predators. Granivorous species like grasses that are allowed to go to seed at the end of the summer. Butterflies and moths are more abundant at an intermediate level of grazing intensity than ungrazed or continuously grazed pasture (Pöyry et al. 2004). There is some evidence to suggest that some small mammals benefit in the presence of livestock because of the greater number of insects attracted to the dung or because of the increased open patches (eg., short-tail shrews). However, other studies show that grazing can compact the soil and make it difficult for burrowing as well as reducing the amount of litter and residual vegetation (Giuliano & Homyack 2004). Livestock tend to congregate in riparian ecosystems, and can inflict concentrated impacts on these sites (Fleischner 1994). Thus aquatic organisms can be affected as well as terrestrial.

Managed grazing, however, has the potential to maintain habitat quality and diversity (Vavra 2005). Grazing can be both ecologically responsible and a tool for conservation (Curtin 1994). Light grazing can be an important tool for resetting succession and maintaining grasslands (Vavra 2005).

4.1.4.8 Type of Grazing

Rotational grazing provides a matrix of heterogeneous habitat that benefits the widest variety of grassland species. In areas of concentrated waterfowl nesting, including dense nesting cover (DNC) may be considered.

Intensive grazing has the same effect on grassland as frequent and early mowing: plant species diversity and structural diversity are decreased. Shorter, denser swards decrease invertebrate populations both above and below ground, which has impacts along the food chain to birds and other insect-eaters (Atkinson et al. 2004; Whittingham & Evans 2004). Cowbirds also thrive in this type of short vegetation and often prefer habitats created by large grazing mammals (Mayfield 1965). Intensive grazing can have negative impacts on other wild herbivores. For example, sites lightly grazed by cattle over the summer are preferred by elk in the fall while moderate cattle grazing over the summer creates sites preferred by elk in the following winter and spring (Crane & Laramie 2002; Vavra 2005).

Grazing extensification is the opposite of intensification: reducing the number of grazing individuals per hectare. This method results in approximately half the stocking density of intensive grazing (approx. 6 cows/ha compared to 12 cows/ha) (Pavlù et al. 2006). Extensification is a good ecological management strategy because it helps to restore grassland conditions and reduces or eliminates the need for inorganic fertilizers and changes the time and frequency that the swards are grazed (Pavlù et al. 2006). Average sward height of extensively grazed plots (4.4-5.8cm) was approximately twice that of intensively grazed plots (8.8-10.8cm) (Pavlù et al. 2006). Extensive grazing decreases the animal production per unit area for the farmer, but individual animal performance, measured in weight gain over the year, is similar under extensive and intensive management systems (Hofmann et al. 2001; Pavlù et al. 2006). The same result was documented for sheep grazing as well as cattle (Barthram et al. 2002).

In extensive grazing, livestock can be more selective about the plants they graze, leading to patchy fields where favourite grazing plants or clumps are cut shorter than other vegetation (Rook et al. 2004; Pavlù et al. 2006). The resulting uneven sward structure is important for avian, butterfly, and mammal diversity. However, caution must be exercised on high-fertility soils as the grasses can grow up in dense swards if only lightly grazed, and litter can build up smothering out other growing vegetation (Vickery et al. 2004). In addition, idle plots showed greater plant species diversity than either intensive or extensive grazing (Pavlù et al. 2006).

Some areas remain idle in a third type of grazing: rotational grazing. In rotational grazing, pastures are divided into smaller range units and cattle are periodically moved among these units (Lapointe et al. 2000; Undersander et al. 2000). It is possible to reduce negative impacts of grazing in this way, and it is inexpensive to farmers (Gjersing 1975; Barker et al. 1990; Lapointe et al. 2000; Undersander et al. 2000). There is greater ground cover for wildlife, and more undisturbed cover for nesting birds at any given time. With intermittent grazing, there are often more forbs available in the field as these are not all eaten by livestock and are allowed time to regrow (Vavra 2005). Forbs are an important food for some grassland birds as well as butterflies and bees. Rotational grazing also reduces cowbird predation (Stauffer & Best 1980; Morris & Thompson 1998; Shaffer et al. 2001). Bird species diversity is greater on rotationally grazed fields compared to row crops and continually grazed pasture (Undersander et al. 2000).

Rotational grazing creates a matrix of different seral stages which tends to maximize grassland bird species diversity and abundance (Fritcher et al. 2004). On a western wheatgrass-green needlegrass pasture, populations of grasshopper sparrow (*Ammodramus savannarum* Gmlin), bobolink (*Dolichonyx oryzivorus* Linnaeus), dickcissel (*Spiza americana* Gmlin), and brown-headed cowbird (*Molothrus ater* Boddaert) density increased along with the seral stage, as tall vegetation and residual cover increased (Fritcher et al. 2004). Species that preferred the early seral stages including short grass and sparse vegetative cover include burrowing owl (*Athene cunicularia* Molina), upland sandpiper (*Bartramia longicauda* Bechstein), chestnutcollared longspur (*Calcarius ornatus* Townsend), and horned lark (*Eremophila alpestris* Linnaeus). Western meadowlarks (*Sturnella neglecta* Audubon) preferred early-mid seral stages. Providing these different stages of succession in the landscape can benefit each group.

Rotational grazing is also beneficial for cattle: calf weight gain per hectare is greater than with continuous grazing (Barker et al. 1990), and plants are maintained at a vegetative stage that provides digestible forage (Lapointe et al. 2000). Dairy, beef and sheep farmers can all use rotational grazing (Undersander et al. 2000). Both rotational grazing and extensive grazing are recommended for conserving avian communities in pastureland (Söderström et al. 2001).

Another method to enhance duck nesting success is establishing dense nesting cover (DNC). In eastern Canada this has consisted of mixtures of reed canary grass with timothy, tall fescue, orchard grass or tall wheat grass, or a mixture of western wheatgrass and crested wheatgrass (Lapointe et al. 2000).

In a study of nest success in Quebec, cattle were grazed in rotation between improved and unimproved pasture, surrounded by idle field and DNC. Improved pasture was grazed between mid-May to July (nesting season) and the unimproved pasture between July and September. The reed canary grass mixture DNC showed the greatest nest density and success followed by an idle field, unimproved pasture, the wheatgrass mixture DNC, a ploughed field, and improved pasture (Lapointe et al. 2000). Unimproved pasture consisted of red-top (*Agrostis alba* L.), red fescue-grass (*Festuca rubra* L.), Kentucky bluegrass (*Poa pratensis* L.) and cow vetch (*Vicia cracca* L.) along with some reed canary grass (*Phalaris arundinacea* L.) and Canada reed-grass (*Calamagrostis canadensis*). Improved pasture was sown with timothy (*Phleum pratense* L.), sweet clover (*Melilotus officinalis* [L.] Desr.), smooth brome (*Bromus inermis* Leyss.) and clover (*Trifolium* spp.).

However, studies in southern Saskatchewan did not show greater nest success using DNC (McKinnon & Duncan 1999). This could be due to a difference in climate between Saskatchewan and Quebec. In drier areas, DNC reaches maximum growth after 3-5 years and may become too dense for nesting by 7-8 years (Duebbert & Kantrud 1974; Duebbert et al. 1983; Lapointe et al. 2000). Maximum growth may be reached earlier in Quebec under more favourable growing conditions. Under a shorter time cycle, short-term cattle grazing in the fall can help maintain cover quality of the DNC (Lapointe et al. 2000).

The DNC system is most effective in reduce avian predation rather than mammalian (Clark & Nudds 1991). It may be most useful in areas of abundant and concentrated waterfowl populations; otherwise the size of DNC required may become prohibitive (McKinnon & Duncan 1999).

4.1.4.9 Pasture Design

Divide the pasture fields into large, block-shaped range units for rotating livestock. Include a large area in the centre of the pasture where possible for deferred summer grazing. Include some paddock trees or shelterbelt along an edge. Fence off riparian areas and wetlands. Light grazing in wetlands may be considered in the fall of the occasional year if there is trouble with a dominant species or woody vegetation taking over.

Rotational grazing between different range units seems to be the strongest method for improving biodiversity in pasture lands. Similar to designing hayfields, the pasture units should be large and block-shaped to minimize edge (Shaffer et al. 2001).

Peak nesting season also coincides with the time of peak pasture growth. During this time there is abundant grass available for grazing, so there is usually a portion of the range units that can be deferred for summer grazing. Units near the centre, surrounded by pasture and farther from any tree shelterbelts, are important refuges for grassland birds and should not be grazed during peak nesting time (mid-May to early July) (Undersander et al. 2000). Selecting these centre units for deferred grazing maximizes wildlife benefits and increases grassland bird nest success. This area has a lesser risk of cowbird predation (Shaffer et al. 2001) as well as predation from other mammals. However, having paddock trees adjacent to some edge pasture units can house a diversity and abundance of invertebrates (Oliver et al. 2006).

Livestock should generally be fenced off from riparian areas and wetlands. They can cause extensive damage in riparian areas, including effects on water quality and seasonal quantity, stream channel morphology, hydrology, riparian zone soils and vegetation, and aquatic and riparian wildlife ((Belsky et al. 1999). Small mammal communities such as meadow voles and meadow jumping mice benefit when cattle are fenced off from a grassed riparian area (Giuliano & Homyack 2004). However, light grazing in the fall of the occasional year can help reduce monocultures of wetland dominants and reduce woody vegetation without impacting nesting waterfowl (Vavra 2005)). Other ungrazed wetland areas can provide tall residual cover for nesting birds come spring.

This rotational system provides a diversity of structural habitats, ranging from patches of bare ground and short grass in the grazed range units to growth of forbs and mid-height grasses to a tall-grass pasture in the centre.

4.1.5.0 Timing

Graze areas near the centre of the field, away from wetland areas, in early spring (before mid-May). From mid-May to early-mid July, graze livestock in alternate range units for no more than 2 days in each, or until grass height reaches 4 inches. Defer the centre area for summer grazing in mid-July. Late summer and fall grazing can include the centre area.

In a rotation system, livestock are concentrated into one or two groups. It is recommended that the groups should graze one unit each for two days maximum before moving to the next range unit (Undersander et al. 2000). There is typically a 3-week interval before cattle graze in the same unit again. If possible, pasture units with high populations of grassland birds (typically open pastures farther from any trees) should have a longer non-grazing interval. Rotating livestock at a 4-inch grass height increases bird nest success and also increases the rate of plant recovery, increasing yield (Undersander et al. 2000). Rotating cattle to maintain grass heights taller than 5cm is also recommended for minimizing nest predation by cowbirds (Morris & Thompson 1998; Shaffer et al. 2001).

Grazing the refuge area before May 15 delays forage maturation. The unit will then maintain its quality longer into the summer for the delayed mid-July grazing period (Undersander et al. 2000). This system also provides extra pasture in early spring when there is strong pressure on new growth of forage grasses. Grazing range units near wetlands should be avoided in early spring to avoid early-nesting ducks (West & Messmer 2006).

Grazing alternate rather than adjacent range units is recommended, as this leaves greater ground cover within each bird's territory than if the units were grazed in sequential order (Undersander et al. 2000). Thus, a square pasture sub-divided into 9 units (one centre unit and eight 'edge' units) might be grazed starting in the centre unit 1 (before mid-May) followed by units 2, 4, 6, 8 and then 3, 5, 7, and 9. Unit 1 would be skipped until mid-July (Undersander et al. 2000).

Walk and Warner (Walk & Warner 2000) emphasize the importance of low-intensity, late-season grazing for creating heterogeneous habitat to increase both avian abundance and diversity. Grazing in the fall also leads to a greater diversity of invertebrates (Vickery et al. 2004). Fall and winter grazing should be minimized near riparian habitats, however, as some ducks nest early in the spring and require tall residual vegetation (West & Messmer 2006).

4.1.5.1 Pasture Plants

Include legumes in the deferred summer grazing area. For late summer and early fall grazing, consider including warm-season grasses. Maintain a diversity of vegetation in all range units.

In rotational grazing, livestock can be more selective with their forage choices and will preferentially eat certain forages available in the field. To maintain the quality of summer forage in the deferred area, including 40-50% legumes into the mix is beneficial for the livestock as these do not lose their forage quality as quickly as cool-season grasses (Undersander et al. 2000). White clover, for example, can be mixed with species such as meadow fescue, orchardgrass and late-maturing timothy for eastern regions of Canada with cooler soil and air temperatures (McKenzie et al. 2005).

The concern for fall grazing is often the nutritional content of forages at this time of year. Jefferson et al. (Jefferson et al. 2004) studied the nutritional value of native prairie cool- and warm-season grasses for September-October grazing and found that western wheatgrass, a cool-season species, had adequate nutritional content for dry pregnant beef cattle. The maturity time of warm-season grasses is later in the year, so inclusion of these grasses may be appropriate for grazing later in the season when a mid summer gap occurs on cool season fields.

A diversity of planting material is beneficial for wildlife in pasture lands. It can also be beneficial to the livestock themselves: Skinner et al. (Skinner et al. 2006) studied whether increasing plant species diversity could enhance forage yield, resistance to weed invasion, and soil C accumulation in grazed pastures. Three forage mixtures containing two, three, or 11 species were grazed by dairy heifers. The 11-species mixture developed 43% more forage dry matter than the 2-species mixture and developed 30-62% more root biomass with a greater proportion of the roots in deeper soil layers than the other mixtures (Skinner et al. 2006). This deeper rooting could help in drought-stressed conditions, reducing risk to the farmer.

Summary of Permanent Cover and Grassland Management BMPs

BMP	Benefits to Biodiversity	Quantitative Effects	Descriptive Effects
Permanent Cover Conservation Reserve Plantings	• Improved habitat for many species	• 10 times more bird nests • Warm season grasses and forbs significantly reduce nest predation • A matrix of short and tall vegetation with only 60% harvest is beneficial	• Stabilizes some populations but management is important • Does not help some species requiring large areas • Short grass haying can cause significant mortality
Perennial Energy Crops	• Food source • Nesting habitat for some species	• Positive effects of grassy cover for 5 years and longer • Similar benefits to CPR plantings	• Nesting birds not disturbed • Greatly enhanced food and cover over annual crops
Short Rotation Forestry	• Some habitat improvement and contribution to travel corridors	None available	• Biodiversity increases as stand age increases • Biodiversity of plantations greatly influenced by surroundings
Grassland Management/Hayland Management	• Haylands can be a sink unless harvest delayed • Haylands can be food and cover for a multitude of grassland species • Flushing bars reduce mortality of nesters • Minimized edge reduces predation	• Mortality can be reduced by up to 100% by delayed harvest • Tall growth favours larger bird species and butterflies • Technology is available from DUC	• Amount of damage depends on timing of harvest to avoid nesting • Foraging increases in sparser stands or numerous openings • A mosaic of forage species, field layouts and harvest timing is most effective
Pasture and Range Management Grazing Regimes	• Some birds only in native or perennial cover • Rotational grazing increases species richness	• Baird's sparrow, Sprague's pipit use native pasture • Great variety of birds and other taxa found • Food, cover supplied • Predation reduced significantly • A diversity of pasture land management practices needed to create a mosaic of vegetation, height, density, food and water required	• Variable grazing intensity needed to supply habitat requirements and heterogeneity • Grazing systems must be designed to fit regional and landscape conditions • A balanced ecosystem created

Grazing Timing	• Contributes to habitat mosaic	• 3 week grazing intervals often works best • Avoid early grazing (before May 15) near wetlands • Low intensity late season grazing around wetlands increases some species richness • Fall and winter grazing destroys nesting habitat	• Altering timing of grazing helps maintain the desired mosaic of plants and habitats
Pasture Plants	• Legumes in the mix increases food for livestock and wildlife	• 40-50% legumes is beneficial	• Legumes and other forbs greatly enhance insect diversity and in turn other wildlife

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4.2 Woodlot Management

Retain relatively large blocks of wooded habitat, with a diversity of structure and composition at all spatial and trophic levels.

Although habitat loss and fragmentation are widely regarded as major factors contributing to the decline of many wildlife populations, the relative importance of each phenomenon is seldom evaluated. This appears to be particularly true for woodlot management in agricultural landscapes. Some researchers have questioned the generality of responses to habitat fragmentation, given variation in life history characteristics, the natural dynamics of systems, and land use patterns.

The analysis of a review by Schmiegelow et al, (2002), indicated that system- and species-specific considerations are important when assessing the potential outcome of habitat loss and fragmentation on regional biota. These researchers concluded that although outright conversion of forested communities to agriculture accounted for most loss of bird species abundance, there were other impacts related to fragmentation of remnant forest parcels and to the distribution and connectiveness of the remnant parcels.

Increased predation and parasitism are often blamed for reducing bird populations in fragmented landscapes, a condition common to many agricultural areas of Canada. In this study however there was evidence that predation and parasitism of forest birds by species such as brown-headed cowbird, (*Molothrus ater),* was much less a problem in boreal forest clearings removed from grasslands than in the hardwood forests of eastern North America. They believed this was largely the case because there was insufficient suitable food availability to adequately support grassland species like cowbirds. Be that as it may, most areas cleared for agriculture do sustain a livestock population and suitable food supplies for edge and grassland species such as cowbirds and bluejays, *(cyanocitta cristata).* Paracitism is likely once colonization of the area by the opportunistic species occurs.

A general theme for maximizing species diversity is to conserve large blocks of suitable habitat. The minimum size of parcel conserved to create suitable habitat varies from species to species. In general terms ability to produce adequate food is a pre-requisite to any habitat assessment. In fact food availability is a possible measure of the value of larger parcels compared to smaller ones.

Very few studies have been reported on this topic but Zanette et al, (2000), working in New south Wales, Australia, found that when comparing remnants of forested habitat, biomass of surface dwelling invertebrates was approximately 50 percent less in parcels of less than 55ha. compared to parcels in excess of 400 ha. The impact on reproductive capability of a ground foraging insectivorous bird, yellow robin, *(Eopsaltria australis)* was significant. On the small parcels, the breeding season was shorter, females left the nest to forage more frequently, the males brought 40 percent less food to the incubating females, and eggs and young were significantly lighter. These workers concluded that area sensitivity in this species was likely influenced by food availability. Nesting territories and home ranges for each species is different such that only general guidelines would be able to be developed for managing parcel size of remnant habitat patches.

Jobes et al, 2004 did an analysis of relative abundance of hardwood forest dwelling birds in Ontario to determine the effects of selective tree harvesting. They found that abundance of some forest interior birds such as ovenbird was decreased by as much as 50 percent after harvesting while others such as white-throated sparrow (*Zonotrichia albicollis)* and chestnut-sided warbler, (*Dendroica pensylvanica)* were more abundant in the more brushy harvested parcels. Some species such as the yellow-bellied sapsucker (*Sphyrapicus varius)* and black-throated blue warbler (*Black-throated blue warbler)* abundance was not effected by this kind of selective harvesting although canopy coverage was reduced in the harvested plots for up to 20 years. Johns, (1993) found that the size of aspen groves played a large role in bird abundance and that diversity was greatly influenced by grove size.

Species richness of edge, interior/edge and interior species was significantly correlated to area of the grove. Species richness was strongly correlated to area of the habitat parcel for insectivorous birds but species richness of omnivors was not evident.

Migratory strategy of the species was correlated with size of the grove. All told, for 20 species studied, densities of 15 species were correlated with area, densities of four species with isolation and one species was correlated with both area and isolation. Komonen, (2003) working in the boreal forests of Finland, discovered that fruiting bodies of wood decaying macro-fungus species in supported high species richness of insects. Many of these insect species were listed as rare or potentially threatened but very poorly studied. This worker concluded that certain microhabitats and woodland features such as of decaying woody structure, ant nests and perhaps other micro-habitats within woodlots should be recognized as part of forest management practices. Often micro-habitats such as decaying logs and snags are rendered scarce as a result of harvesting and intensive woodlot management.

Rodewald et al, (2005) found that shrubland passerine birds such as indigo buntings (*Passerina cyanea)* and yellow-breasted chats *(Icteria virens)* avoided edges of shrub stands. Sample plots comparing plots 20 m from the edge to those placed 80 m from the edge of mature forest, revealed reductions in shrub bird numbers of up to 50 percent. These findings suggest that shrub habitats should be managed in blocks and that narrow woodlot trails or shrub plantings within wooded or grassland areas may be ineffectual for managing shrub birds. Sargent et al, (1998) studied predation rates on shrub nesting song birds in shrubby hardwood edge habitats adjacent to agricultural fields compared to similar shrubby edge habitats adjacent to mature pine stands. The predation rate, especially by avian predators, was significantly higher adjacent to agricultural fields resulting in the suggestion that productivity of small birds in small woodlots could be enhanced by plantings of conifers around the perimeter of the site.

King et al. (2001) determined that most passerine bird guilds in forested habitat benefited from larger blocks of habitat rather than a mosaic of small parcels less than one ha. in size. Species characteristic of large forest openings such as chestnut-sided warbler, yellow-breasted chat, rufus-sided towhee (*Pipilo erythrophthalmus)* and prairie warbler (*Dendroica dicolor)* benefited from larger clear cuts of several ha in size. Birds common to mature forest such as red-eyed vireo (*Vireo olivaceus)*, wood thrush (*Hylocichla mustelina),* and ovenbird (*Seiurus aurocapillus),* benefited from the forest being managed to use larger cut blocks and larger leave blocks rather than a series of small cut block groups scattered throughout the stand.

The Eastern Ontario Model Forest work has reviewed a number of studies relating bird populations to forest patch size and shape of woodlots in various watersheds, (Friesen et al.) and (Austen et al.). The general consensus was that larger patches of forest tend to have a greater diversity of habitat niches and therefore are more likely to support a greater richness and /or diversity of wildlife species. Generally forest patches of 100 ha. in size are considered to be the minimum size for southern Ontario. Tate, (1998) used four large forest patches ranging in size from 140 to 201 hectares, in the Severne Sound area as test cases. He found over 70 percent of the regional pool of forest bird species in the forest tracts collectively and 79 to 87 percent of the expected forest interior species in individual tracts between 100 and 200 hectares in size. It was determined that a single tract of 100 hectares was too small to support the regional forest bird community. Instead a forest patch of 200 hectares was recommended, which would be more likely to provide suitable habitat for species that prefer interior habitat conditions and where over 88 percent of all expected species might occur. Several large tracts of forest were recommended, as they will support 90 to 100 percent of all expected species.

Austen et al. (2001) found that edge-intolerant species increased and edge-tolerant species decreased both with both increasing woodlot size and core area. Recognizing that intact mature hardwood parcels of at least 100 hectares are required to sustain viable populations of interior birds ideal specific sizes of cut and leave blocks in different studies have varied slightly. The critical cutting block size to favour song birds in many hardwood forests studies seems to be between 8 and 15 ha. for species such as red-eyed vireo, wood thrush and ovenbirds.

Table 2: Relationship between woodlot size and species response

Patch Size	Response by Forest Associated
200 ha	Supports 80 % of edge-intolerent species including most area-sensitive species
100 ha	Supports arox. 60 % of edge intolerent species including most area-sensitive species
50-75 ha	Supports some edge-intolerant species, several will be absent and edge-toerant species will dominate
20-50 ha	May support a few area-sensitive species but few that are intolerant of edge habitat.
<20 ha	Dominated by edge-tolerant species only

Forest patch shape is also very important in preserving requirements of edge-intolerant birds. Shapes that translate into greater amounts of interior habitat not only support more interior species but also contribute to landscape richness such that there is a greater range of habitats represented, Rowsell, 2005.

Table 3: Wildlife use of various sized habitats

Area	Forest/Treed Swamp
1 ha	Edge tolerant mammals (gray squirrel) Common edge-tolerant birds (blue jay, American crow) A few birds may be associated with mature trees (black-capped chickadee, eastern wood-peewee)
4 ha	A few very cinnib edge-tolerant birds (downy woodpecker, great crested flycatcher)
10 ha	Still dominated by edge-tolerant species, but may have very small areas of interior habitat supporting low numners of modestly area-sensitive species (hairy woodpecker, white-breasted nuthatch)
30 ha	May be large enough to support some spaecies of salamander Small populations of edge-intolerant species (winter wren, brown creeper, black-and-white warbler
50-75 ha	A variety of area-sensitive species may be present; somme will be absent if there is no nearby habitat Still predominantly edge influenced, but will support small population of most forest bird spacies; some will be absent if there is no nearby suitable habitat
100-400 ha	All forest-dependent species Many will still be in low numbers and may be absent if there is no nearby suitable habitat Woodland jumping mouse may be present
1,000 ha	Suitable for almost all forest birds Some forest-dependant mammals present, but most still absent
10,000 ha	Almost fully functional ecosystem, but may be inadequate for a few mammals such as greay wolf and bobcat (10,000 ha has been suggested as a minimum).

Rowsell also points out that when overall forest cover dclines to around 15 percent (in combination with fragmentation into smaller forest patches), 20 to 25 percent of edge-intolerant species disappear.

On the northern Great Plains, Kelsey, (2001) concluded that woodland obligate and neotropical migrant species richness values were higher in non-fragmented landscapes (either grasslands or woodlands) whereas more edge species and generalists were observed in fragmented landscapes. Greater vegetative diversity of natural woodlands attracted significantly more species of woodland obligates and neotropical migrants while edge and generalist species were more abundant in planted woodlands. Generalist had the highest density in small patches of planted and natural woodlands. Woodland obligate and edge species preferred either deciduous or mixed woodlands, while 50.1% of the individual birds in evergreen woodlands were generalist species. From the perspective of biodiversity conservation, the generalist species tend to be generally more secure than the more obligate species. Kelsey concluded that especially for non-game bird species, highest priority should be placed on preserving existing wooded habitat but if planted woodlands were required, they should be as large and wide as possible.

Grant et al. (2005) studied the influence of woodland edge on abundance of two forest/grassland edge species in North Dakota. They found that clay-colored sparrow (*Spizella pallida)* and vesper sparrow (*Pooecetes gramineus)* nest survival was higher for nests located near woodland edges, for nests with greater cover of Kentucky bluegrass (*Poa pratensis*), and for nests more concealed by vegetation. Vesper sparrow nest survival increased as the percent cover of tall shrubs near the nest increased. These researchers felt that this preference for locating nests close to woody cover was due to increased predation of thirteen-lined ground squirrels (*Spermephilus tridecemlineatus)* when nests were located farther from woody cover.

Retain connectivity and diversity within the woodlot environment by ensuring a variety of tree ages, retaining isolated small ponds, canopy coverage, old trees, snags and decaying wood structure on forest floor.

Habitat connectivity is likely to mean different things to different species. Grialou et al. (2000) studied the effects of forest harvesting on ground dwelling amphibian species. In eastern hardwoods, deMaynadier et al (1999) found woodland amphibians such as wood frogs (*Rana sylvatica)* and spotted salamanders (*Ambystoma maculatum),* benefited from preservation of connectivity consisting of closed canopy tree and shrub cover from breeding pools to their terrestrial woodland habitat. This connectivity was essential for juvenile dispersal.

Small mammals are important prey base for many carnivores associated with woodlands and are important for dispersal of seeds and spores of woodland plants. Ucitel et al, (2003) studying relationships of course woody material (CWM) on the forest floor to numbers of small mammals, found that red – backed voles, (Clethrionomys sp.) a species occurring commonly in forested landscapes across Canada, were found in greatest numbers where CWM was highest. Their observations identified a common biodiversity preservation problem in woodlot management wherein insufficient post harvest large woody debris is left on the forest floor to support ground dwelling fauna.

Canopy coverage of woody vegetation is important as cover for many wildlife species. Roseberry and Sudkamp, (1998) found that bobwhite quail (*Colinus virginianus)*, a species frequenting shrubby habitats and considered at risk in Southern Ontario, selected woody canopy coverage of approximately 50 percent for many of their daily activities. Grindal and Brigham, (1998) found that small openings (0.5 –1.5 ha) in the canopy coverage in hardwood woodlots increased use by insectivorous bats but had no measurable influence on insect availability. Influences of larger openings were not studied and the required patch size of wooded area was not determined.

Large old, decaying trees and particular canopy characteristics are important management considerations in farm woodlots. In the ranching country of the Cypress Hills, Kalcounis and Brigham, (1998), found that big brown bats (*Eptesicus fuscus)* used secondary cavities in mature aspen trees (*Populus tremuloides)* implying that this species required wooded patches that contained sufficient mature to decadent trees and snags. These trees encouraged cavity excavation by woodpeckers.

Flemming et al.(1999) studied pileated woodpeckers (*Dryocopus pileatus)* in New Brunswick and found that they selected larger trees (over 27 cm) in diameter) with considerable decay for foraging and excavating cavities. In this region of Fundy National Park the woodpeckers seemed to prefer balsam fir trees but other species such as red spruce and deciduous tree species were used as well.

Miller et al, (2003) did a comprehensive review of literature pertaining to habitat requirements for forest – roosting bats in North America. They concluded that because of the paucity of studies, (fewer than 55 in all of North America) and research design problems such as small sample sizes, the understanding of bat habitat relationships was thin. Most studies have dealt with roost sites and do prove that bats roost in snags during daylight hours. However, other measures of habitat importance to bats such as prey availability in different forest habitat types and management regimes are lacking.

One study showing the importance of food availability in woodlands was conducted by Fisher et al., (2005) on red squirrel (*Tamiasciurus hudsonicus*), distribution related to forest landscape structure. Red squirrels are obligate coniferous cone seed feeders and generally depend on mature coniferous pine and spruce trees as the critical part of their habitat. These rodents also eat other fruits, fungi and a variety of animal material on occasion when available. When attempting to predict the abundance of red squirrels on landscape composition and configuration, these researchers found that, when measuring the distribution of red squirrels, at several spatial scales, they were able to predict squirrel presence of squirrels in the three landscapes under study. However, even within a short two-year time frame, the significant landscape variables for red squirrel occurrence changed across spatial scales, across time and across landscapes. Thus it would follow that even when attempting to manage for species that have relatively specialized habitat requirements, it is necessary to maintain habitat diversity to accommodate these variables within dispersal distances to accommodate continuous changes in landscape ecological function.

Agricultural production of palatable wildlife foods has been shown to reduce pressure on native plants that are sensitive to herbivory from wild animals such as white-tailed deer, (*Odocoileus virginianus)*. Augustine and Jordan, (1998) found that at some times of the year, variability of browsing on palatable woodland plants was directly related to availability to the deer of alfalfa, row crops and fields within 1.5 km radius of the wooded stand in south central Minnesota. They pointed out that by providing more palatable food elsewhere, deer could be dissuaded from browsing fragile vegetation requiring temporary protection from herbivory.

4.2.1 Conclusions

The over riding considerations for woodlot management BMP's appears to be the need to retain relatively large blocks of wooded habitat, with a diversity of structure and composition at all spatial and trophic levels. The fact that in most cases, the larger the parcel size of wooded or shrub habitat, the greater the species diversity is based on greater availabillity of food, better hiding cover from predators and more suitable space for carrying out different life functions of a variety of organisms. Brook et al.(2002), determined that the effects of inbreeding on species at risk was directly proportional to the population size. Thus, in light of the extensive habitat fragmentation on most agricultural lands, the need to preserve patch size of sufficient size to support adequate population size and subsequently, genetic diversity is extremely important.

Basic wildlife habitat management seeks to maintain critical ecological functions such as availability of food, cover, water and adequate space. If critical aspects of the woodland habitat parcel are missing, especially because of inadequate size, it may be possible to add to its ecological functionality. Complementary land management practices can be incorporating such as planting food species, planting coniferous buffers around the woodlot, creating a more permanent water supply or amalgamating with neighbouring woodlots. By so doing, a relatively small woodland may develop sufficient ecological complexity and diversity with the aid of surrounding farm land to supply the requirements for preserving much of the native biodiversity indigenous to the area. Ideally by managing the vegetative and ground level woody structure within a woodlot itself, the critical ecological functions may be able to be supplied within the unique environment of that particular woodland landscape.

In general the optimum size of remnant woodlots should be dictated by the ecological needs of wildlife species that traditionally existed there and that can be tolerated by the agricultural community. Studies reviewed indicated that this minimum size may be dictated by the spacial requirements of interior dwelling species. This implies that the size needs to recognize the home range or breeding territory and the ecological needs of the species with the greatest demands or requirements that are most limiting.

Wooded habitats managed for production of logs and other forest products on the farm, should be managed to maintain a diversity of tree sizes, a variety of shrubs and forbs (including food bearing species) and a forest floor with great structural diversity. The presence of rotting logs, dead and dying snags, and ephemeral ponds is particularly important to maintain diversity of lightly studied taxa such as invertebrates, fungi, and micro-organisms. If these primary organism are preserved, rare vascular plants and faunal species at risk will benefit as well. Care should be taken to maintain the small ephemeral ponds in isolation and not connected to fish bearing water bodies. These ephemeral ponds that support specialized reproduction in species such as woodland frog and salamander inhabitants will lose their ecological function as nurseries if predacious fish are introduced to their nursery ponds.

4.2.2 Gaps in Literature and Further Research Needs

- The literature available pertaining to biodiversity in farm woodlots is heavily weighted toward studies that evaluate the effects of parcel size on various birds and small mammals.
- Because birds are easily studies and of interest to the scientific community, there is considerable information on nesting occurrence and reproductive success as the result of wood harvesting practices and parasitism/predation.
- These studies and others related to fragmentation of agricultural woodlands were usually found to be of short duration.
- As such there was little information to assess long term implications to biodiversity of various harvesting and silvicultural activities in farm woodlots.
- The need for travel corredors and requirements for specific taxa was lightly covered for few species and there was little information recognizing the whole life history habitat requirements for indigenous plant and animal species in any of the Canadian agricultural regions.
- We found little meaningful scientific documentation of woodland habitat requirements of various guilds or groups of wildlife as they related directly to farming practices.
- We found no scientific literature that dealt with farm woodlots as reservoirs for problem wildlife or as natural controllers of agricultural pests.
- We found some studies of long term ecological studies of woodlots related to food, water, shelter and space of a particular species in other jurisdiction but not for Canada.

Summary of Woodlot Management BMPs

BMP	Benefits to Biodiversity	Quantitative Effects	Descriptive Effects
Conservation of large wooded blocks	• Reduces predation • Superior insectivorous food supply for decling populations	• Food supply jeopardized in under 55 ha parcels • 100-200ha parcels required to sustain 79-87% of expected bird species • Restricting cutblocks to less than 15 ha will sustain most interior bird species	• Interior species require area and associated isolation • Larger blocks have greater diversity of wildlife
Retention of Connectivity	• Needed for juvenile dispersal and movement between activity centers	• Tree, shrub, ground structure sufficient as cover connecting between critical habitats required	• Woody canopy cover is important in corridors for many species • Extent of canpopy must support dispersal distance of species in question

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5.0 Soil Management

5.1 Shelterbelt Establishment

Shelterbelts provide wooded habitat amongst the expanse of cropland and pastures in Canada. Sometimes called windbreaks, these belts can be used by a large number of birds as well as mammals and beneficial insects. Shelterbelts are used by wildlife for cover, corridors, food, and nesting (just to name a few). Shelterbelts should be designed with multiple rows and various species to provide the maximum benefits for indigenous wildlife in the area.

Agricultural areas in Canada can be highly susceptible to wind erosion. There are a number of ways that a field can be protected from erosion, and one of these is through shelterbelts. Shelterbelts are widely used in areas of the Great Plains where croplands are highly susceptible to wind erosion. These sites are usually composed of sandy soils that are easily eroded by winds (Kulshreshtha and Kort 2005).

The Prairie Provinces of Canada are characteristic of their arid to semi-arid conditions making them vulnerable to the high winds that these areas receive in the summer and winter (Chrapko 2001). Conversion from natural vegetation to agricultural crops, along with associated tillage practices, generally exposes the landscape to other forms of degradation such as erosion and structural decline of the soil, loss of organic matter and nutrient leaching (Yunusa et al. 2002). According to Sparrow (1984) in the three Prairie Provinces, 36% of the cultivated land is susceptible to severe wind erosion (Kulshreshtha and Kort 2005). Campbell-Clause (1998) showed that a 4-m windbreak reduced wind speed by between 70% near the belt and 30% at about 90m away from the break (Yunusa et al. 2002).

A shelterbelt or windbreak is a linear arrangement of trees, shrubs and plants used for the purpose of lessening the impact of wind erosion by diverting it through and over the trees and therefore modifying certain factors such as wind speed, temperature and humidity across neighboring crop fields (Horvath 2006; Santiago and Rodewald 2004). Shelterbelts can be designed with one or more closely spaced rows, varying in species composition. An ideal shelterbelt composed of multiple species, coupled with numerous rows of trees and shrubs will greatly reduce wind speed across the field (Chrapko 2001). The benefits gained from using multiple species when designing a shelterbelt is that they will be less prone to disease (Horvath 2006).

The location of a shelterbelt can be determined by which way the prevailing wind is most often comes from. The shelterbelt should be perpendicular to the damaging winds. The best way to establish a series of shelterbelts is through the use of aerial photographs (Johnson 2003). After the landowner studies the photos he will be able to determine where the most appropriate locations exist to plant a series of belts.

The Prairie Farm Rehabilitation Association (PFRA) recommends planting up to five rows on the north and west sides to protect from prairie winds; two or three rows are adequate for the south and east. Around the farmstead, use fast growing, long-lived, tall and dense species. A dense shrub (preferably fruit-bearing to be utilized by wildlife) should be planted on the outside to trap snow. A fast growing species should be utilized for the second row and a long-lived species the third (Chrapko 2001). If you have room for only two rows, one should be dense shrubs and the other dense trees. Leaving at least ten feet between rows allows sufficient room for maintenance equipment to pass through (Johnston 2006; Santiago and Rodewald 2004).

Shelterbelts must be designed with species to allow them to be semi-permeable to wind so that wind speed is reduced but turbulence is not created. Impermeable barriers prevent any wind from passing through therefore creating high turbulence on the leeward side of the shelterbelt (Platt 1993).

5.1.1 Benefits to Wildlife

Shelterbelts have far more benefits than just providing wind erosion control. In the Great Plains region farmstead shelterbelts are often the only source of wooded habitat amid extensive croplands and pastures in intensively-farmed regions (Griffith 1976 as cited in Yahner 1983), therefore providing important habitat for many species of birds (Martin 1980; Yahner 1982a, 1983a, as cited in Yahner 1983). Shelterbelts also provide critical habitat for a number of wildlife and small mammals (Johnson 2003).

Shelterbelts provide more habitat for a larger variety of birds and wildlife that would otherwise be absent from the area (Papowski 1976 as cited in Schroeder 1986). Shelterbelts provide critical habitat for species such as ring-necked pheasants (*Phasianus colchicus*), gray partridge (*Perdix perdix*), sharp-tailed grouse (*Tympanuchus phasianellus*), mourning dove (*Zenaida macroura*), cottontail rabbit (*Sylvilagus floridanus*) and a variety of songbirds (Shroeder 1986; Kulshreshtha and Kort 2005). white-tail deer (*Odocoileus virginianus*) also find food and cover within shelterbelts.

Several shelterbelt studies were conducted in North Dakota and from them it was found that 64 species of birds used shelterbelts during the breeding season, and a further 68 species of migratory birds utilized shelterbelts at some point throughout their migration (Schroeder 1986; Mah 1999 as cited in Kulshreshtha and Kort 2005).

Providing wildlife habitat through shelterbelts can have a number of on-farm benefits. Shelterbelt habitat can include nesting sites, food, shelter and cover from predators (Chrapko 2001). Availability of food and cover are most critical during the winter months when the energy needs of wildlife are greatest (Yahner 1981). Trees and shrubs which retain their fruit above the snowline throughout the winter provide an important source of high quality winter food (Koford and Best 1996). Dense shrubs and trees such as conifers provide important thermal cover for wildlife by protecting them from cold temperatures. In addition, trees and shrubs provide refuge from predators and during the summer months and can furnish cover for nesting and raising young (PFRA 2006).

Wildlife using the shelterbelts may also consume pests such as insects, mice, rats and rabbits. A number of studies have shown that many wildlife species will consume large numbers of insects that can damage crops and surrounding vegetation, and therefore reduce the cost of pest control to the landowner (Johnson 2003).

5.1.2 Design Recommendations

When designing shelterbelts for wildlife, the landowner must take on a different approach than when planning for wind erosion. Farmers traditionally use single row shelterbelts to minimize against spray-drift and act as a windbreak; however, these belts have limited value for biodiversity, which requires several rows to support local wildlife and fauna (Yunusa et al. 2002; Chrapko 2001).

Factors to take into account when planting shelterbelts for wildlife include: distance to water, distance to food source and connectivity. Cropland that is adjacent to shelterbelts can provide an important food source for birds and wildlife. Connectivity between remnant patches of vegetation allows species to interact with other sub-populations preventing inbreeding within the population. It also allows re-colonization to areas where a species has become extinct (Yunusa et al. 2002). Shelterbelts provide the maximum benefits when connected to other sources of cover such as a woodlot, ridgeline or riparian area (Johnson 2003).

In Kansas it was found that wildlife was more abundant in shelterbelts that contained at least 10 rows of shrubs, hardwoods and evergreens and had an area greater than 1.2 hectares in size (Swilling 1982 as cited in Schroeder 1986; Koford and Best 1996). Studies indicate that breeding birds, small mammals, and migratory birds all have a positive correlation to the size of the shelterbelt (Schroeder 1986). Species-area curves as developed by Martin (1978) for migratory birds as well as breeding birds in shelterbelts are illustrated in (Figure 1) (Schroeder 1986).

In a North Dakota study, Cassel and Wiehe (1980) found that shelterbelts with numerous rows of trees (more than 20) contained far more breeding birds than shelterbelts with less than 20 rows (Schroeder 1986). Shelterbelts with only a few rows of trees attracted birds that are more accustomed to open areas, whereas belts with more rows tend to attract birds that are generally found in more forested habitats (Schroeder 1986; Koford and Best 1996). The primary species that were observed during this study included the least flycatcher (*Empidonax minimus*), yellow warbler (*Dendroica petechia*), northern oriole (*Icterus galbula*), northern flicker (*Coloptes auratus*), horned lark (*Eremophilia alpestris*) and vesper sparrow (*Pooecetes gramineus*). Of these species it was found that least flycatchers, yellow warblers, northern orioles, and northern flickers were almost absent from shelterbelts containing less than 20 rows of trees, showing that they prefer dense habitat. On the other hand horned larks and vesper sparrows were absent from dense belts and preferred areas that are more open, including more grasses and smaller shrubs (Cassil and Weihe 1980 as cited in Schroeder 1986).

Hagar (1999) found that the relationship between bird abundance and width of shelterbelts was variable, but in that study belts that were >90 m wide tended to support at least 80% of bird species found in undisturbed riparian vegetation (Yunusa et al. 2002). A good practice is to include dense growing shrubs along the outer edges of the belt, with tall trees close to the center. This provides adequate cover for species that prefer to reside at lower heights as opposed to raptors that like to perch and nest higher up in the vegetation.

Shelterbelts that have a certain degree of heterogeneity are better suited for wildlife than ones that are more monoculture. Shelterbelts that contain a dense layer of grasses will support greater species richness. The species richness declined if there was a dense shrub layer within the shelterbelt. The interior of the belt should not contain dense growing shubs, however low growing shrubs that contain berries may produce significant food sources for birds within the belts (Schroeder 1986). Insect populations are found to be more abundant in shelterbelts with good ground and litter cover (Christian et al. 1997). The presence of insect populations will have a greater effect on bird populations that utilize them in their diet (Christian et al. 1997).

The age of the shelterbelt has an impact on the species richness. Bird species in North Dakota tend to prefer stands that are older than 5 years. Older stands (greater than 40 years) provides adequate habitat for cavity nesters and raptors. The number of species positively correlates with the age of the stand (Schroeder 1986).

The use of multiple species will greatly reduce the chance of a disease or insect outbreak destroying the whole shelterbelt (Schroeder 1986). Shelterbelts with a greater variation of species will support greater bird species richness. In a Minnesota shelterbelt study Yahner (1982) found that the highest majority of birds utilized trees in the Acer, Populus, and Picea genera. Bird sightings in these tree families ranged from 54.5 percent to 69.1 percent of the total observations, however, only 29.6 percent of the trees observed were in these three families (Schroeder 1986).

Soil type is one consideration that needs to be evaluated to determine which species would most likely be successful (Garrett 1994). The United States Department of Agriculture developed a table that lists the best choices for species composition to use under certain conditions (Table 2).

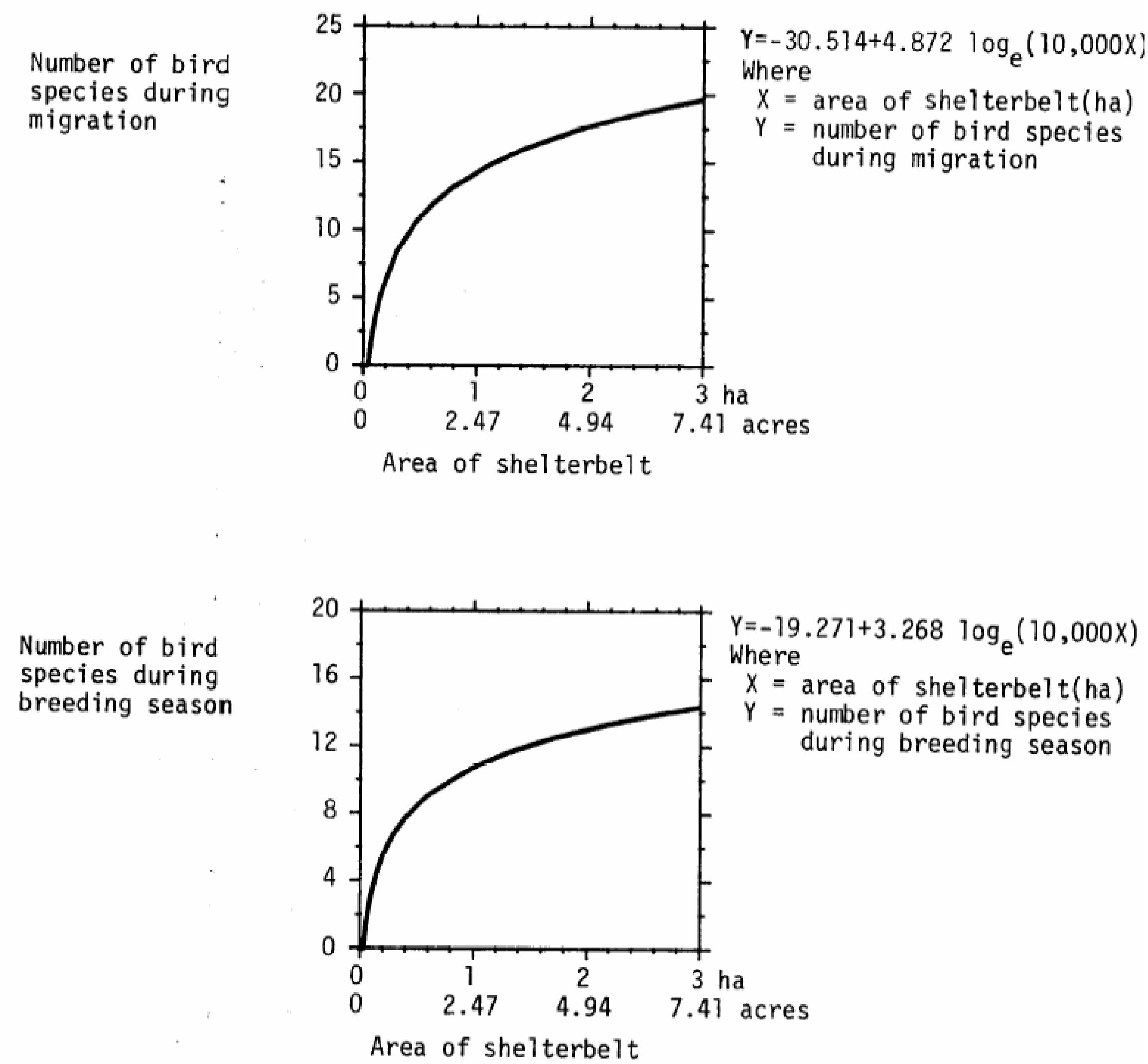


Figure 1: Species-area curves for birds in South Dakota shelterbelts

(from Martin 1978 as cited by Schroeder 1986).

When designing shelterbelts a landowner has to realize that since indigenous wildlife species have co-evolved with native plants, they rely heavily on these resources for food and shelter (Santiago and Rodewald 2004). When planting shelterbelts it is recommended to use structurally diverse native shrubs, trees, and perennial grasses that mimic natural plant communities because these provide the most resources to the majority of wildlife (Garrett 1994). Native plants are well adapted to local climate conditions and growing regions, often require no additional irrigation once established, and are usually naturally resistant to pest pressures (Wild Farm Alliance 2003).

Table 4: Various plant materials and their use in shelterbelts/windbreaks
(USDA 1999)

Species *1	Wildlife Use Cover(C), Food(F)	Deciduous/Evergreen	(see Recommended Use Codes below)*2
Eastern Redcedar	F/C	E	2,4,5,7,9,10
Rocky Mtn Juniper	F/C	E	2,4,5,9,10
Arizona Cypress	C	E	1,4,9,10
Ponderosa Pine	C	E	1,9,10
*Austrian Pine	C	E	2,4,9,10
*Scotch Pine	C	E	2,10
*Afghanistan Pine	C	E	1,4,10
Leland Cypress	C	E	2,4,10
*Kettler Juniper	C	E	2,10
Green Ash	C	D	1,4,5,8,10
Bur Oak	F/C	D	1,5,6,9,10
Red Oak	F/C	D	1,5,9,10
Little Walnut	F/C	D	1,5,8,9,10
Black Walnut	F/C	D	1,5,9,
Hackberry	F/C	D	2,5,8,9,10
Cottonwood	C	D	1,4,5,6,
Desert Willow	C	D	2,4,9,10
Redbud, Eastern, TX	C	D	2,5,8,9,10
Hawthorn	F/C	D	3,5,8,9,10
Chickasaw Plum	F/C	D	3,5,7,9,10,11
Skunkbush Sumac	F/C	D	3,4,5,8,9,10
*Red Honeysuckle	F/C	D	3,7,9
*Chinese Elm	C	D	1,7,10,11

* - Denotes an introduced species.
*1 - Different ecotypes of the same species may have different use codes check local guides for final use.
*2 - Recommended Use Codes

1 = Tall Growth Type
2 = Medium Growth Type
3 = Short Growth Type
4 = Saline/Alkaline Tolerant
5 = Adapted for Use Along Streams
6 = Adapted to High Water Tables
7 = Problem with Escaping
8 = Shade Tolerant
9 = Resistant to Insects
10 = Drought Tolerant
11 = Spreads Easily/Rootsprouts

In some areas it not recommended to plant shelterbelts. The biology of native grassland communities can be thrown off if a shelterbelt is introduced into the area. Johnson (1996) found that woody vegetation can fragment habitat and reduce quality for some area sensitive species (Neave 2005). Many grassland birds require large tracts of un-fragmented habitat and when a shelterbelt is introduced it breaks up these tracts. In grassland areas shelterbelts may also provide perches for raptors, and an increase in predation may occur to native species that might be threatened or at risk already (Neave 2005). Shelterbelts are best suited for agricultural areas that undergo tillage operations, as their main purpose is to provide wind erosion control.

5.2 Improved Cropping Systems

Improved cropping systems are implemented to reduce the effect of cropping practices on the land as well as biodiversity of the farmland. No-tillage is recognized as a very beneficial practice to reduce the effects of erosion, while leaving the stubble provides habitat for birds, small mammals and insects. Earthworms and other soil-dwelling organisms that are beneficial to soil health are found to be more abundant on lands that are not tilled annually. The conversion from cropland to perennial forages has many benefits to the flora and fauna of an agricultural ecosystem.

Canadian agriculture relies heavily on soil quality and the availability of water to grow and produce crops (AAFRD 2004; Neave 2005). Traditional farming often includes cultivation to remove last years litter and to allow a new crop to be planted. The annual cultivation of cropland often leads to degraded soils and water quality issues. Continuous cultivation of fields can make them highly susceptible to wind and water erosion, as well as nutrient deficiencies in the soil (AAFRD 2004).

Improved cropping systems (ICS) are implemented to allow carry-over of litter and to enhance the biodiversity of the farmland. ICS not only apply to cropland, but to hay land as well. These ICS can be applied across Canada in any agricultural region, however, for the most part are practiced throughout the Great Plains (AAFRD 2004).

Cropland dominates much of the land cover in the Canadian Prairies and makes up a large percentage of habitats available for birds and other wildlife (Best et al. 2001; Neave 2005). Although birds generally do not nest in cropped fields, over 50 species of birds have been documented using row crop fields during the breeding season. Bird use of crop fields is largely dependent on the amount of crop residue left on the land after harvest (Best et al. 2001).

Conventional farming disturbs the soil during planting, tillage operations, and harvest. This presents implications for a number of species that utilize cropland as habitat (Neave 2005). Burrowing animals such as the Richardson's ground squirrel (*Soermophilus richardsonnii*), pocket gophers and voles are greatly impacted by soil disturbances such as tilling (Neave 2005).

Some examples of ICS's that can be implemented are:

- Conservation tillage
- Strip cropping
- Crop rotations

5.2.1 Conservation Tillage

Conventional tillage systems use multiple tillage passes for weed control, fertilizer application, seed bed preparation and seeding (Dimmick and Minser 2006). A number of problems that may be associated with conventional tillage is that the soil experiences an increased rate of organic matter decomposition, the soil has less ability to hold moisture, the size and stability of soil aggregates are reduced, therefore leading to compaction and crusting, and the crop residue (stubble) is buried leaving the soil prone to erosion (AAFRD 2004; Choudhury et al. 2004).

Tillage can affect birds in numerous ways (Koford and Best 1996). The amount of tillage applied to cropland influences bird use by affecting the amount of crop residue on the surface of the soil (Koford and Best 1996). An immediate effect of cultivation may be to expose arthropods and other prey to foraging birds, etc. A greater and longer lasting effect, however, is a reduction in abundance of the litter-dwelling arthropods that are prey items for many birds. Conventionally tilled fields have lower arthropod abundance than no-till fields or idle areas except during pest outbreaks in the crop (Hendrix et al. 1986 as cited by Koford and Best 1996). Early-summer cultivation also can disrupt nesting activity, destroying nests or causing nest abandonment (Koford and Best 1996).

Conservation tillage systems reduce the amount and intensity of tillage. Conservation tillage systems include zero tillage, direct seeding and reduced tillage. Conservation tillage has revolutionized cropping in western Canada, resulting in reduced soil erosion, greater soil water conservation, improved soil quality, and higher crop yields (Blackshaw 2001). Direct seeding and zero tillage practices aim to enhance soil quality and conserve soil moisture (AAFRD 2004).

Conservation tillage benefits wildlife by retaining vegetative residues on the surface. These residues provide food, cover for nesting, and protective cover during winter. Greater numbers of insects in no-till fields enhance food supplies for young birds during summer. Reduction in mechanical disturbances from summer tillage reduces nest destruction, loss of flightless young, and mortality of incubating hens. However, there is in-sufficient wildlife research literature to permit wide-ranging evaluation of long-range benefits of conservation tillage (Dimmick and Minser 2006)

5.2.2 Zero Tillage

As the name implies zero tillage does not use any form of cultivation to break up the soil, and in turn the only disturbance to the soil is the actual planting of the seed (Dimmick and Minser 2006). Utilizing zero tillage practices has been consistently identified as a method to conserve soil moisture, reduce soil erosion, improve water quality, benefit wildlife, increase labor use efficiency, limit equipment investments, and sequester atmospheric carbon dioxide (Beck et al. 1998; Dimmick and Minser 2006; Neave 2005).

In general there is no more than 40% disturbance to the site; however, some no-till farmers strive for less than 25% disturbance, and a few are even as low as 10%. The amount of soil disturbance is often estimated by the type of equipment being used to seed the crop (AAFRD 2004).

The benefits of zero tillage to wildlife will depend on how technology evolves in the future. Cowan (1982) found that nest success was lower in zero-tillage fields because of the type of seed drills used: the hoe openers are wide and therefore drag the nests when they pass over, and wide wheels tend to crush the nests (Cowan 1993; Neave 2005). During a study that Cowan (1982) conducted, he found that farmers that utilized narrow disc openers and packing wheels had greater nest success on their land; near 50% (Cowan 1993).

Basore (1984) observed 12 species of birds nesting in no-till corn and soybeans in Iowa compared with 3 species in conventionally tilled crops; overall nest density was 7.5 times greater in no-till (Dimmick and Minser 2006). Warburton and Klimstra (1984) reported significantly more birds in a southern Illinois no-till cornfield than in a conventionally tilled field during April -September, though specific use of the fields for nesting was not mentioned. Bobwhites were common in the no-till field, and uncommon in the conventional field. Castrale (1985) reported 32 percent more species of birds using no-till fields in southern Indiana, as compared to conventional tillage (Dimmick and Minser 2006).

No-tillage practices can increase the diversity of arthropods and earthworms as well as predatory insects such as spiders, mites and carabids (Fawcett and Towery 2002 as cited by Neave 2005). Most of these insects can be very beneficial as they will break down soil organic matter and prey on insect crop pests, therefore reducing the cost of pest management (Neave 2005). Insects and arthropods are an important food source for a wide variety of farmland birds. Fields that provide residual cover will have greater insect abundance and will have greater species richness of birds and wildlife than conventionally tilled fields.

By far the most recognized benefit to biodiversity on no-till land is from the drastically reduced soil erosion and its consequences to aquatic ecosystems. Aquatic ecosystems are home to a large variety of insects, birds, wildlife, reptiles, amphibians and fish. For example, the sediment yield from a single, intense rainstorm on single crop no-till soybeans in west Tennessee's highly erodible soil was 309 pounds per acre, vs. 22,785 pounds per acre from single crop conventionally tilled soybeans (Shelton et al. 1982 as cited in Dimmick and Minser 2006).

5.2.3 Direct Seeding

In direct seeding systems, the soil is not tilled before planting. However, in contrast to zero tillage, direct seeding allows some soil disturbance to deal with special situations. These special instances may include some tillage in the seeding operation to solve immediate weed problems, harrowing to deal with soil crusting or excessive crop residues, or a fall fertilizer injection (AAFRD 2004). Any fall soil disturbance must leave the soil surface level, minimize stubble knock-down and keeps most of the crop residue on the surface, in order to conserve soil moisture and increase snow trapping (AAFRD 2004).

There are several benefits that direct seeding and zero tillage have over conventional tillage, such as improved moisture-holding capacity, better yield potential, better fertilizer use efficiency, and less time spent on field operations (Dimmick and Minser 2006). However, changing to these systems requires changes in management of crop residues, weeds and soil fertility. The landowner may have to utilize crop rotation changes to prevent specific pest problems that were previously kept in check by tillage (AAFRD 2004).

The retention of stubble on Canadian farmlands provides benefits to many species of birds and wildlife (Butler et al. 2005). It creates habitat in a fragmented area that would otherwise be void of habitat under conventional tillage practices (Neave 2005). Cowan (1982) documented 27 species of birds and 16 species of mammals utilizing direct seeded crops in Manitoba; 14 of the bird species were nesting in the stubble (Cowan 1993). Five species of waterfowl [mallard (*Anas platyrynchos*), northern pintail (*A. acuta*), blue-winged teal (*A. discors*), gadwall (*A. strepera*), and northern shoveler (*A. clypeata*)] were all found to commonly nest in these fields (Cowan 1993; Butler et al. 2005).

Canadian winters can be very cold with a large volume of snow falling across agricultural lands (AAFRD 2004). The stubble that is left standing on croplands helps trap this snow and not only does it increase moisture content of the soil, it also acts as protection for sharp-tailed grouse (*Tympanuchus phasianelles*) (Butler et al. 2005). The snow trapped in the stubble allows the grouse to burrow into it during the cold winter nights (Pearse 1993). Stubble also provides forage for deer early in the spring when the waste grain from the previous fall begins to sprout (Pearse 1993). Fawcett and Lowery (2002) found that leaving 10-12 inches of stubble height will benefit wildlife far more than shorter stubble heights (Neave 2005).

5.2.4 Reduced Tillage

Reduced tillage leaves crop residue on the cropland which helps prevent soil erosion and conserve moisture. Reduced tillage systems save time and money and are comparable to the costs of conventional tillage, if not lower. Herbicide applications reduce the number of times that the field is worked to prevent weed growth. Tillage equipment that maximizes the amount of residue cover left on the field is most beneficial (Table 3).

Methods to minimize the impact of tillage practices:

- avoid fall tillage so the crop residue cover is retained to trap snow and prevent soil erosion during the fall, winter and spring.
- replace deep tillage with shallow tillage to minimize disturbance of soil.
- reduce the number of tillage passes
- reduce tillage speed
- use equipment that buries the least amount of crop residue
- Use contour tillage when farming slopes. Till and plant crops across the slope, rather than up and down, this will help prevent erosion
- avoid tillage when the soil is wet (AAFRD 2004).

Reduced tillage is a beneficial practice; however, it does not provide the biodiversity benefits that are gained from no-tillage and direct seeding. Bird use of cropland for nesting have been found to be consistently higher on no-till and direct seeded fields compared to reduced tillage fields. Lokemoen and Beiser (1997) found that nesting densities were considerably higher on no tillage fields.

5.3 Strip Cropping

Strip cropping involves alternating between strips of crops and strips of fallow. The strips run along the contours of the land if the main purpose is to reduce water erosion. They go across the prevailing direction of wind if the main purpose is to reduce wind erosion. Crop residues on the fallow strips are retained with reduced tillage fallow or chemfallow (chemfallow is the use of herbicides alone to control problem weeds). The strip width can be determined by the convenience for which the equipment can operate (AAFRD 2004).

Strip cropping is most beneficial to birds and other wildlife when perennial forages are planted between the rows. This provides sufficient habitat for the birds to use as cover, as well as provide them with a food source nearby (Best et al. 2001).

Table 5: Effect of tillage equipment on crop rotation

(An Introduction to Wind Erosion Control. Alberta Agriculture, Food and Rural Development, Agdex 572-2. (Timmermans, J. and Larney, F. 1998).)

EFFECT OF TILLAGE EQUIPMENT ON CROP RESIDUE

IMPLEMENT	PER CENT OF RESIDUE COVER REMAINING AFTER ONE PASS
Moldboard Plow	10
Chisel Plow (less than 12-inch)	50 to 70
Sweeps (20-inch to 30-inch)	80
Blade (more than 30-inch)	90
Offset Disc	50
Tandem Disc	60
Harrow – springtooth	65
Harrow – steel Tooth (more than 12-inch)	95

5.4 Cropping Rotations

Crop rotations can provide many rewards to the landowner if he is knowledgeable with the practice, and knows what species to alternate after the harvest of last years crop (AAFRD 2004). Crop rotations can help reduce disease outbreaks, insect pests and weeds. A key factor to effectively managing weeds when using crop rotations is to improve the competitiveness of crops with weeds. This can be accomplished by utilizing cultivars, higher crop seed rates, altered crop seeding dates, selective fertilizer placement (Neave 2005). The use of cover or green manure crops that inhibit weed growth through physical and allelopathic interactions can be supplemented to increase productivity in cropland (see cover crops for more details). Sweetclover (*Melilotus officinalis*) has shown good potential for this purpose on the Canadian prairies (Blackshaw 2001).

Rotations can be chosen depending on the land conditions. If there is little residue left after a crop then the farmer may choose to plant a crop that provides more litter, which in turn will help increase the moisture content of the soil, build more organic matter, reduce nitrogen fertilizer inputs, and lower excessive levels of soil nutrients (Beck et al. 1998).

Crop rotation is especially beneficial after a crop such as potatoes or beets are planted**,** as there is little residue left after harvest (Neave 2005). Legumes are a good choice when considering rotation because they help fix the nitrogen in the soil. It is best to avoid planting the same crop two or more years in a row (Dimmick and Minser 2006). Long-season crops can be rotated with short-season crops to provide better weed management through the use of early-season herbicides. The benefit of a short-season crop is that it can be harvested earlier in the year allowing a fall seeded crop to be planted, such as winter wheat or fall rye (see cover crops for more details on fall-seeded crops) (AAFRD 2004)

5.5 Cover Crops

Soil erosion is a major concern in croplands across the Canadian Prairies (AAFRD 2004; Neave 2005). Soil erosion leads to decreased soil fertility and in turn poor crop production on eroded sites (AAFRD 2004). The Canadian prairies generally receive a low amount of rainfall each year which dries out the soil and makes it perceptible to wind erosion. Wind erosion can be devastating on fields that have been cultivated after harvest. These cultivated fields are also known as summer fallow; a large amount of topsoil may be lost if these fields are not protected (AAFRD 2004).

There are a number of ways to protect summer fallow fields from wind erosion, and one of these is to plant cover crops. Cover crops have been known to increase soil cover, reduce erosion, fix nitrogen, add organic matter, improve soil structure, break up "hard pan", and reduce nitrogen losses (Stewart and Johnson Unknown Date). A cover crop can be planted shortly after harvest in the fall which allows the roots and above-ground vegetation to become established and hold the soil together (Hartwig and Ammon 2002). It may be planted just before a fallow year or after crops such as sugar beets, potatoes and beans that leave little residue cover (Duval 1997).

Cover crops can be used in the following ways:

- As green manures established the year before planting a crop such as potatoes. Several studies have indicated increase in crop yield and quality of potatoes with a preceding cover crop due to improved nutrient cycling and soil tilth. This fact holds true in warm climates where nutrients decompose rapidly, but has also been reported in cold climates. It is estimated that the effect of a preceding cover crop is equivalent to the application of 10 to 90 t/ha of manure, depending on whether the green manure was fertilized or not (Duval 1997).
- As catch crops after harvest. A catch crop is planted almost immediately after harvest of the previous year's crop. The main role of cover crops in this case is to protect the soil from erosion and to prevent leaching of nutrients unused by the previous crop (e.g. potatoes). It can be tilled in the fall or kept as an over wintering cover crop that will be tilled in the spring (Duval 1997).
- As a full-season crop in rotation with the desired crop of choice. The benefits gained from this practice are that it usually increases the organic matter in the soil and involves tilling in mature plants rather than green ones. It can also be part of a non-chemical weed or pest control strategy (Duval 1997).

Cover crops are typically spring cereals, which are inexpensive to seed, killed by freezing over the winter, and competitive with weeds in the fall but do not compete with the following crop (Duval 1997). Cover crops use some of the nutrients in the soil but only for a short time, and the used nutrients are cycled back through decomposition, becoming available to the subsequent crop. The amount of soil moisture used by the cover crop is minimal and is derived from shallow depths, and in turn is usually replaced over the winter (AAFRD 2004).

Cover crops are most beneficial when used in conjunction with reduced tillage practices, and other improved copping systems (See improved cropping systems for more information).

5.5.1 Cover Crop Species Considerations

A number of species can be used when planting cover crops. The species considered is dependent on what type of crop was planted prior, and what type of crop will be planted the following spring. Soil sampling is sometimes necessary to find out what nutrients are lacking, as well as which are over-abundant in the soil. Research has been going on at the Lethbridge research center, and they found that a well established, vigorous fall rye cover crop that was killed by herbicides or tillage in the spring suppressed weeds for the remainder of the fallow season. The cover crop protected the soil from erosion and provided about a 50% reduction in weed biomass in the fall compared to bare fallow (Frick and Johnson Unknown Date).

When choosing the type of cover crop to plant the landowner should be aware that although spring cereals such as oats and barley germinate quickly, they are killed by early frost. There will be little to no surface residue remaining the following spring, unless the crops are planted by early September and considerable biomass was produced before the cooler weather arrived (PEI AFA Unknown Date). Plants that develop a living root mass earlier and can resist the winter temperatures will result in much better erosion control in the spring. Fall rye and winter wheat are very good choices for cover crops following a potato harvest. Aside from providing good cover, both of these crops produce a cereal grain the following year. Winter wheat is a more valuable cereal grain crop, but it does not grow as aggressively if planted late in the fall (PEI AFA Unknown Date).

The types of plants that can be used as cover crops can be broken down into these 4 main categories:

- Legumes
- Cereals and grasses
- Crucifers
- Other

Legumes

The legume family comprises fodder crops like clovers, vetches and alfalfa, as well as pulse crops like soybeans, fababeans and lupine (Duval 1997). They have the ability to fix nitrogen from the air with the help of specific bacteria that gives them a special value as a source of nitrogen on the farm (Drinkwater et al. 1998). The most common legumes used for cover crops include red clover and hairy vetch (Duval 1997). One disadvantage of legumes is they require a higher pH than many other crops.

Pulse legumes are usually used as rotational crops but they can be used as cover crops as well. Soybeans can provide a good source of green manure when planted before potatoes especially in warmer climates (Drinkwater et al. 1998). Lupine is one of the favorite cover crops grown in Eastern European countries as its effect lasts for about two years. However, most varieties have not adapted Northeastern North America (Duval 1997).

Perennial legumes such as alfalfa and clovers provide acceptable habitat for grassland birds and waterfowl. These crops will maximize their benefits if left on the land for a few years in a row. They provide good residual cover, and are highly utilized by birds for nesting and rearing their broods. Butterflies and insects are highly abundant in hayfields, and provide a good food source for birds nesting in the hayfield.

Cereals and Grasses

Rye has been a very popular cover crop in several countries, especially in light soils. It is known to be one of the best plants to prevent nitrate leaching in the fall, and is also very tolerant of low winter temperatures. A disadvantage of rye is that it is of limited value as a cash crop, although it can be used as animal feed. Rye is also very susceptible to ergot (Duval 1997).

Rye provides a protective soil cover for the winter that tends to be cheaper than hay mulches. In northern regions, planting dates should fall around mid-September, however, in more favorable regions it can be sown up to early October. If sown later, higher seeding rates should be used (Mutch and Martin 2004). If rye is going to be harvested the following year, it is recommended to chop the straw after harvest and incorporate it into the soil; this will ensure the soil has an acceptable level of organic matter (Duval 1997).
Spring cereals are often used as rotational crops instead of cover crops. However, oats, barley or even wheat can be sown as inexpensive catch crops after a fall harvest. These crops will die in the winter reducing the amount of herbicides and tillage needed in the spring (Duval 1997).

There are a number of grasses that can be used as cover crops. Japanese millet, sorghum/sudan grass or ryegrass can be used and can also be sources of forage for cattle and wildlife. These crops are often planted to increase the amount of organic matter in the soil and to prevent erosion. Japanese millet and sorghum/sudan grasses will die if they are subjected to frost therefore, the landowner must wait until danger of frost is gone (Duval 1997).

Crucifers

Crucifers are plants in the cabbage family such as white mustard, oilseed radish and canola/rape. They are often used as cover crops in potato farming, especially in Eastern European countries. Crucifers offer several advantages. They grow quickly, resist cold fall temperatures, are excellent nitrogen accumulators, their seeds are cheap and they are winter-killed. They are also known to suppress nematodes (Duvall 1997).

Other Cover Crops

Sunflowers provide a good cover crop and are very competitive against weeds; however, they require more heat than other crops fore-mentioned and therefore only useful in warmer regions (Mutch and Martin 2004). Buckwheat is a fast growing cover crop but is very susceptible to frost damage. It is more useful when used as a rotational crop instead of a cover crop (Duval 1997).

5.5.2 Recommended Seeding Dates

The latest recommended seeding dates will vary from year to year across the provinces depending on soil type, local climatic conditions, field exposure and the species of cover crop being grown (Mutch and Martin 2004). Table 6 shows the latest recommended seeding dates, based on long term weather records, for drilled cover crops that are established after potato harvest across most of the province (PEI AFA Unknown Date).

Table 6: Recommended seeding rates and dates for cover crops

(PEI AFA Unknown Date).

Latest Recommended Seeding Dates for Drilled Cover Crops	
Species	**Date**
annual ryegrass	August 30
spring cereals	September 05
winter wheat	September 15
fall rye	September 20

Recommended Seeding Rates for Drilled Cover Crops	
Species	**Seeding rate**
annual ryegrass	25-35 Kg/ha (23-32 lbs/acre)
winter wheat or fall rye	135-150 Kg/ha (120-135 lbs/acre)

5.5.3 Benefits to Wildlife and Biodiversity

The problem with traditional agriculture is there are more than 20 million acres of conventionally spring seeded crops in Alberta alone (AAFRD 2004). This presents a problem to nesting birds because their nests will be destroyed if any seeding activity takes place. Ducks Unlimited Canada (DUC) has been working with landowners to promote the use of winter wheat. Winter wheat is seeded and germinates in the fall, and begins growing again in the spring. This means that waterfowl have attractive and safe habitat to nest in when they return in the spring (Soetaert 2005).

By seeding winter wheat, not only does it benefit Alberta producers by increasing their net returns and spreading their workload, it is also providing breeding habitat for waterfowl (Soetaert 2005). Nests that are present in those areas typically don't get destroyed. It also provides good cover from predators. When comparing nesting rates in conventional spring tillage as opposed to fall seeded crops there are on average one nest for every 150 to 200 acres. On fall seeded crops there can be one nest for every 10 to 15 acres in high waterfowl population areas (Soetaert 2005). Because winter cereals are usually harvested before fall flight, they are usually less susceptible to waterfowl damage that typically occurs in the fall.

Cover crops often provide acceptable habitat for beneficial insects as well. Intensive agricultural practices can negatively affect the abundance, diversity, and efficiency of these insects (Neave 2005). Frequent disturbances such as cultivation, pesticide applications and other agricultural practices have been found to be detrimental to beneficial insects (Carmona and Landis 1999; Neave 2005).

Ground beetles are considered beneficial arthropods found in agroecosystems and have the potential to reduce populations of both weeds and insects. Some Carabid beetles are known to eat up to 40 weed seeds per square foot per day (Carmona and Landis 1999). Research has been shown that reducing pesticide applications, providing cover crops, using crop rotations, and reducing tillage practices can have a great impact on the population of ground beetles (Carmona and Landis 1999).

In a study conducted in northern California is was found that over a two-year period, codling moth infested 36.1 percent of the apples in an orchard with a cover crop, whereas a nearby-cultivated orchard without a cover crop suffered a 45 percent fruit loss from this pest. This resulted from the cover crop attracting beneficial insects that controlled the number of codling moths (Bugg and Waddington 1993).

5.6 Soil Erosion and Salinity Control Management (Non-riparian)

5.6.1 Soil Erosion

Soil erosion is a serious matter for farmers in the Canadian agricultural regions. The landowner should become familiarized with the negative impacts of soil erosion, and implement practices on his land that help reduce the amount of erosion on the cropland. Grassedwaterways are constructed in low lying areas that tend to be more prone to erosion. Grassedwaterways provide acceptable habitat for a number of birds as well as mammals, amphibians, reptiles and insects.

Soil erosion can affect the quality of our soil, water, and air (Wall et al. 2003). Wind and water are the main erosion agents on farmland. Tillage is the leading cause of erosion out of all the farming practices, although livestock trails and overgrazing are contributors as well (AAFRD 2004). Erosion leads to the loss of topsoil, the most productive portion of the soil, in turn it reduces the nutrient availability and productivity. Soils that have been severely eroded may produce crop yields 50-100% lower than those from stable soil in the same field (Wall et al. 2003).

There are generally to types of erosion concern to agriculture: water erosion and wind erosion. Both types occur throughout agricultural areas and the dry semi-arid conditions of the Canadian Prairies are highly susceptible to erosion (AAFRD 2004).

Soil conservation practices have been implemented across Canada to reduce the risk of erosion. These practices have decreased the risk by 17% in British Columbia, 11% in the Prairie Provinces, and 16% in central Canada; the risk increased by 0.5% in the Maritime Provinces because of increased row-cropping, but this increase did not account for risk reductions where terraces and grassed waterways have been installed (Wall et al. 2003).

Land management practices that help to control erosion include managing residues, extending crop rotations, growing winter cover crops, planting shelterbelts, strip-cropping, using conservation tillage, and restructuring the landscape (Table 7) (terraces, diversions, and grassed waterways) (Wall et al. 2003).

Erosion has a number of indirect affects to biodiversity, however there is no real scientific literature explaining the direct threats. Sedimentation of wetlands and streams is probably one of the greatest effects that soil erosion has on biodiversity. Sediment loading in streams and other waterbodies can have various impacts from increased turbidity, sediment deposition, and increased surface water input that will likely impair natural wetland functions (Gleason and Euliss 1998). Swanson and Duebbert (1989) stated that direct impacts of turbidity and sedimentation may include covering of invertebrate eggs, the clogging of filtering apparatuses, and the covering of organic substrates important in aquatic food chains (Gleason and Euliss 1998). High levels of suspended silt and clay have been shown to be toxic and to reduce zooplankton feeding rates and assimilation (Robinson 1957; McCabe and O'Brien 1983; Newcombe and MacDonald 1991 as cited by Gleason and Euliss). Other impacts of sedimentation on aquatic invertebrates and plants may result from agrichemicals attached to the sediments (Hartman and Martin 1984, 1985 as cited by Gleason and Euliss 1998).

This section will describe non-riparian erosion control structures. For more information on erosion control structures related to riparian areas see (Riparian and water management).

Table 7: Erosion control practices of Canada, 1991

(percentage of farmers reporting) (Dumanski et al. 1994. as cited in Wall et al. 2003.)

Province	Forages	Winter Cover crops	Grassed waterways	Strip-cropping	Contour cultivation	Wind breaks
British Columbia	23	11	10	2	5	13
Alberta	43	7	17	10	11	29
Saskatchewan	22	6	12	21	18	35
Manitoba	35	7	12	5	13	37
Ontario	60	20	15	4	7	21
Quebec	52	4	4	3	4	8
New Brunswick	44	10	9	5	8	8
Nova Scotia	34	12	8	3	8	7
Prince Edward Island	72	9	11	4	10	16
Newfoundland	17	7	4	1	7	12
Canada	42	10	13	9	10	15

5.6.2 Water Erosion

The risk of water erosion is apparent across all of Canada's agricultural regions (Table 8). The Peace and Fraser River basins of British Columbia, the sloping summer fallowed land in the Prairie Provinces, the rolling upland landscapes of Ontario and Quebec, and the shallow and fragile soils in the Maritime Provinces are most susceptible to water erosion (Wall et al. 2003).

Water erosion can occur on the land when there is too much precipitation for the soil to hold. The water picks up soil particles and transports them along the flow path (called runoff). The loss of soil particles leads to the degradation of the soil, and if the runoff flows into a water body, water quality can be affected as well (AAFRD 2004).

Table 8: Inherent (bare soil) risk of water erosion on Canada's cultivated land percentage

(Wall et al. 2003).

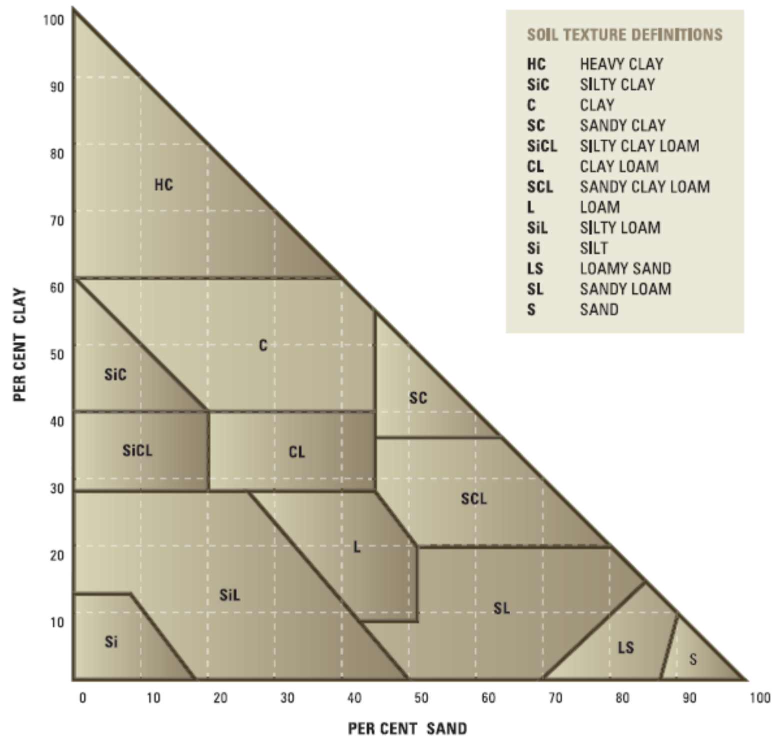
Risk class	B.C.	Alta.	Sask.	Man.	Ont.	Que.	N.B.	N.S.	P.E.I.	Canada
Negligible	5	39	51	35	12	18	0	3	1	40
Low	8	16	26	41	11	21	4	6	7	23
Moderate	13	17	19	6	24	14	16	4	11	17
High	3	10	3	4	25	4	13	3	37	7
Severe	72	18	1	14	27	43	67	84	44	13

Sediments that are carried off agricultural land by water can silt up drainage ditches and severely alter aquatic habitats. Nutrients and pesticides that are transported with the eroded soil reduce the water quality of ponds, streams, and lakes. Controlling soil, nutrient, and pesticide losses from agricultural land is an important component in protecting the quality of both surface water and ground-water (Wall et al. 2003).

The impact of sedimentation on wetland wildlife is likely indirect, involving habitat changes in response to sedimentation. An important function of wetlands is to provide wildlife habitat. Alteration of vegetative cover and aquatic invertebrate communities has a direct impact on all wetland wildlife. Aquatic invertebrates compose a large percent of the diet of waterfowl (Krapu 1974a; Swanson et al. 1974, 1985; Euliss and Harris 1987; Miller 1987; Euliss et al. 1991 as cited by Gleason and Euliss 1998) and other wetland-dependent birds. Waterfowl hens need these protein-rich invertebrate foods to meet the physiological demands of the breeding and nesting season (Krapu 1979; Gleason and Euliss 1998) and they provide essential amino acids for other seasonal changes such as feather molt (Heitmeyer 1988 as cited by Gleason and Euliss 1998). Aquatic invertebrates are directly affected by sedimentation as it tends to smother their eggs and habitat. Agricultural chemicals that may be present in the sediment as a result of runoff may destroy important habitat and even kill the invertebrates (Gleason and Euliss 1998).

Bare soils void of vegetation and comprised of fine-medium textured aggregates (especially clays and silts with low organic matter) are most susceptible to water erosion (Figure 4) (Wall et al. 2003). Soils with high clay content are highly erodable because the moisture cannot permeate the clay layer, and therefore runs off the land transporting the topsoil with it (AAFRD 2004).

Figure 2: Soil Texture



Adapted from: Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food. 1997. Best Management Practices: Soil Management. Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food. p. 8.

5.6.3 Wind Erosion

The risk of soil erosion by wind on agricultural land is a concern in many regions of Canada. Areas that are considered more vulnerable include the sandy soils along the Fraser River in southern British Columbia, the tobacco lands in southern Ontario, the Organic soils of southern Quebec, and the coastal areas of the Atlantic Provinces (Wall et al. 2003). However, the Prairie Provinces are the most susceptible to wind erosion (Chrapko 2001). This is due to dry semi-arid climate and the large areas of agricultural lands that undergo cultivation each year. Estimates of the relative risk of wind erosion on bare, unprotected soil across the prairies are shown in (Table 9) (Wall et al. 2003).

Table 9: Relative risk of wind erosion on percentage of cultivated land in the Prairie provinces

(Adapted from Wall et al. 2003).

Risk class	Alberta	Saskatchewan	Manitoba	Prairies
Negligible	7	4	8	6
Low	39	23	37	31
Moderate	24	34	19	29
High	27	33	30	30
Severe	4	7	5	6

Conservation tillage systems have reduced the risk of wind erosion by about 5% in some of the arid regions of Saskatchewan and Alberta, whereas the change in cropping systems has had only a minimal effect. A significant shift from annual crops to perennial forages in some sandy areas has reduced the wind-erosion risk by as much as 20-30%. Wind erosion has been reduced slightly more in the Black, Dark Gray, and Gray soil zones than in the southern prairies, mainly because of a marked reduction in fallow and some replacement of annual crops with forages in these zones (Wall et al. 2003).

5.6.4 Erosion Control Structures

Erosion control structures can be implemented in agricultural areas, and are designed to minimize erosion by slowing down the flow of water and wind (Young 2005). Some structures are meant to filter out such things as sediments, chemicals and other agricultural inputs, while others are just designed to slow the flow; whether it be wind or water (Chrapko 2001). The following list and descriptions of these structures are designed for non-riparian areas. Information on riparian area erosion control structures can be found in (Riparian and Water Management).

Some of these structures provide many direct biodiversity benefits, while others provide indirect benefits as a result of reduced erosion and better productivity of croplands.

(A) Grassed Waterways

A grassed waterway is a natural or constructed channel shaped or graded to required dimensions, and established with suitable vegetation for the safe disposal of runoff water (Koford and Best 1996). Grassed waterways may be used alone or in combination with diversion terraces and other structures to discharge surface runoff as part of an erosion control system (New Brunswick DFA Unknown date).

In order to establish a healthy grassed waterway a landowner may have to maintain it annually. Some common maintenance problems that can occur include insufficient grass, encroachment of weeds and brush, sedimentation, gullies and insufficient capacity (Pfost and Caldwell 2005). Insufficient growth may be caused by establishment problems, low soil fertility, smothering from lodged growth, accumulated sediment, or competition from weeds, legumes and nearby trees or brush (Pfost and Caldwell 2005).

Properly maintained grassed waterways provide habitat for a variety of birds, however, the quality of the habitat can be affected by annual haying. Haying the grassed waterway alters the structure of the vegetation, which in turn can affect the bird community. Some species of birds that inhabit grassed waterways prefer tall, dense vegetation that is greater than 60cm tall (e.g. dickcissels, common yellowthroats, and red-winged blackbirds) (Koford and Best 1996). On the other hand vesper sparrow nest densities were greater in mowed waterways (Bryan and Best 1994 as cited by Koford and Best 1996). Grasshopper sparrows tended to nest only in grassed waterways that had been mowed the previous year; sedge wrens nested only in waterways that had not been mowed the previous year. The timing of mowing may also affect populations. Birds that have been displaced from mowed hayfields may move into grassed waterways with suitable vegetation structure. Mowing waterways at the peak or late in the nesting season may interfere with some birds' last nesting attempt of the season (Koford and Best 1996).

Competition from weeds and bush can cause grassed waterways to malfunction. It is recommended that the waterway should be hayed occasionally to maintain proper height, and to prevent lodging and smothering. Haying should be delayed until July 15 to prevent destruction of waterfowl nests and wildlife habitat (see Delayed haying for more details). Carefully controlled grazing may be permitted if the soil is not too damp to control vegetation growth (Pfost and Caldwell 2005).

Wildlife will prefer to use grassed waterways if they are constructed of species that they tend to utilize more frequently. Native warm-season grasses such as switchgrass, bluestem, Indiangrass, partridge pea and many other bunchgrasses provide adequate habitat (USDA 1999).

Grassed waterways are used heavily by a number of bird species. In Iowa, 48 bird species were documented using grassed waterways, as opposed to the 14 species found in surrounding cropland (Koford and Best 1996). The most common birds that use waterways include redwing blackbirds (*Agelaius phoeniceus*), dickcissels (*Spiza americana*), barn swallows (*Hirundo rustica*), grasshopper sparrows (*Ammodramus savannarum*), brown-headed cowbirds (*Molothrus ater*), song sparrows (*Melospiza melodia*), and western meadowlarks (Koford and Best 1996).

Grassed waterways can be applied in any ecoregion where agricultural activities take place. The only consideration that may be taken into account is the type of species that are used the waterways (Young 2005). The species used could be based on the native species that grow naturally in the area, depending on the ecoregion.

(B) Vegetative Filter Strips

A vegetative filter strip (VFS) is a strip of vegetation bordering a cropped field. The strip is designed to reduce runoff from the cropland into surrounding areas (e.g. a stream or wetland). The VFS filters out sediment, nutrients, organic material and chemicals that are present on the cropland, and prevents them from running off into surrounding water bodies (Smith 1999; USDA 2000). The width of the VFS depends on the slope of the land. Recommended widths for various slopes can be seen in (Table 10).

The filtering efficiency of a VFS depends on the species used, amount of sediment buildup, width of strip, slope of land, and infiltration rate of the soil (Wenger 1999). Occasional maintenance of the VFS is required to maintain the ability of the strip to filter out the runoff. Using sod-forming grass species better filtering capabilities than bunchgrasses do (Smith 1999).

Species such as bromegrass and canary reedgrass can be used, however, it is recommended to use native species like switchgrass, indiangrass, and big bluestem. Native species will have more benefits for wildlife and birds than the tame grasses (USDA 2000; Wenger 1999). Guidelines for seeding rates can be seen in (Table 11). Multiple species may be used to create better biodiversity benefits. Rows of trees can be included in the VFS to create more habitat for nesting birds and other wildlife. Poplar, ash, and maple can be planted, as well as some shrubs like red osier dogwood and ninebark along with the perennial grasses (Smith 1999).

Table 10: Minimum guidelines for width of filter strips related to field slopes
(Smith 1999).

Minimum guidelines for width of filter strips related to field slope.

Field slope	**Minimum** width of filter strip
%	feet
0-10	15
10-20	20
20-30	25

Soil Conservation Service Field Office Technical Guide, 1988.

Vegetative filter strips are most useful when used with other practices such as conservation tillage. Sediment runoff on fields that are heavily tilled may degrade the VFS and prevent it from properly filtering (USDA 2000). VFS should not be hayed because the more dense the vegetation is, the better filtering capabilities it presents (Smith 1999).

Table 11: Suggested grass seeding rates for vegetative filter strips

(Smith 1999).

Suggested grass seeding rates for vegetative filter strips.

Type of Seeding	Grass Species	Pure live seed (PLS) lb/a
Permanent	Reed canarygrass	10
"	Reed canarygrass	6
"	Tall fescue	6
"	Smooth bromegrass	20
"	Switchgrass*	10
Temporary	Oats	64
"	Sudangrass	10-20
"	Wheat or rye	90

* Switchgrass is tolerant of the herbicides atrazine and simazine.

Adapted from Soil Conservation Service Field Office Technical Guide, 1988.

(C) Conservation Tillage

Conservation tillage refers to a range of tillage practices aimed at reducing soil erosion and improving soil quality. Any tillage and planting system that leaves 30% or more of the soil surface covered with crop residues after planting is considered to be conservation tillage (Fawcett 1987; Foster et al. 2000 as cited by Hilliard et al. 2002).

There are many variations of conservation tillage practiced on Canadian farms. By far the most successful at reducing erosion is no-tillage. No-tillage or zero tillage involves no disturbance to the land other than the process of seeding. Conventional tillage buries most of the crop residue leaving the soil exposed to wind and water erosion risks (Hilliard et al. 2002).

Crop residue often provides erosion protection regardless of soil type. There have been reports of 50 to 90% erosion reduction in fields that have adequate residue cover (Logan et al. 1987 as cited by Hilliard et al. 2002). In most of the Prairies, conservation tillage, in conjunction with sound pesticide and nutrient management, should be considered best practice (Hilliard et al. 2002).

More details for conservation tillage and its benefits to biodiversity can be found in the conservation tillage section under Improved Cropping Systems.

(D) Shelterbelts

Shelterbelts are an excellent approach to reducing and preventing wind erosion in croplands on the Prairies. It has been found that the drier conditions are, the greater the benefits gained from shelterbelts (Young 2005). Shelterbelts can vary widely in terms of structure, from single rows of trees to thick strips of native vegetation, the latter of which provides the best biodiversity benefits (Hilliard et al. 2002).

Shelterbelts have been used for centuries to reduce wind erosion. There is no question that they are an effective soil conservation practice. Other benefits of shelterbelts include snow-trapping, soil moisture conservation, wildlife habitat, and the creation of higher temperature micro-climates. The benefits of shelterbelts have been appreciated for many years and continued or increased use will contribute to water quality protection (Hilliard et al. 2002).

Shelterbelts provide a great deal of wildlife habitat amongst the endless acres of cropland in the agricultural areas of Canada. For more information on how shelterbelts can benefit wildlife and biodiversity see Shelterbelt Establishment.

(E) Cover Crops and Permanent Cover

Cover crops can be planted to greatly reduce the risk of erosion. The key to cover crops is to select a species that will grow quick and provide good root mass. The roots are what hold the soil together, therefore, the better the root mass, the more erosion resistance they provide (Wilsey 2005). Forage crops such as alfalfa can be planted to reduce erosion risk. These crops will also bring increased returns to the farmer. The forage can be cut and used for livestock feed, or grazed during the summer and winter months. See the Cover crops and Permanent Cover sections for more details on erosion protection and biodiversity benefits (Wilsey 2005).

(F) Wooded Fencerows

Fencerows that are planted with woody or herbaceous species can provide a certain degree of erosion protection. They may trap important top soil from leaving the field, as well as trap snow for added moisture in the winter. Wooded fencerows can provide biodiversity benefits as well. Shalaway (1985) found that 16 species of birds nested in herbaceous and woody fencerows in Michigan; nest density was 43.5 nests/ha (Koford and Best 1996). Nest density was most influenced by fencerow width, adjacent field type, and area of open shrubs (i.e., <50% shrub cover 1.5-2.0 m above the ground). Wider fencerows tended to support greater nest densities (Koford and Best 1996). Song sparrows, American robins, northern cardinals, red-winged blackbirds, gray catbirds, brown thrashers, northern flickers, and ring-necked pheasants were the most frequent nesters in fencerows. The most abundant mammals found along fencerows were raccoons (*Procyon lotor*), red foxes (*Vulpes vulpes*), striped skunks (*Mephitis mephitis*), and long-tailed weasels (*Mustela frenata*) (Koford and Best 1996).

5.6.5 Salinity Control

Many prairie soils in Canada contain high levels of water-soluble salts, including the sulfates of sodium, calcium and magnesium. These salts are the product of a chemical action on minerals in the upper layers of the glacial till that is present in the soils of this region. When these salts form on the surface of the soil through natural processes, it results in a condition known as soil salinity (Eilers et al. 2003).

If soil salinity is high enough, there are enough dissolved salts in the soil to decrease plant growth (AAFRD 2004). Soil salinity is controlled by the presence and movement of water throughout the soil profile. The geology, hydrology, climate, plant cover and farming practices all affect, and can change the level of soil salinity (Eilers et al. 2003). Saline soils are present throughout many areas of the Prairie Provinces. Moderate to severe salinity can reduce the annual crop yields of most cereal and oilseed crops by about 50%.

Some signs that soil salinity is present include:

- Irregular crop growth patterns and lack of vigor
- White crust on the surface of the soil
- White ring of salt around water bodies
- White spots and streaking on the soil
- Presence of salt-tolerant vegetation [e.g. Red samphire (*Salicornia rubra*)] (Eilers et al. 2003).

High soil salinity can have the same effect as drought does on vegetation. High levels of salt in the soil impairs the vegetations ability to uptake water, if salinity is high enough it may even draw water out of the plant (Eilers et al. 2003; AAFRD 2004). There are approximately 36% of soils affected by salinity in the agricultural areas of the prairies (Table 12). Medium texture soils that are nearby small wetlands or sloughs are affected the most by salinity. Soils in the Cypress Hills Uplands and Moose Mountain in Saskatchewan, as well as Turtle Mountain in Manitoba are areas that have been known to suffer from soil salinity. Areas that have limited drainage are also affected by soil salinity (e.g. Quill Lakes, Saskatchewan and Red River Basin, Manitoba) (Eilers et al. 2003).

Table 12: Land at risk of increasing salinity (%) assessed using a salinity risk index (SRI)

(Adopted from Eilers et al. 2003).

Degree of risk	Prairie region	Manitoba	Saskatchewan	Alberta
Low	66	61	59	80
Moderate	27	25	34	17
High	7	14	7	3

5.6.6 Land Use Practices to Prevent Salinization

Cultivation can be considered the number one cause of soil salinity problems in agricultural areas. In areas that are affected by salinity, conservation tillage systems should be introduced to help minimize the impacts on the soil and vegetation. The use of cover crops and forage crops are ways of decreasing the risk of soil salinity problems. Using crops that are salt tolerant and uptake more water to lower the water table are best suited for saline soils (Table 13).

Switching from row crops to forage crops can help reduce the affects of salinity on agricultural soils. Alfalfa is a perennial forage crop that can send its roots down up to 5m into the soil. Alfalfa can lower the water table if it is used as a forage crop for about 5 years. (Figure 5) shows the ability of alfalfa to decrease the amount of moisture in the soil as compared to continuous cropping and crop-fallowing. Alfalfa can be used as a rotational crop to decrease soil salinity; however, maximum benefits from this are only seen if the forage is left for several years (Eilers et al. 2003).

Table 13: Salt tolerance of annual field crops

(Eilers et al. 2003).

Degree of salinity tolerated		
Nonsaline to weakly saline	**Moderately saline**	**Strongly to very strongly saline**
Annual field crops		
Soybean Field bean Fababean Pea Corn	Canola Flax Mustard Wheat Fall rye[1] Oat Sunflower Barley[1] Sugar beet	Barley may produce some crop but this land is best-suited to salt-tolerant forage crops

Manure contains salt originating from the salt in animal rations. Over application of manure can lead to increased levels of salt in soil (AAFRD 2004). See the section on Manure Application for information about manure application regulations to prevent salt accumulation.

Table 14: Salt tolerance of forage crops

(Eilers et al. 2003)

Forage crops		
Red clover Alsike clover Timothy	Reed canarygrass Meadow fescue Intermediate wheatgrass Crested wheatgrass Bromegrass Alfalfa Sweetclover1	Altai wild ryegrass Russian wild ryegrass Slender wheatgrass[1] Tall wheatgrass[2]

[1] Crops that are intolerant of flooding, which is common in some saline areas.
[2] Under dry conditions, slender wheatgrass is more tolerant than tall wheatgrass.

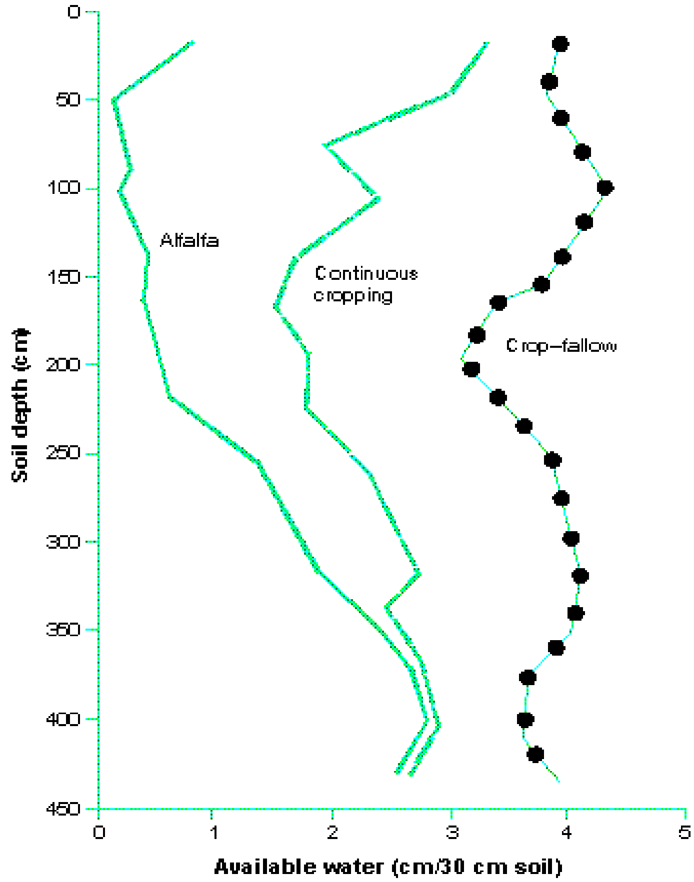


Figure 3: Available soil moisture under various cropping systems

(Anon 1991, as adopted by Eilers et al. 2003).

Preventing salinization of soils can be a difficult task for a landowner to undertake. Using a number of different practices together will encourage the greatest results in minimizing the amount of saline in the soils. Grassed waterways help remove excess water that may cause salinization, as well as planting cover crops and forage crops. Conservation tillage systems can be utilized to help minimize the risk of soils becoming salinized.

5.6.7 Impacts on Biodiversity

Soil salinity alters the density and composition of vegetation in wetlands and other areas. Salinized soils usually have low growing vegetation that only grows in saline affected areas. This vegetation provides little or no cover for wildlife and the salt-resistant plants are not considered a desirable food source. Water quality is affected in saline soils as well. The amount of salt present in the water can classify the water quality as un-consumable and even dangerous to drink (Eilers et al. 2003). Saline waterbodies can pose a hazard to fish populations and are generally avoided by waterfowl (Eilers et al. 2003).

5.7 Manure and Nutrient Land Application

Manure can provide many essential nutrients for a plant to intake, however, if over-applied it can lead to serious effects on waterbodies that receive the manure. Land that has manure applied to it will be more productive, including many organisms that help break down organic matter into more usable forms for the crop to utilize. Manure should not be spread nearby any waterbody, or if there is heavy rainfall forecasted. Manure that is applied should be incorporated into the soil somehow within 48 hours.

Livestock production in Canada has seen producers increasing the herd size of their farm without increasing the amount of land they own. This leads to more animals concentrated into smaller areas, and when it comes to manure production this can cause serious problems (Hilliard et al. 2002). Manure production from these operations can be problematic when dealing with water quality. Depending on the location of livestock facilities manure can runoff and create excessive pollution in nearby water bodies (Lanyon 1994).

Manure can be a valuable resource if handled properly. It is an excellent source of nutrients and can improve soil tilth, structure and water-holding capacity. Manure has several advantages over commercial fertilizers, including on-farm availability, nutrient composition and ability to enhance the organic matter of soil (AAFRD 2004).

Animal manure, including that from dairy cattle, contains significant amounts of the primary nutrients (N, P, and K) as well as other essential plant nutrients and is an excellent nutrient source for crops (Newton et al. 2003; AAFRD 2004).

Nitrate leaching losses and ammonia volatilization from manure are dependent on three factors: content of available nitrogen in manure (the largest concentrations are found in slurries and poultry manures), manure application rates and timing of applications together with mineralization and local hydrology (Chambers et al. 2000). Following applications, nitrogen is directly lost to the atmosphere by ammonia volatilization, or by leaching or denitrification after nitrification of ammonium in the soil. High nitrogen mineralization rates are related to manures with low C:N ratios. Nitrogen is not the only nutrient of importance, care must also be taken when applying manure to meet crop nitrogen requirements as regular manure application will result in excessive phosphorus loading on soils (Williams et al. 1999). Generally manure should be applied respecting phosphorus limits, and crop nitrogen provided by leguminous crops and cover cropping, or supplemented with side dressings of nitrogen fertilizer.

To reduce leaching and volatilization of nitrogen, application of liquid manure to arable soils is best done through split applications. This involves applying some manure during planting and then side dressing the crop with more manure when the plants enter the vegetative phase of their life cycle and when nitrogen requirements increase rapidly.

Band application of liquid manure improves penetration into the crop canopy, decreases manure contact with plant surfaces, and decreases nitrogen loss through volatilization (Chen and Samson 2002). Manure can also be injected into soils, especially under conservation tillage measures, which also reduces volatilization and surface runoff and results in better nitrogen utilization efficiency by plants.

To reduce nitrate leaching loss from manure application, liquid manures containing large amounts of available nitrogen such as slurries and poultry manures should not be applied to well-drained soils during fall or early winter (Chambers et al. 2000). Application of liquid manure is best immediately before a large period of vegetative growth, this usually occurs in late spring or, if cover cropping, during midsummer for fall growth (Samson *et al.*, 1992). If manure is applied before catch crops such as oilseed radish or winter rye, nitrogen becomes tied up in the plants where it can over winter and become available again the following spring. Solid manures release nutrients much more slowly. Solid manure can be applied at moderate rates in late fall as nitrogen release from solid manure is much slower than that from liquid manure (Loro et al. 1997). If solid manures are applied in the springtime, nutrients are immobilized while the organic carbon is being broken down and nitrogen is only available later on in the growing cycle.

Farmers may face a number of challenges during manure application that relate to farm equipment and storage facilities including limitations in storage space to over winter manure before spring application, estimation of application rates with existing farm equipment, poor performance of manure spreaders, and recommendations on equipment that can improve accuracy of nutrient application rates (Chambers et al. 2000).

5.7.1 Nutrient Impacts on Different Taxa

Flora

Nitrogen is often found to be the limiting factor for species composition in many sensitive ecosystems (Bobbink et al. 1998) with soil nitrate levels having a considerably negative correlation with plant species diversity (Wedin and Tilman 1996). Low levels of nitrogen appear to be essential for high species co-existence and the survival of native grassland species (Hovd and Skogen 2005; Walker et al. 2004b) as only then are slow-growing native plants, including many sensitive herbs and mosses, adapted to nutrient-poor soils able to compete (Dukes and Mooney 1999; Pitcairn et al. 2003).

Nitrogen pollution has been referred to as the equivalent to terrestrial eutrophication (Wedin and Tilman 1996). Long term nitrogen enrichment alters soil microbial communities (Siguenza et al. 2004), promotes invasions and gradually leads to the competitive exclusion of native species by non-native, nitrophilic plants (Bobbink et al. 1998; Dukes and Mooney 1999). In most communities, increased availability of nitrogen favors fast growing perennial grasses and weeds (Bakker and Berendse 1999; Boutin and Jobin 1998; Walker et al. 2004b), which can out compete a great range of native slow-growing, broad-leaved, shorter plant species adapted to nutrient-poor soils. Invasive species have several highly aggressive traits which make them successful under a wide range of ecological conditions including: the capacity for early season growth, rapid vegetative spread, high stem elongation potential, wide physiological tolerance and high architectural plasticity (Lavergne and Molofsky 2004). Acid-tolerant plant species may also be favored at the expense of rare, native plants when increased nitrogen deposition results in soil acidification (Bobbink et al. 1998). Invasive plants that often possess large flowers have also been shown to compete with native plants for pollinator services, often to the detriment of native plants (Larson et al. 2006). Domination by invasive species can introduce alien pollen and nectar into native plant populations, which can affect reproduction by mechanical blockage, chemical interference with fertilization, or hybrid production. Fecundity of native species can also be reduced by pollinators carrying native pollen to aliens. Nitrogen increases have also been shown to directly reduce flowering of native species, which can then affect pollinator visitation for insect pollinated shrubs (Walker et al. 2004a), and potentially have implications for both insect and plant communities (Munoz et al. 2005)

Generally in grasslands dominated by native warm season grasses, nitrogen increases will favor low-diversity cool-season (C_3) mixtures which decrease biomass carbon storage levels and elevate mineralization and soil nitrate levels and high nitrogen losses (Wedin and Tilman 1996). Unfortunately, the high residual soil nutrient levels resulting from long-term fertilizer use will produce species-poor grasslands with high numbers of invasive species, even after fertilization is discontinued (Walker et al. 2004b). Invasive species pose a serous threat to native plant communities and are an important contributor to decreasing biodiversity (Lavergne and Molofsky 2004). Reed canary grass is one example of an invasive grass that can outcompete native plants, resulting in monospecific stands with low plant and insect diversity, and ultimately an alteration in ecosystem function.

Restoration of species rich grassland communities may also be more difficult due to abiotic factors such as eutrophication, acidification and a limited seed bank and seed dispersal mechanism in the present fragmented landscape (Bakker and Berendse 1999). Nutrient depletion along with gap creation is essential for the return of plant biodiversity on restored land formerly used for intensive agriculture (Walker et al. 2004a). Extensive cutting and grazing management has also been shown to facilitate diversification and re-colonization on ex-arable soils, although rates of reassembly of plant communities are generally slow (Walker et al. 2004b).

Intensive agricultural systems that require high herbicide and fertilizer inputs along with regular tillage favor invasive, weedy plant communities (Boutin and Jobin 1998). Annual tillage creates opportunities for invasive species to dominate, allowing them to colonize gaps created by other disturbances in adjacent habitats such as woodlots and hedgerows, which in turn can then become a source of weeds themselves. Non-crop habitats, which are important for the integrity of landscape level biodiversity, are also affected by high rates of fertilization as the deposition of fertilizers at field edges drives community composition towards annual weeds (Stoate et al. 2001). Many arable field margins are now often composed of tall, nutrient demanding invasive species when compared with semi-natural areas such as road margins (Hovd and Skogen 2005). Restoration of these areas will require a reduction of soil nutrient levels and improved seed dispersal (Blomqvist et al. 2003).

As many invasive species respond positively to increasing impacts of global change including elevated CO_2, temperature and nitrogen levels, increased agricultural intensification and habitat fragmentation, the annual precipitation increase predicted in arid/semi-arid regions of North America predicted by global warming models, could increase invasions of invasive alien species (Dukes and Mooney 1999). Dominance of these invasive plant communities could potentially alter ecosystem function that could in turn feed back to affect important components of global change.

Soil Microbes, Fungi and Nematodes

Soil microbes function as a nutrient sink in the soil by releasing nutrients from organic matter for use by plants (Tu et al. 2006). As a result, plant growth, nutrient availability and nitrogen mineralization are directly increased with increasing soil microbial biomass and activity. In turn, microbial activity and biomass are affected by productivity of different grass species and any changes in plant community composition, primarily from the use of fertilizers, can affect the soil microbial community (Sarathchandra et al. 2001). Plant community composition is also known to affect the diversity of microbes and microfauna in the rhizosphere. Soil biological activity is not only influenced by soil microorganisms, but also by microfauna and mesofauna grazing on these organisms (Parfitt et al. 2005). The presence of collembola, microbial feeding nematodes and earthworms has been found to result in greater microbial productivity, increased microbial respiration and enhanced soil nitrogen mineralization. High amounts of organic inputs to both arable and non-arable land also often result in high microbial biomass and activity (Tu et al. 2006), and the addition of manure to grasslands found to increase the population of soil nematodes and protozoa (Forge et al. 2005). Overall microbial activity was found to be significantly higher in organically managed soils (Hole et al. 2005; Tu et al. 2006).

Estimates suggest that one gram of healthy soil can contain in the region of one billion organisms including 5 million bacterial cells, 10,000 protozoa, 200m of fungal hyphae and around 100 nematodes. Along with earthworms and arthropods (e.g. mites, springtails and beetles) these organisms play an important role in maintaining soil health (Kladivko 1993). The application of manure adds organic matter to the soil thus helping sustain arthropod and nematode populations to maintain a healthy soil profile (AAFRD 2004).

The application of inorganic fertilizer has been found to directly affect the composition of the soil microbial community, particularly under vulnerable systems such as plant monocultures and fallow soils (Sarathchandra et al. 2001). Increased soil nitrogen can result in decreased microbial biomas and decline of microbial species (Siguenza et al.

2004). Fungal species have also emerged as effective indicators of nitrogen enrichment through decreases in mycorrhizal root colonization, root biomass, spore density and community and morphotype richness (Dighton et al. 2004; Siguenza et al. 2004). Easily accessible nutrients from fertilizer application encourages the development of opportunistic bacteria and colonizer nematodes, reducing numbers of native bacteria and nematodes in the soil community (Sarathchandra et al. 2001). The improved microbial activity from increased meso and macro fauna activity brought about by organic farming practices can increase nutrient cycling and decrease the overall need for the use of inorganic fertilizers (Holland 2004).

A number of farms worldwide have adopted the techniques of Nature Farming as a strategy for restoring depleted soil and enriching the microbial diversity in cultivated fields. These practices originated in Japan and are characterized by the use of naturally occurring soil microbes which are collected, cultured, and applied to the soil. This may help restore microbiological communities that have been negatively impacted by the use of inorganic fertilizers, decreased soil pH and decreased soil organic matter (Valarini et al. 2003). These techniques have not yet been adequately explored in the Canadian agricultural context, but may represent inexpensive strategies for enhancing soil microbial diversity, organic matter and nutrient mineralization.

Invertebrates

Earthworms

Earthworms play a major role in agroecosystems as mediators between the aboveground and below-ground systems with a role in nutrient cycling, decomposition of organic matter and building soil structure (Kladivko 1993). They are also an important food source for birds (Hole et al. 2005). As such, the impact of agricultural practices on earthworm abundance, biomass and biodiversity is a key consideration in overall agroecological biodiversity. Factors which can affect agricultural earthworm populations include: level and type of fertilization, tilling practices and tractor and livestock traffic. The worms have sometimes been shown to improve crop growth and yield directly, but more often their activity affects crop growth indirectly through their effects on soil tilth and drainage (Kladivko 1993). Shallow-dwelling worms create numerous tunnels and channels throughout the soil, improving porosity and filtration. They consume organic matter and as it passes through their digestion system it breaks down the organic matter into more usable nutrients for plants. Their casts are high in organic matter and can considerably improve the soil structure. It has been reported that earthworms can turn over the top six inches of soil with 10 to 20 years (Kladivko 1993).

The application of manure to arable fields has been linked to increased earthworm populations. This is probably due to an increase in available organic matter both from the manure itself as well as an increase in plant productivity leading to increased organic matter available through primary production. Earthworm abundance was found to increase with the application of dairy cattle manure to cornfields over the course of 4 years. The species profile remained similar overall but the relative abundance of certain species changed (Estevez et al. 1995). Long term use of solid cattle manure over a 14 year trial period also demonstrated increased earthworm abundance (Estevez et al. 1996).

The use of solid manure compared to urine or mineral fertilizer has a significant positive impact on earthworm populations (Hansen and Engelstad 1999). The use of mineral fertilizers has a range of effects on earthworm populations. A number of studies have compared the effects of manure versus mineral fertilizers on earthworm populations. The impact of mineral fertilizers on earthworm populations is variable. In general, however, the positive impacts of inorganic fertilizers on earthworm populations are small relative to the use of organic fertilizers and there is a documented history of negative impacts associated with specific forms of inorganic fertilizer.

The combination of mineral fertilizers with an organic amendment such as manure or a cover crop can mitigate these negative impacts. A 14-year investigation of earthworms in soils fertilized with solid cattle manure versus NPKMg fertilizer showed that the organic nutrient source favored increased earthworm populations compared to the NPKMg treatment (Estevez et al. 1996). A combined treatment of the organic and inorganic fertilizers led to a quantitatively similar increase in species abundance. The use of NPKMg alone did increase total species abundance relative to a control but the increase was small compared to soils treated with manure (Estevez et al. 1996). In another study the use of farmyard manure increased earthworm populations compared to controls. Yet again, the use of NPK fertilizer led to only small increases in earthworm populations compared to treatments that incorporated organic nutrient sources (Edwards and Lofty 1982).

Other experiments have found that NPK fertilizer use led to a 9.4% decrease in the biomass of the endogeic earthworm (*Octolasion tyrtaeum*), although biomass increases were noted in this study when NPK treatment was supplemented with farmyard manure (Marhan and Scheu 2005). Experiments with mineral and inorganic nitrogen sources have found that earthworm densities decrease with increasing application rate of fertilizers. This has been related to the negative impact of these supplements, in particular ammonium sulfate and synthetic sulphur-coated urea, on soil acidity and organic matter content (Ma et al. 1990).

Farm fields can be a significant source of earthworm biodiversity when appropriate management practices are employed. Fields fertilized with liquid manure and mineral nitrogen under moderate soil cultivation with a rotating cultivation practice had higher earthworm abundances than field boundaries. Cultivated fields are therefore sources for earthworms, if the right conditions are maintained (Lagerlof et al. 2002). Field boundaries had lower earthworm abundance but they are also important in the context of earthworm biodiversity management because they may represent sources for recolonizing the field centers in the case of population declines under unfavorable management practices such as high tillage (Reeleder et al. 2005). Population densities of earthworms have also been found to be highly affected by tractor traffic (Hansen and Engelstad 1999), with more worms presents in plots that received low traffic. The biodiversity of the plant community has not been found to affect earthworm communities in grasslands (Gastine et al. 2003).

In summary, earthworm abundance and biodiversity has a significant impact on soil health and also provides a food source for other taxa, such as birds. Crucial factors in maintaining earthworm biodiversity include: the use of organic fertilizers or combinations of organic and mineral fertilizers, reduced tillage and tractor traffic and reduced livestock trampling. The biodiversity of grassland plant communities has not been identified as a significant determinant of earthworm biodiversity. Although farm fields generally have higher abundances and biodiversity of earthworms than surrounding land, it is important to protect the edge environment in order to maintain a population of worms that can recolonize the farm fields in case an agricultural practice such as excessive tillage or pesticide application decimates the field population.

Butterflies, spiders, beetles and other arthropods

Arthropods represent the most diverse and abundant multicellular taxonomic group. In an agricultural context butterflies are important pollinators while specific beetles (such as carabid beetles) and spiders are predators of crop pests. Pest insects can cause important damage to crops each season. The biodiversity of arthropods is important to ensure the presence of predators of crop pests, to provide food for birds and other vertebrates and also to ensure flower pollination. Agricultural fertilizer and manure applications have impacts on key arthropod groups. Dairy slurry applications to stands of the perennial grass (*Festuca arundinacea*) increased the abundance of the carabid (*Pterostichus melanarius*) while the abundance of other carabid species remained constant. This population effect persisted for 2 years after the cessation of slurry application.

Chemical fertilizer, on the other hand, did not cause a change in carabid population or abundance. The predatory capacity of *P. melanarius* increased with increasing numbers, indicating a positive impact of dairy slurry fertilization on carabid predation of pest arthropods (Raworth et al. 2004). Sewage sludge and urea-phosphate fertilizer applied to old-field communities also increased the increased biodiversity of carabid beetle species (Larsen et al. 1996). These positive responses to crop inputs should be interpreted cautiously because the excessive use agrochemicals can have a negative impact on carabid biodiversity. In a study of cereal crop rotations, the plots that received optimized levels of fertilizer and pesticide inputs had higher carabid species diversity than in high input plots (Ellsbury et al. 1998).

Vegetation-related factors also have an impact on carabid beetle diversity. The sward height of upland temperate pastures is an important factor in determining carabid population structure, with reduced grazing and increased height leading to increased biodiversity and abundance. The vegetation in the pastures studied received regular fertilization. However, cessation of N fertilization did not have an impact on carabid beetle populations due to the persistence of nitrophilic grass species and colonization of the sward by N-fixing white clover, which compensated for reduced nutrient inputs

(Dennis et al. 2004). Approximately 55% of carabid beetle community diversity is explained by vegetation community heterogeneity, while structural density of the habitat is important for the larger beetle species in order to provide a refuge from predators (Brose 2003).

The abundance and diversity of over wintering staphylinid and carabid beetles in winter wheat and wildflower stands has been studied and both of these parameters were higher in the wildflower plots. Increasing plot age also increased both of these factors (Frank and Reichhart 2004). These vegetation effects demonstrate the need to control nutrient contamination of neighboring ecosystems in order to maintain diverse populations of wild plants that may provide important habitats. In the context of agricultural fields, the application of manure and organic fertilizers increases predatory species of carabid beetles while fertilizers appear to have a positive effect on populations at low application rates and a negative impact at high application rates. Overall, optimizing and targeting nutrient inputs should allow increases in beneficial carabid species.

Spiders represent an important class of beneficial arthropod predators. Spider abundance does not appear to be directly impacted by nutrient applications, but there are indirect impacts of nutrients and farming practices on the agricultural landscape that do have a significant effect upon spider populations. Linyphiid spider and other invertebrate species (collembola and seed-feeding carabids) abundance have been directly related to weed species abundance in maize fields (Brooks et al. 2005). This, in turn, is negatively affected by excessive use of nitrogen, as previously discussed in the “Flora” section.

The primary factor that affects species richness of ground-dwelling spiders is the complexity of the surrounding landscape, which provides a higher availability of refuge and over wintering habitats. Biodiversity increases with increasing percentages of non-crop habitats in the landscape, irrespective of local management. However, organic agriculture has a favorable impact on spider population density (62% increase relative to conventional management), possibly due to reduced toxicity from agrochemicals (Schmidt et al. 2005). Although the primary focus of spider biodiversity enhancement should be the availability of suitable, non-crop, habitat, the quality of this habitat may be impacted by agricultural nutrient contamination. Excess nitrogen, in particular, may damage the diversity of these areas.

There are both direct and indirect impacts of nitrogenous fertilizers on butterfly populations. In agricultural settings it has been found that nitrogen fertilizers negatively impact butterfly populations both directly through fertilization and by atmospheric N deposition (Ockinger et al. 2006). Butterfly species that depend on plant species in nutrient poor habitats can become extirpated or extinct when nitrophilic grass species invade communities enriched by atmospheric N deposition (Weiss 1999). Indirect impacts of nitrogenous fertilizer on butterfly species include changes in oviposition and feeding choices that may negatively influence fitness in offspring.

The study of plant-insect interaction between *Plantago* spp. that act as hosts for larvae of the butterfly *Junonia coenia* reveals just such a subtle effect of nitrogen on butterflies.

Nitrogen enrichment increases N content of the plant leaves but reduces their level of chemical defense. The butterflies tend to select the high nitrogen plants for oviposition. However, the larvae feeding on these plants have decreased chemical defences against predators. The presence of additional N in the system leads the female butterflies to make a suboptimal oviposition choice, which may have a long-term impact on the viability of the population (Prudic et al. 2005).

In a separate study, nutrient enrichment of the soil increased the amino acid content of nectar in *Agrostemma githago*, leading to a potential preference of pollinators for plants growing in enriched soils (Gardener and Gillman 2001). This can lead to a redistribution of pollinators and changing plant-insect interaction dynamics. These are of particular concern due to the tight co-evolution between a number of plant and insect species. Disrupting these dynamics may have important impacts on the entire ecosystem.

Overall, the impacts of agricultural nutrient inputs on various arthropod taxa are complex and may occur through both direct and indirect mechanisms. Predatory carabid beetle species appear to benefit from increased manure application on soils but also to prefer tall and diverse grassland habitats which occur under low nutrient conditions. Spiders are not directly impacted by nutrient applications but are also dependent on non-farm landscapes for habitats and over wintering areas. Such habitats can be negatively impacted by nutrient pollution from neighboring fields. Butterflies are affected both by changing habitat conditions due to nutrient enrichment and by direct toxicity from nitrogenous fertilizers. Other indirect effects on butterflies include altered host-plant chemistry and secondary metabolism which alters oviposition and feeding preferences.

Taken together, these impacts reflect the need for minimal fertilizer and manure applications and containment of nutrients within the agricultural system. Even though some of the impacts of fertilizer appear to be positive, as is the case with increased populations of carabid beetles, it is difficult to predict their long-term effects. If population increases of predatory species are too large they may begin to have a negative influence on other beneficial species as well as on pest insects.

Vertebrates

Mammals and Birds

Population declines of farmland birds has been attributed to more intensive agricultural management (Freemark and Kirk 2001) with high rates of fertilizer use contributing to a change of farm land flora, and the resulting highly-dense crop structure limiting nesting and foraging potential for birds (Stoate et al. 2001). Although nutrients may not directly affect species richness and diversity of birds and mammals directly, the dramatic effects of monospecific plant invasions, altered microbial communities and function, reduced seed food resources and invertebrate abundance in conventional systems indirectly affect bird populations (Hole et al. 2005).

Species richness and abundance of birds is significantly greater on organically managed sites. Greater habitat heterogeneity such as that provided by non-crop habitats, permanent cover crops and less intensive management is important for maintaining bird diversity (Freemark and Kirk 2001). A variety of solutions to diffuse pollution, including conservation tillage, buffer strips and constructed wetlands could simultaneously provide some of the resources required by farmland birds (Bradbury and Kirby 2006).

5.7.2 Food Web Summary and Potential for Synergies

The previous sections have identified the impacts of agricultural nutrient inputs on the health and biodiversity of different taxa. An important consideration is the interaction between these different taxa in the larger context of the food web. A negative impact of nitrates on the biodiversity on one taxonomic group may be felt throughout a number of different taxa by affecting habitat, behavior and/or food sources. For example, earthworms and amphibian populations are both reduced in the presence of nitrates, which may then reduce available food to some species of birds. The uptake of increased quantities of nutrients by plants in ditches and fields adjacent to farmland may alter pollinator preferences and thereby the population dynamics of plants and pollinators. Invasive plants with large flowing displays have been shown to compete with native plants for pollinator services, often to the detriment of native plant fitness (Larson *et al.*, 2006). Due to the effects of nitrogen enrichment on plant community alteration, species that use these communities as habitats may be exposed to increased predation or lose important food sources. Spiders can have both positive and negative effects on agroecosystems by reducing pest pressure and increasing primary production or by preying on detritivore populations and thereby slowing the release of nutrients to the soil (Wise et al. 1999). There are numerous ways in which the different taxa in a food web depend upon and compete with each other.

An additional consideration with regards to the effects of agricultural nutrients on biodiversity is the level of synergy that negative impacts of nutrient pollution may exhibit in combination with other stressors to which populations are exposed. In the case of amphibian populations there are a number of factors that have been associated with their decline. These include the presence of endocrine disrupting chemicals and nitrates in surface water, increased UV-B radiation due to ozone depletion, and habitat loss and fragmentation. Any one of these factors may weaken individuals in affected populations, increasing vulnerability of adults to increased nutrient pollution of terrestrial systems. Unfortunately, there are very few studies that investigate the link between multiple stressors and overall fitness. Measures adopted to protect vulnerable populations should probably leave a more conservative margin of error in order to account for possible synergistic effects that exceed the impact of any given pollutant.

5.7.3 Salt Content and Management

Manure can contain considerable amounts of salt that may affect soil quality. High levels of sodium can disperse aggregates, degrade soil structure and reduce water infiltration into soil. Management of soil salinity is crucial for sustainable crop production. Saline soils can reduce crop production and limit cropping options (see Salinity Control).

Producers should follow the following guidelines when managing for salt content:

- Feed rations of livestock should be monitored for its salt content.
- Electrical conductivity (EC) should be monitored (EC is the measurement of soil salt content and is measured in deciSiemens/meter (dS/m). A change of more than 1 ds/m may indicate a soil quality problem, if the EC is more than 2 dS/m plant growth and yield may be affected, and an EC of more than 4 dS/m manure application should not even be considered.
- Monitor the sodium absorption ratio (SAR) levels of the soil (SAR is a measurement of sodium in relation to calcium plus magnesium). SAR levels above 8 can reduce soil permeability and increase the chances of the soil becoming waterlogged (AAFRD 2004).

5.7.4 Beneficial Management Practices for Applying Manure

Manure should not be applied to any land that is near a stream or any other water body. If manure is applied near a water body excess nutrients may runoff into the water and cause environmental problems (Lilly 1991). It is recommended that if the manure is being injected the landowner should leave at least 10 meters between the water body and the applied manure, and at least 30 meters should be left if it is being spread on the surface of the soil (AAFRD 2004).

When applying manure the slope of the land must be taken into consideration. The steeper the slope, the further away it must be applied from a water body (Table 14). With surface spreading the manure should be incorporated into the soil within 48 hours (Moore and Willrich 1993). It is not recommended to apply manure on top of snow or ice as the spring runoff will cause the manure to enter some form of water body (AAFRD 2004).

A vegetative buffer zone or filter strip planted in between will ensure that manure does not enter the water body (AAFRD 2004; Moore and Willrich 1993). Conservation tillage practices should be incorporated to ensure that water infiltration into the soil occurs and to minimize nutrient losses from wind and water erosion. The more crop residue left on the field the better. Crop residue will help prevent wind and water from moving the manure into undesired locations. Shelterbelts can also be used for this purpose (Lilly 1991). Manure should not be applied if heavy rain is predicted (AAFRD 2004).

Soil samples should be collected and analyzed once every three years or so to ensure that manure is not being over-applied, as this will lead to excess nutrients in the soil. Manure can be applied to the land in many ways. The most popular is solid spreading with a box spreader. The manure can also be injected in the soil using liquid injectors (Table 15).

Table 15: Minimum setback distances for surface-applied manure on forage, direct seeded crops, and frozen and/or snow covered soil

MINIMUM SETBACK DISTANCES FOR SURFACE-APPLIED MANURE ON FORAGE, DIRECT SEEDED CROPS, AND FROZEN AND/OR SNOW-COVERED SOIL*

AVERAGE SLOPE**	REQUIRED SETBACK DISTANCES FROM COMMON BODY OF WATER
Less than 4%	30 m
Greater than 4% but less than 6%	60 m
Greater than 6% but less than 12%	90 m
More than 12%	No application allowed

* AOPA Standards and Administration Regulation, Schedule 3, Tables 1 and 2

** Slope, expressed as a per cent is calculated as the (rise/run) x 100.

Source: Alberta Agriculture, Food and Rural Development. 2002. Reference Guide: Agricultural Operation Practices Act. Alberta Agriculture, Food and Rural Development.

Table 16: Types of manure and spreading equipment

(Davis et al. 1999)

Types of manure and spreading equipment.

Manure form	% Solids	Equipment
Solid	35-80	Box spreaders
Semi-solids	10-35	Flail spreaders (slingers)
Liquid slurry	2-12	Tank wagons
Liquid manure	0-7	Big guns or gated pipe
Storage pond or lagoon water	0-4	Sprinklers*, big guns, gated pipe

*may require screening or chopping

5.7.5 Crop Nutrient Requirements

The nutrient requirements of a crop will vary between the species that are planted. Some crops have the ability to uptake and remove more nutrients than others, and the landowner must be aware of this before determining application rates. Targeted yield for a given crop is an important factor in determining the amounts of nutrients to be added. Crop yield targets can be used to determine nutrient requirements and the manure application rate. To estimate targeted yield, a landowner can add 5-10 percent to the average yields over 4 years. The objective of this is to determine an accurate and appropriate manure application rate for that crop type (AAFRD 2004).

To determine crop nutrient requirements:

- Apply the manure with the highest nutrient content to crops with the highest nutrient requirements (See Table 16).
- Generally legumes do not require added N. Do not apply high N manure to legumes.
- Apply manure with the lowest nutrient content to fields closest to the manure storage site and the highest nutrient content to the furthest fields. This reduces the cost of hauling because a lower amount of manure is needed when nutrient concentration is higher (AAFRD 2004).

5.7.6 Timing of Manure Application

Manure is most beneficial when applied before the early stages of crop growth. Spring application is the most desirable for Alberta operations because high nutrient availability matches crop uptake (Table 17). However, in the spring there are usually fewer opportunities for application because of inclement weather, risk of soil compaction and the time required for other activities. Manure can also be applied in the fall. But, the longer the time between application and the stage at which the crop uses the nutrients, the higher the risk of nutrient losses (AAFRD 2004).

Table 17: Nutrient removal and uptake for various crops

(AAFRD 2004).

Crop		Yield	N	P_2O_5	K_2O
		Tonne* or kg/ha	kg/ha		
Spring Wheat	Removal [1]	2,690	67	27	20
	Uptake [2]	2,690	95	36	82
Winter Wheat	Removal	3,360	55	29	19
	Uptake	3,360	76	35	80
Barley	Removal	4,300	87	38	29
	Uptake	4,300	124	50	120
Oats	Removal	3,810	69	29	21
	Uptake	3,810	120	46	164
Rye	Removal	3,450	66	28	22
	Uptake	3,450	103	52	147
Corn	Removal	6,280	109	49	31
	Uptake	6,280	171	71	145
Canola	Removal	1,960	76	41	20
	Uptake	1,960	126	58	91
Flax	Removal	1,510	57	18	17
	Uptake	1,510	80	22	49
Sunflower	Removal	1,680	61	18	13
	Uptake	1,680	84	29	41
Potatoes	Removal	45*	143	41	242
	Uptake	45*	255	75	334
Peas	Removal	3,360	131	39	40
	Uptake	3,360	171	47	154
Lentils	Removal	1,290	68	21	37
	Uptake	1,290	103	28	86
Alfalfa		11*	103	28	86
Clover		9*	255	75	334
Grass		7*	242	63	226
Barley Silage		10*	115	34	146
Corn Silage		11*	174	59	138

[1] Total nutrient taken up by the crop.
[2] Nutrient removed in harvested portion of the crop.
* Conversion of yields to metric units assumed the following bushel weights (in pounds per bushel): wheat = 60; barley = 48; oats = 34; rye = 56; corn = 56; canola = 50; flax = 56; sunflower = 30, peas = 60; and lentils = 38.
$P_2O_5 \times 0.4364 = P$
$K_2O \times 0.8301 = K$
kg/ha x 0.8924 = lbs./ac.
tonne/ha x 0.4461 = ton/ac.

Source: *Canadian Fertilizer Institute (Modified)*

Table 18: Environmental Risks and BMPs for manure application at different times of the year (AAFRD 2004).

Season	Watch For	BMP
Winter	• Runoff that can pollute surface water. • Sensitive areas. • Sloping topography. • Saturated frozen ground with slope or no infiltration.	• Manure should go into storage. • Avoid application on frozen or snow-covered ground. • Avoid spreading on land with a history of floods or heavy runoff.
Spring	• Wet soils that are prone to compaction. • Denitrification that happens in cold, wet soils. • Excessive application that can create a pollution hazard. • Very dry soils with large cracks. • Heavy surface residue that slows the drying process of seedbeds. • Planting too soon after heavy manure application, which can create ammonia toxicity and reduce germination and growth.	• Apply to land before seeding annual crops. • Incorporate manure into soil within 48 hours of application. • Apply to well-drained soils. • Apply to pasture early to avoid trampling re-growth.
Summer	• Loss of nitrogen if there is no rainfall within 72 hours. Rain will help manure soak in but excess rain will increase runoff. • Mature crops that are not growing and don't need nutrients.	• Compost manure to reduce odour and break up clumps.
Fall	• Denitrification in cold, wet soils. • Manure that soaks into wet fields slowly; excess water will run off. • Wet soils that are prone to compaction.	• Apply to annual cropland before ground freezes and incorporate within 48 hours. • Base application rates on soil tests and crop rotation for next year. • Apply to well-drained soils.

5.8 Conclusion

For centuries agriculture has contributed to the global decline of biodiversity. There are hundreds of species in Canada that are affected by agriculture, many of these are endangered or species at risk listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Agricultural practices tend to directly affect wildlife in many different ways. The largest cause of habitat loss is from the conversion of native grasslands into croplands. This leads to a mosaic of fragmented patches of native habitat. Some species require large tracts of undisturbed native habitat, therefore agricultural areas are deemed as unsuitable for these species.

Landowners and organizations can work together to develop environmental farm plans (EFPs) that are beneficial to the flora and fauna in the area. EFPs can be implemented to help protect biodiversity and ensure that the farmland remains a sustainable ecosystem.

A number of BMPs can be combined together to preserve and create wildlife habitat in an area that is otherwise void of habitat. Shelterbelts have a number of benefits to wildlife and are most beneficial when designed with wildlife in mind. Shelterbelts are best suited for cropland areas that require a certain amount of wind protection to prevent erosion. Numerous studies have proven that shelterbelts are good habitat for nesting and cover for a wide variety of farmland animals and birds. To maximize the benefits of shelterbelts they should be planted in relation to a good food source. Shelterbelts planted for wildlife should be connected to other sources of habitat such as riparian areas and woodlots. This provides corridors for the animals to travel safely to and from other sources of habitat. Native species should be used when considering shelterbelts, to ensure that it does not upset the ecological patterns of the area. Shelterbelts should be composed of numerous rows as opposed to just a single row of trees. The larger and more complex the shelterbelt the better benefits it will provide.

Shelterbelts can be combined with other practices such as cover crops. Cover crops should be planted with a species that wildlife tend to prefer. Cover crops can be utilized by birds and animals for food, nesting and cover. Shelterbelts planted nearby can provide a good source of cover for birds and wildlife utilizing the cover crop. Winter wheat provides a number of benefits when planted as a cover crop. Winter wheat produces enough plant residues in the spring that waterfowl can use it as nesting habitat. Pintails are just one of the many species that benefit from these crops.

Cover crops can be used as a rotational crop or as a green manure crop. Turning the crop into green manure adds organic material to the soil making it more fertile and productive. Green manure will benefit a number of soil related arthropods as well.

Improved cropping systems can be implemented to lessen the impact of cropping practices on wildlife. A number of cropping practices directly affect wildlife while others have an indirect effect. Haying directly affects wildlife as the nests of birds are crushed or the females are killed while sitting on the nest. The use of flushing bars can be used to provide the adults enough time to get out of the way of the cutting blades and wheels. A better practice is to delay the haying until nesting season is over, around July 15th. This provides birds adequate time to finish nesting and hatch their broods.

Conservation tillage is another practice that can be used to protect biodiversity in an agroecosystem. Not only does conservation tillage protect against soil erosion, but it provides a number of benefits to wildlife as well. The more crop residue that is left after the harvest season the better source of habitat it becomes. Stubble is most beneficial when it is cut to a height that provides adequate cover for birds and wildlife. Many beneficial insects are found in no-tillage systems and are needed for the breakdown of organic materials and to keep crops pests in check.

Grassed waterways can be used in relation to conservation tillage to compound the erosion benefits. Grassed waterways provide a good source of cover for wildlife; however, they can become “sinks” if not managed properly. This can also be considered an ecological trap if it is a small patch of unconnected habitat. Predators can easily seek out prey residing in these areas if the tracts are too small in size. The larger the grassed waterway the more beneficial it will become. Grassed waterways can also be used in unison with shelterbelts to maintain diversity across the fragmented landscape.

Landowners should strive to maintain biodiversity across agricultural regions of Canada not only for better crop production and increased revenues, but also from an ecological standpoint. Every landowner should adopt an environmental farm plan that will work best with their method of farming. Conserving wildlife on agricultural lands can be tough and costly at times, but without conservation agricultural areas may become ecological deserts if not managed properly.

5.9 Gaps in Literature and Further Research Needs

During the process of conducting research for this project, some gray areas were found in which there was not enough adequate research completed on the BMP to be able to accurately develop a standard. Manure application was one of these areas. The application of manure to land does not really have any direct affects on biodiversity other than the fact it will affect water bodies if the manure enters the water. Manure benefits the biota of the soil; however, there are no physical effects that can directly harm wildlife or their habitat.

There was little scientific literature pertaining to soil erosion and salinity control management with respects to biodiversity. Sure some of the erosion control structures such as grassed waterways provide a little habitat, but there is no real justification that preventing erosion directly benefits biodiversity. There was little reference material on the benefits of salinity control to biodiversity. Some species actually thrive in saline areas and alkali sloughs (the endangered Piping Plover for example).

Further areas of research could include the actual effects of manure application on biodiversity. Studies could be conducted in areas that receive a large amount of manure application, and to determine what species are affected and how they are affected. With respect to salinity control further research could be conducted on what species use the saline areas and how they can be properly managed.

Another area that could be researched more is how certain habitat (whether natural or man made) acts as a “sink”. These ecological traps sometimes have a great impact on the resident wildlife. Shelterbelts may act as sinks if they are not constructed properly.

Summary of Soil Management BMPs

BMP	Benefits to Biodiversity	Quantitative Effects	Descriptive Effects
Shelterbelt Establishment	• Used by birds, mammals and insects for cover, food and nesting	• 64 species of birds use shelterbelts during the breeding season and a further 68 migratory species utilize them throughout their migration	• Maximum benefits achieved when belts contain more than 10 rows
Conservation Tillage	• Leaves crop residue on the field allowing birds to nest, conserves moisture, prevents erosion, increases organic matter	• Nest density has been found to be 7.5 times greater on no-till fields compared to conventionally tilled fields, up to 50 bird species have been documented to use row crops throughout the breeding season	• No-tillage practices can increase the diversity of arthropods and earthworms as well as predatory insects such as spiders, mites and carbids
Strip Cropping	• Prevents erosion, provides habitat for birds and wildlife	None Available	• Beneficial when perennial forages are planted between the strips of crop
Crop Rotations	• Prevents disease and insect outbreaks, conserves soil quality, prevents weeds from becoming established	None Available	None Available
Cover Crops	• Prevents erosion, provides nesting habitat for birds, food for wildlife	• Fall seeded crops may support 1 nest for every 10-15 acres, whereas conventional crops may only have 1 nest for every 150-200 acres	• Cover crops have been know to increase soil cover, reduce erosion, fix nitrogen, add organic matter, improve soil structure, break up “hard pan” and reduce nitrogen losses •
Grassed Waterways	• Prevents erosion, provides nesting habitat, acts as corridors	• In Iowa, 48 species were documented using grassed waterways, opposed to the 14 species in surrounding croplands	• Birds will use waterways for nesting, small mammals for loafing and cover, and ungulates will utilize it as a forage resource
Vegetative Filter Strips	• Prevents nutrient runoff into waterbodies, provides nesting habitat for birds and cover for wildlife	None Available	• The use of mutliple species has greater benefits, trees could be included to suit the needs of birds that prefer to nest higher off the ground
Wooded Fencerows	• Reduce erosion, provides perches for birds, cover and food	• A study conducted in Michigan found that 16 species of birds nested in	• Song sparrows, American robins, northern cardinals, red-winged blackbirds,

		herbaceous and woody fencerows; nest density was 43.5 nests/ha	gray catbirds, brown thrashers, northern flickers, and ring-necked pheasants were the most frequent nesters in fencerows
Salinity Control	• Healthier vegetation, more habitat for birds and wildlife	None Available	None Available
Manure Land Application	• Increases organic matter, more insects and arthropods, better soil productivity	• One gram of healthy soil can contain in the region of one billion organisms including 5 million bacterial cells, 10,000 protozoa, 200m of fungal hyphae and around 100 nematodes, as well as an abundance or earthworms and arthropods	• The application of manure adds organic matter to the soil thus helping sustain arthropod and nematode populations to maintain a healthy soil profile

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6.0 Riparian Areas and Water Management

6.1 Introduction

Study and understanding of riparian area function and structure is relatively recent, but an ever expanding field of interest and environmental concern. Thus, because it is a young and ongoing area of study, a single precise ecological definition for the term riparian area is not evident. However, it is apparent that riparian areas are defined by their location in the landscape, hydrology, and sometimes vegetation and soil type. It also follows from the range of studies and definitions that riparian areas are the transitional land between terrestrial and aquatic ecosystems that are both significantly influenced by the surface and subsurface hydrology associated with a waterbody, and significantly influence exchanges of energy and matter with the aquatic system. They connect a stream, lake, wetland, or estuarine-marine shoreline with their adjacent uplands.

They are often superficially defined by the zone of vegetation and soils that are strongly influenced by the hydrology of the adjacent aquatic system. However, they are clearly a product of water and material interactions, receiving water from groundwater discharge, overland flow, and flow from adjacent surface waterbodies (Committee on Riparian Zone Functioning and Strategies for Management). Water management and upland water runoff can, therefore, be discussed within the context of riparian areas and riparian management.

An important feature of this definition is the concept of riparian areas having gradients in environmental conditions and in functions between uplands and adjacent aquatic ecosystems. This feature leads to two points which should be bore in mind when considering the applications and scopes of this review and, ultimately, this program (i.e. the development of environmental standards within the agriculture sector):

1) When considering the extensive variety of ecoregions, jurisdictions, and agro-environmental settings within Canada it will be important to recognize that the extent and boundaries of the riparian zone are dependent on environmental factors (surface and subsurface hydrology, soil, vegetation, topography, climate). The gradient between a water body and the adjacent uplands, which defines the riparian zone, is dependent on these environmental factors through time. Just as the environmental factors will vary spatially (across the ecoregions, provinces and agro-environmental settings in Canada) and temporally, so will the gradient and definition of the riparian area. Thus, in this review of how agricultural practices affecting riparian areas and water resources will impact biodiversity, findings from studies may be applied to a wider theme or geographic area than the original site-specific conditions. Yet, it will be vital during the development of beneficial management practice standards that the standards account for some level of site specific variability in both the definition of the riparian area and the changes, benefits, and functions gained from the implementation of a standard practice. A summary and examples of environmental and functional differences within riparian

areas is taken from Bellows 2003 (Appendix A1: *Recognizing Regional and Environmental differences within Riparian Areas*). These factors should be considered when integrating site-specific practices.

2) When discussing riparian areas and water management in the context of biodiversity it is again key to consider riparian as a gradient in functions between uplands and aquatic ecosystems. Riparian functions will influence wetlands and adjacent aquatic and upland environments within the landscape. In turn, practices impacting upland water use and runoff and riparian functions in upland, aquatic, and wetland environments will all have significant implications on the biodiversity of the associated landscapes and aquatic environments.

It may then be argued that special emphasis may be placed on the development of beneficial practices that impact riparian structure or function directly or indirectly. Within North America, traditional agriculture is probably the largest contributor to the decline of riparian areas (Committee on Riparian Zone Functioning and Strategies for Management). Enhancing riparian areas at any level of the environmental or functional gradient that they compose may have broad implications towards enriching biodiversity at many levels throughout the landscape. In addition, in the current time and state with specific emphasis on the prairie regions, riparian areas are often the primary or lone source of natural vegetation and habitat within the agricultural landscapes of Canada typified by intensive cropping or livestock systems. Likewise, they may be the most prominent source of biodiversity and offer a high potential for biodiversity enhancement within these landscapes. While they typically comprise a relatively small area within the landscape, riparian areas are disproportionately important to biodiversity.

6.2 Buffer/Filter/Vegetation Strips: Establishment, Conservation and Restoration

The term riparian buffer is a term referring to a management area and not an ecological term defining a part of an ecosystem or landscape. Riparian buffers are an area within the riparian gradient where perennial vegetation is managed primarily to provide conservation benefits such as filtering runoff and improving habitat. Several other management terms such as streamside management zone, stream protection zone, riparian management area, riparian filter strip, and vegetation filter strip are commonly used but, with slight variation, they all pertain to this riparian buffer concept.

6.2.1 Impact on Biodiversity

Riparian buffer systems are effective at retaining and removing nutrients, pollutants, and sediment from overland and subsurface flow within cropland and livestock settings. Improved water quality and pollutant removal from soils and soil water has great implications on the ecosystem's food web and biodiversity. In agricultural field boundaries, biodiversity was has been found to be highest under low nitrogen and reduced disturbance regimes. More species could be obtained from widening buffers versus lengthening them. Riparian areas can function as habitat corridors and may compensate for the negative impacts associated with fragmented agricultural landscapes. It is important to maintain heterogeneity in riparian strips in order to maintain high wildlife diversity. Shrubby riparian strips had a higher diversity of herpetofauna, whereas a higher diversity of small mammals was found in herbaceous and wooded riparian strips. Riparian buffers may act as a pool for small mammal populations. Grassland birds do not benefit from shrubby and woody riparian buffers, whereas other bird species are abundant on those buffer strips.

6.2.2 Landscape

On the landscape level, riparian buffers are widely prescribed to improve and protect water quality in agricultural landscapes within both prairie and forested regions (Dosskey 2005). They intercept field runoff, retain nutrients, restrict and slow soil and channel erosion, and retain pollutant loads before it reaches the aquatic system. Water quality and runoff concerns span beyond biochemical and geochemical issues, as improved water quality and pollutant removal from soils and soil water has great implications on the ecosystem's food web and biodiversity at all levels (genes, species, populations, and communities) within the landscape. Moreover, excess nutrient inputs from fertilizer and herbicide application, soil erosion, and manure and wastes can be detrimental to soils, terrestrial ecosystems, and aquatic ecosystems through direct application and water runoff. The ability of riparian buffers, within specific environmental settings, will have great implications on biodiversity enhancement within the terrestrial and aquatic systems of the landscape.

Phosphorus inputs into aquatic systems cause eutrophication, effecting turbidity, oxygen levels, and primary production, which all directly alter biotic processes, food webs, and ultimately causing detrimental effects to the systems biodiversity. Likewise, nitrogen pollution is equivalent to terrestrial "eutrophication" (5). Plant species diversity has a significant negative correlation with soil nitrate (5-REAP citation) and fertilization can increase the dominance of non-native species (141).

6.2.2.1 Nutrients and Nonsource-point Pollutants

Buffer vegetation, including woody plants, may be effective in removing soluble nutrients from surface runoff and subsurface water by improved infiltration into the buffer soil (Vought et al., 1994 in (Lee 2003)) and subsequent uptake by the vegetation. Nitrogen can be removed through uptake and storage in vegetation, microbial immobilization and storage in the soil as organic nitrogen or denitrification, the microbial conversion process of nitrogen to gaseous forms (Mander et al. 2005). Native Warm season grass stands have high biomass carbon and soil nitrogen uptake levels (Wedin and Tilman 1996). In agricultural field boundaries, biodiversity was found to be highest under low nitrogen and reduced disturbance regimes (Schippers and Joenje 2002a; Schippers and Joenje 2002b; Zechmeister et al. 2003).

In a series of studies within agriculturally developed eastern-temperate forests of Georgia, USA, planting riparian buffers structured either with 3 vegetation zones or an entire perennial-grassed buffer showed significant reductions of nutrient and pollutant loads in the adjacent stream water and nearby ground water (Durham 2003). The study sites received nutrient and various pesticide and fertilizer sourced pollutants from both nearby annual crops and large-scale livestock facilities. Riparian buffers were planted with 3 zones: Zone 3 was a grassy edge that sits next to the field, zone 2 was a managed forest buffer that was situated further from the field, and zone 1 was a permanent forest along the stream. These studies showed that the restored riparian wetland buffer retained or removed at least 60 percent of the nitrogen and 65 percent of the phosphorus that entered from the adjacent manure application site. This is the first time that a study of a restored riparian buffer has shown that the retention of phosphorus was as high or higher than nitrogen retention (Durham 2003). Nutrient uptake by the pure grass buffer was limited, with uptake of nitrogen at almost 45 percent and phosphorus at nearly 20 percent. This research indicates that grass buffers do not work well as a sole buffer against nitrogen and phosphorus runoff in eastern temperate zones, but work better when combined with other buffer systems such as forested buffers.

During the 3-year study, the three-zone riparian buffer was also effective at reducing the amounts of two herbicides, atrazine and alachlor, that entered the shallow groundwater and surface runoff. In contrast to the nitrogen and phosphorus results, the grass filter strip received higher amounts of herbicides and provided a higher rate of removal. Thus, the three zone buffer system was effective at reducing herbicide concentrations to below detectable levels and in substantially reducing nutrient amounts.

Most studies have reported effectiveness for nutrient removal by riparian buffers of various widths, which were dependent on site specific environmental conditions (Parsons et al. 1995 in (English 2003)). From the results of four years of experiments with simulated rainfall on buffers of 6, 12, and 18m width, it was concluded that nitrogen losses could be reduced by 47 to 100% and P losses from 22 to 89% (Patty et al. 1997 in (English 2003)). This work also indicated that the buffers would be effective under intense rainfall and runoff events. Results showed that 64 to 74 % of applied nitrogen and 58 to 69% of applied phosphorus were removed by 4.6 and 9.1 m buffers, respectively (Dillaha et al. 1986 in (English 2003)). Removal was more effective on cropland than feedlots however. Following the assumption that most phosphorus is sediment bound, it was expected that phosphorus reductions would mirror sediment removal. Surprisingly, this study found higher levels of soluble phosphorus in the outflow. It was suggested that previously trapped manure continues to break down in the buffer and can release soluble phosphorus to runoff water as it passes through the buffer. These studies may imply that additional site-specific management, such as riparian fencing or grazing management to limit manure inputs in and around the riparian zone, may be required in feedlot/grazed settings to eliminate nutrient runoff and inputs into aquatic systems from retained manure.

In an Iowa study conducted by (Lee 2003), a multi-species buffer was established to determine its effectiveness in trapping sediment, nitrogen, and phosphorus from cropland runoff during natural rainfall events. Plots were installed in a previously established buffer and a cropland source area was paired with either no buffer, a 7.1 m (23 ft) switchgrass (*Panicum virgatum* L. cv. Cave-n-Rock) buffer, or a 16.3 m switchgrass/woody buffer (7.1 m swithgrass/9.2 m woody). The switchgrass buffer removed 95% of the sediment, 80% of the total-nitrogen (N), 62% of the nitrate-nitrogen ($[NO_3]$-N), 78% of the total phosphorus (P), and 58% of the phosphate-phosphorus ($[PO_4]$-P). The switchgrass/woody buffer removed 97% of the sediment, 94% of the total-N, 85% of the $[NO_3]$-N, 91% of the total-P, and 8o% of the $[PO_4]$-P in the runoff. There was a significant negative correlation between the trapping effectiveness of the buffers and the intensity and total rainfall of individual storms. While the 7 m switchgrass buffer was effective in removing sediment and sediment-bound nutrients, the added width of the 16.3 m (53.5 ft) switchgrass/woody buffer increased the removal efficiency of soluble nutrients by over 20% and increased sediment removal from >92% to >97%. Similar or even greater reductions might have been found if the 16.3 m buffer had been planted completely to native warm-season grasses (Lee 2003). In this buffer, combinations of the dense, stiff, native warm-season grass and woody vegetation improved the removal effectiveness of the nonpoint source pollutants from agricultural areas.

In summary, the switchgrass and switchgrass/woody buffers reduced surface discharge of runoff and mass transport of sediment and nutrients from the crop field to the stream. During one rainfall event the difference in removal of sediment was 24% less in the narrower buffer than wider switchgrass/woody buffers. These results would suggest that the narrower switchgrass buffer alone is effective in removing sediment and sediment-bound nutrients, but that the wider switchgrass/woody buffer significantly increases removal of soluble nutrients in all but the most intense storm events (>75 mm [hr.sup.-1]). The results from this study suggest that, while all buffers were effective in removing nutrients and sediment, there are major functional differences between narrow grass filters and wider mixed grass and woody plant buffers. Buffer width should be taken into great consideration and selection should be based on the problems of each particular site. These points may also imply that while many examples of riparian buffer systems prove effective at reducing and removing nutrient and sediments from runoff in croplands, there may be room for significant improvements by further increasing buffer widths.

Evaluations of the efficacy of riparian buffer zones done in croplands have yielded similar results, but somewhat lower retention rates, than trials conducted using fertilized plots in summer fallow (English 2003). This could be due to a possible overload effect or reaching a retention capacity level in the cropland riparian buffers, which presumably may have receive nutrient and pollutant loads annually over a longer period than experimental fertilized plots. If true it may be inferred that, while buffers can retain up to 100% of the nutrients from ground water and runoff, they may reach a retention capacity. Beneficial cropping and livestock management practices could work synergistically with riparian buffers to decrease the nutrient and pollutant loads on the buffers and enhance their capacity to benefit water, soils, and biodiversity.

Study of riparian buffer systems have shown they are very effective at retaining and removing nutrients, pollutants, and sediment from overland and subsurface flow within cropland and livestock settings. Whereas on-site BMP's reduce pollutant transport from the agricultural sources in many cases, they are not adequate to meet national water quality goals in other situations (Clausen and Means, 1989 in (Lee 2003)). Once again this supports the notion that on-site BMP's should be used synergistically with riparian buffers to attain adequate enhancement value to biodiversity.

6.2.2.2 Erosion

Just as nutrient and pollutant loads can be detrimental to biodiversity by altering habitat, food webs, and biotic processes, soil erosion and stream bank and channel alterations effect terrestrial and aquatic biota. Vegetation provides general protection from erosion in the buffer zone itself, but it also acts to decrease the velocity of water flowing over it from a field or other pollution source (English 2003). This reduces the sediment-carrying capacity of the flow and sediment is trapped and held by the buffer (Robinson and Ghaff. 1996 *in* (English 2003)).

Research has shown that vegetated buffer zones of various structure provides high sediment trapping efficiencies when the vegetation was not submerged by the runoff water (Niebling and Alberts. 1979 *in* (English 2003)). However, the effectiveness can decrease when runoff flow increases, to a point where completely submerged vegetation is almost ineffective at removing sediment. Moreover, it has been suggested that on slopes greater than 4%, buffer strips would be unable to provide significant infiltration (Dillaha 1988). On grassed test plots with 1% slopes, Wilson (1967 in (English 2003)) found that 3, 15.2, and 122 m. strips were needed to remove the largest proportions of the sand, silt and clay fractions, respectively. However, it has also been noted that much wider buffers are needed to remove significant amounts of clay- sized particles (English 2003). Soil and local topography conditions within the local watershed should therefore all be factored into buffer design, implementation and effectiveness.

The majority of research and riparian management programs seem to focus and put a significant amount of weight on the buffer width. However, experiments with grassed buffers of varying height and width, suggested that height is more important than the width of a buffer (Pearce et al. 1997 *in* (English 2003)). Simulated erosion from feedlot and cropland sources indicated that 4.6m and 9.1m grassed strips could remove 81% and 91% of sediment respectively from feedlot runoff and 63% and 78% respectively from cropland runoff. While variations in effectiveness were also attributed to the incoming sediment load, and the flow rates, the buffer features which most influenced effectiveness were vegetation height and density and filter slope (Dillaha 1988). Again, these studies have shown that site specific environmental conditions must be taken into account for buffer design and to ensure buffer effectiveness and functioning so that conditions detrimental to biotic communities and biodiversity are minimized.

Riparian vegetation facilitates not only the removal of suspended sediments, but also associated nutrient content from surface runoff (Peterjohn and Correll, 1984; Lowrance et al., 1988 in (Lee 2003)). It is important to note that plant nutrients, as components of suspended organic matter or attached to eroding mineral particles, can be removed as sediment. It is widely assumed the dominant phosphorus fraction is adsorbed or chemically bound to soil minerals. Thus, by trapping sediment and slowing soil erosion, riparian buffers again act to retain nutrients and prevent overloading into aquatic systems, while retaining nutrients in terrestrial soils. Dissolved plant nutrients, notably nitrate and dissolved mineral phosphorus, can only be removed by infiltration into a buffer zone (English 2003).

6.2.3 Populations and Species

One feature that riparian buffers offer towards biodiversity enhancement that should not be understated is their capacity to create wildlife habitat. Riparian areas with appropriate healthy buffers may also function as habitat corridors that may compensate for the negative impacts associated with a highly fragmented agricultural landscape (Noss, 1983; Fahrig and Merriam, 1985).

Plant species diversity has been found to increase with a corresponding increase in buffer width (Ma et al. 2002) and elongated patches are less likely to include interior species. Thus, more species could be obtained from widening buffers versus lengthening them.

6.2.3.1 Insect Communities

Few studies exist which examine the effects of agricultural practices on insect or arthropod populations, nor how specific beneficial practices such as riparian buffers impact insect habitat and biodiversity. However, being the largest, most successful, and diverse group of animals on the planet, insects are vital components of ecosystems and biodiversity as they perform essential ecological functions and support various other wildlife species as a major food source.

For example, as it has been shown in boreal forest studies (Whitaker 1999), many songbird numbers are influenced by the availability of insect prey and it is likely that this may be true to other ecosystems. Whitaker *et al.*(2000) concluded that, in western Newfoundland, significantly greater numbers of insects, in particular large-bodied flying insects, were found in riparian buffer strips than in undisturbed lakeshores due to the fact that the buffer strips not only provided habitat, but acted as windbreaks which collected airborne insects from the landscape. This phenomenon has also been widely documented in agricultural landscapes (Whitaker 1999) and shown to be common to a variety of types of windbreaks, including walls, wooden fences, artificial windbreaks, hedgerows, and shelterbelts of tall trees (Lewis 1965, 1967, 1969, 1970; Pasek 1988 *in* (Whitaker 2000)). A concurrent parallel study conducted at the same sites investigated the effects of riparian buffering on breeding bird assemblages and found that the riparian buffers also produced high numbers of insectivorous birds likely in response to prey availability. Thus, in this case and likely in agricultural settings as well, riparian buffer strips concentrate flying insects and as a result represent high-quality feeding habitat for those aerial foraging and foliage-gleaning insectivorous bird species that are not restricted to specific habitat types absent from buffer strips.

Other insectivorous wildlife, such as bats (Chiroptera), spiders (Arachnida), and dragonflies (Odonata), which forage heavily on localized concentrations of flying insects along forest/treed edges, may also treat buffer strips as high-quality habitat patches (Helle and Muona 1985; Rachwald 1992; Clark et al. 1993; Wunder *in* (Whitaker 2000). However, caution must be exercised in extrapolating local increases in abundance and habitat quality to the landscape or population level or to alternative ecoregions.

Beetle assemblages in particular may be important components of agriculturally fragmented landscapes as they are the most numerous group of insects, thus a key component of ecosystem biodiversity, as well as being predators of many agricultural pests. While very little research has been conducted on beetle communities and species diversity within agriculturally-based settings, French *et al.* (2001 & 1999) have suggested that many species over-winter in grasslands and riparian zones and disperse from natural habitats and colonize adjacent and nearby fields including annual crops such as wheat.

In a study of macroinvertebrate species diversity and richness in streams running through agricultural and urban areas of Washington State, Moore and Palmer (2005) found that macroinvertebrate richness was strongly related to land use, with agricultural streams exhibiting the highest macroinvertebrate diversity over buffered and non-buffered urban areas. The agricultural headwater streams in this study were not only more diverse than the urban headwaters, but their levels of macroinvertebrate diversity were high compared to other published estimates for agricultural streams (Moore 2005). They suggested that these higher richness values may be due to widespread use of “best management farming practices” (BMP’s), including no-till farming and the implementation of woody and herbaceous riparian buffers.

Insect biodiversity within agro-ecosystems can not be overlooked and understanding their presence and role in these landscapes will be essential to enhancing biodiversity through best management practices.

6.2.3.2 Small Mammals and Herpetofauna

Maisonneuve and Rioux (2001) carried out a study in southern Québec where abundance, composition and diversity of herpetofauna and small mammal communities were compared between three types of riparian strips: herbaceous, shrubby, and wooded. The generalist species' cinereus shrew (*Sorex cinereus)*, meadow jumping mouse *(Zapus hudsonius)*, northern short-tailed shrew *(Blarina brevicauda)*, and american toad *(Bufo americanus)* were abundant in all three types of riparian strips. The deer mouse *(Peromyscus maniculatus)*, Smoky Shrew (*Sorex fumeus)*, Southern Red-backed Vole (*Clethrionomys gapperi)*, and northern leopard frog (*Rana pipiens)* were associated more closely to wooded strips, whereas the wood frog *(Rana sylvatica)* was captured mostly in shrubby strips. The abundance of small mammals and herpetofauna increased with complexity of vegetation structure. Small mammal diversity was higher in herbaceous and wooded riparian strips, whereas the herpetofaunal community was more diverse in shrubby strips. It is also important to note that the northern leopard frog, a species found across Canada and a species of concern in the western provinces, was closely associated with wooded buffer strips.

This study would then indicate that maintaining woody vegetation and a diverse vegetation structure in riparian strips should increase abundance and diversity of wildlife within agricultural landscapes where increasing development pressure is presently contributing to the conversion of such habitats to herbaceous strips (Maisonneuve 2001). However, once again, the regional and environmental conditions should be examined when considering such a statement about habitat and wildlife benefits from a beneficial practice, in this case the structure of the riparian buffer. Species associated with grasslands and the prairies for example may not benefit from a riparian buffer composed of woody or shrubby vegetation. On the other hand, a species of concern in Saskatchewan and Alberta, the northern leopard frog, may benefit from buffers that have a woody component. In the regions of these provinces where woody riparian vegetation is naturally/historically found (e.g. valleys, lakes, pothole regions, and parklands) similar structured buffers may provide key habitat and be beneficial for biodiversity within the landscape.

Another key factor that this study clearly shows is the importance of maintaining a diversity of riparian strips in order to maintain high wildlife diversity within agricultural landscapes. Shrubby riparian strips had a higher diversity of herpetofauna, whereas a higher diversity of small mammals was found in herbaceous and wooded riparian strips.

Moreover, species considered as habitat specialists and intolerant to habitat modifications were present in all of the habitats studied. Thus, all three types of riparian strips were important for different species or groups of species (Maisonneuve 2001). In the highly fragmented landscapes of agriculture, riparian strips often represent wildlife corridors between remaining habitat islands (Wegner and Merriam, 1979; Fahrig and Merriam, 1985; Henderson et al., 1985; La Polla and Barrett, 1993; Burbrink et al., 1998 *in* (Maisonneuve 2001)).

A concern to farmers with regards to habitat refuges such as riparian areas has been that in efforts to enhance biodiversity within the landscape these habitats that are next to croplands support pest populations. From the Maisonneuve and Rioux (2002) study, there was no indication that, unless regularly burned or mowed, riparian strips can become shelters for agricultural pests. Even if the abundance of small mammals increased from herbaceous, to shrubby and wooded riparian strips, this was essentially due to insectivorous species or rodent species restricted to wooded habitats and not considered as pests ((Maisonneuve 2001). Rather, abundance of potential pest species was reduced by the presence of shrubs and trees in riparian strips. This is in agreement with similar studies in which the most abundant small mammal species generally inhabited forested habitats or pastures and were not considered as pest species (Dambach, 1948; Yahner, 1983 *in* (Maisonneuve 2001)).

Not only are pest species less abundant in riparian strips with woody vegetation, the abundance of insectivore species is also greater. As discussed earlier, riparian buffers can host enhanced numbers of insects and it would follow that insectivorous taxa would also be abundant in these areas so as to take advantage of the food source. The diverse vegetation structure of riparian buffers may also contribute to control of insect pests, as these insects would spend part of their life cycle in riparian habitats. In the Maisonneuve and Rioux (2002) study, total mammalian and amphibian insectivore numbers in wooded riparian strips were 2.4 times greater than in herbaceous strips. The presence of linear habitats like wooded riparian strips may then also favour bats (Verboom and Huitema, 1997 *in* (Maisonneuve 2001)).

Chapman et al. (2002) examined the differences in small mammal communities associated with vegetative buffer strips adjacent to row crops of corn or soybeans (a farm arrangement likely to occur if farmers are required to fence out stream areas from grazing) and with riparian areas on grazed pastures in southwestern Wisconsin. Both the species richness and total small mammal abundance were greatest on the buffer sites, with an average of 3-5 times as many animals being found on the buffer sites compared to pasture sites.

Although previous studies have found that prominent land use practices in the agricultural landscape, such as cultivated and hayed fields support a limited small mammal community (Fleharty and Navo, 1983; Sietman et al., 1994; Marinelli and Neal, 1995 in (Chapman 2002)), the value of pastures, particularly in riparian areas, remains unknown. The cyclical growth pattern that characterizes the pastures in this study are similar to those found on hayed fields. Results from a previous study on hayed fields (Sietman et al., 1994 in (Chapman 2002)) suggests that habitats subject to this type of disturbance do not support an extensive small mammal community, likely because hayed fields do not have the temporal habitat stability necessary to support an extensive small mammal community. The meadow vole was the most abundant species in pastures, probably because this species is strongly associated with grassy, moist habitats typical of these areas (Jackson, 1961; Getz, 1970 in (Chapman 2002)). Buffer strips, on the other hand, appear to support a particularly rich and abundant small mammal community. There were more animals, species and a different community of small mammals (including western harvest mice, *Peromyscus* spp., and short-tailed and masked shrews) on buffer sites compared to pasture sites. These results are probably because, in part, buffer sites combine small mammal communities using crop fields and buffer strips. It is known that cropland can support certain small mammal communities such as those dominated by *Peromyscus* spp. in Northeastern US croplands (Furrow, 1994; Marinelli and Neal, 1995 in (Chapman 2002)). Alternatively, buffer strips provide extensive, undisturbed cover along stream areas, which can satisfy habitat requirements for a relatively large variety of small mammals.

Buffer sites may offer this relatively high abundance of small mammal biodiversity because buffer strips and crop fields each provide important resources in close proximity to one another (e.g. crop fields provide access to food and buffer strips provide nesting habitat and protection from predators). Some evidence for this was found in the Chapman study, as *Peromyscus* spp. (highest abundance in croplands) and western harvest mice (highest abundance in riparian pastures) were captured in both buffer strips and crop fields and may have been using the different habitats in conjunction with each other.

Furthermore, total small mammal abundance was greater near the stream than away from the stream, regardless of farm management practice. This would suggest that small mammal abundance may also be related to characteristics other than vegetation structure. For example, meadow jumping mice were captured almost exclusively in stream areas, while meadow voles and short-tailed shrews were also captured more frequently in stream areas. It is certainly reasonable that such species may form niches within specific habitat types such as wetland edges. Riparian buffers can benefit biodiversity by providing habitat requirements for both species associated with specific niches within wetland/riparian habitat and a compliment of other species able to exploit the preserved riparian habitat in conjunction with the adjacent uplands.

In addition, when small mammals experience regionally high population densities, individuals of some species may be crowded out of preferred habitat into lower quality habitats (Getz, 1985 in (Chapman 2002)). Thus, riparian buffers may act as a pool for small mammal populations, which can then move into pasture and cropland during high population density years, supporting biodiversity throughout the local landscape.

6.2.3.3 Birds

A study connected to the Chapman *et al*. (2002) small mammal study was conducted by Renfrew and Ribic (2001) under the same site conditions. However, Renfrew and Ribic (2001) compared the grassland bird community in riparian areas, examining the communities found within grazed riparian pastures and rowcrop fields with 10-m-wide ungrazed buffer strips located along a stream. Bird species richness, species dominance, and density did not differ among land use types. However, grassland bird species which were identified as being of management concern in Wisconsin [Savannah Sparrow (*Passerculus sandwichensis* Gmelin), Eastern Meadowlark (*Sturnella magna* L.), and Bobolink (*Dolichonyx oryzivorus* L.)] were found on pastures but very rarely or never occurred on buffer strips. These species are not considered species of concern in any of the Canadian provinces.

Other bird species (i.e. those not strictly considered grassland species) were abundant on the buffer strips. Furthermore, bird density, which was highest overall in the buffer strips, was related to vegetation structure, with higher densities found on sites with deeper litter (buffer strips had the greatest litter depth and row crops had 0 litter depth). Positive correlations between bird density and litter depth have been found in previous studies of similar bird communities (Sample 1989, Wiens and Rotenberry 1981 in (Renfrew 2001)).

The absence of grassland bird species within buffer strips is consistent with other findings, as Holmquist (1991 in (Renfrew 2001)) rarely found these species on ungrazed herbaceous riparian buffer strips located within grazed pastures in Pennsylvania. In contrast, ungrazed grassed waterways of greater width have been shown to support breeding grassland birds (Robert Howe, Wisconsin Dep. Nat. Resources, 1999, unpubl. Report *in* (Renfrew 2001)), including species common to western Canada such as Western Meadowlark (*Sturnella neglecta*), Sedge Wren (*Cistothorus platensis)*, Dickcissel (*Spiza americana* Gmelin), and Grasshopper Sparrow (*Ammodramus savannarum)* (Bryan and Best 1991 *in* (Renfrew 2001)). However, grassed waterways are non-riparian grassy strips located in upland crop fields, rather than in lowland areas along aquatic systems. Linear grassland habitats, such as road ditches, of similar width to the buffer strips and also surrounded by crop fields, can support grassland bird species such as those mentioned (Warner 1992, Camp and Best 1993 in (Renfrew 2001)). Buffer strips in the Renfrew and Ribic (2001) study may have been unsuitable for grassland species because of their dense, tall vegetation, steep streamside slopes, potential for flooding, limited width, location within unsuitable row crops, the presence of scattered shrubs, or a combination of these factors.

From this study it is clear that pastures provided better habitat for grassland bird species of management concern than 10-m-wide buffer strip/crops in the northwestern United States. However other species did exploit the buffer habitat, as overall bird density was highest in these areas.

6.2.4 Conclusion

Though these studies illustrate that riparian buffers in agricultural settings can be a source of biological diversity within the landscape, they do not provide habitat for all biota that would be found in natural settings within these regions. Moreover, the specific examples of relatively high species abundance in riparian buffers may be due to specific environmental conditions that would not necessarily apply to other regions. For example, results from Renfrew and Ribic's (2001) study which looked at grassland birds suggested that buffer sites were of little value for that group of species (Renfrew 2001). Grassland birds have been declining faster and more consistently than any other avian guild in North America in the last 30 years (Knopf 1995 in (Renfrew 2001)). So without considering the local environmental conditions and the historical or natural communities which would be found in a specific landscape, implementing a BMP such as riparian buffers may not enhance biodiversity or may not benefit key species or communities in that ecosystem.

In the agricultural landscape it may be that, while implementing one practice such as riparian buffers provides habitat and a source of biodiversity, enhancing biodiversity to sufficient levels throughout the entire landscape will be a difficult challenge because the system has become fragmented. This often leaves ecological components separated, each affected differently by different land use practices and being further complicated by the fact that some species require or use more than one habitat type. The challenge, once again, may be finding the synergistic relationships between BMPs, which work towards increasing natural habitat and decreasing fragmentation.

6.2.4.1 Regional/Geographic Applicability

The scientific studies reviewed have an apparent bias to not only US locals, but towards eastern temperate zones of North America. Most of the Canadian-based studies are also located in eastern Canada within the eastern boreal shield and mixed wood ecozones. When considering riparian areas across the country, many of the issues related to biodiversity protection and enhancement may be consistent and widely applicable. Those being land and buffer management practices that effect the general principles and ecological trends presented above, such as nutrient, pollutant, and sediment retention which maintains or improves aquatic habitat health (i.e. water quality, stream functions and morphology, and primary production); and creating or enhancing riparian area habitat and heterogeneity. It appears for example that, independent of geographic location, native grasses and vegetation are the most efficient herbaceous component of buffers in retaining nutrient loads and support the highest levels of biodiversity.

However, implementing effective riparian conservation and buffers does require examining region and site specific conditions such as topography, natural vegetation structure and composition, stream/wetland morphology, among others. Furthermore, various regions may have specific conservation/biodiversity goals or issues to which the buffer or BMP must be designed to meet. The bias in the scientific resources creates a gap in this area and further study and analysis of the literature is needed to understand what features are needed in riparian buffers to be effective at enhancing landscape biodiversity at regional or smaller scales and to emulate the natural environmental conditions. For example, the majority of the research reviewed here indicates that the largest biodiversity gains are achieved through a diverse riparian buffer structure comprised of both herbaceous vegetation as well as shrubby or woody vegetation. Yet, it is clear that some floral and faunal assemblages, such as grassland birds, would not benefit from such habitats and implementing effective riparian buffers and conservation on the prairies may require a different structure or composition and further study.

The information available on both the geographic applicability of some riparian buffer systems and some specific conservation issues in regions where buffers have been employed are summarized below:

<u>Source: (Dosskey 1998)</u>

Riparian buffers are tailored to specific conservation issues that dominate in each region. For example, in the northwest, buffers are employed primarily to restore and protect salmon and trout habitats (Belt, et al. 1992, Elmore and Kauffman 1994). In the arid southwest, buffers improve habitat for more numerous at-risk aquatic and terrestrial species (Krueper 1996). In the east, buffers emphasize reduction of nutrients and sediment that reach streams and estuaries (Welsch 1991, Chesapeake Bay Program 1994). In the Midwest, buffers are used to stabilize stream banks, reduce pollutant runoff, and restore habitat for fish and wildlife in extensively cultivated landscapes (Schultz et al. 1995). This variety of applications is testimony to the flexibility of riparian buffers to address numerous and varied conservation concerns. Riparian buffers have a role to play on rangelands of the Great Plains, as well. Traditional grazing management has reduced vegetation cover and altered plant communities along many of the region's streams, contributing to erosion and degradation of terrestrial and aquatic habitat (Boldt et al. 1979, Chaney et al. 1990; USEPA 1995). Riparian restoration through special grazing management can reverse these problems in many cases (Kinch 1989, Chaney et al. 1990. 1993, Lauenroth et al. 1994).

<u>Source: (English 2003)</u>

Research has focused on the ability of riparian zones to lessen certain agricultural impacts. It has been suggested that maintenance of these zones would provide increased surface area for excess nutrient uptake. Some studies have demonstrated significant removal of NO3-N from surface drainage waters through denitrification in poorly-drained riparian buffers (Jacobs and Gilliam, 1985). However, the Canadian Prairies all undergo seasonal freeze-thaw cycles, limiting the time available for such uptake. As well, a large portion of surficial run-off in the prairies occurs in spring with snowmelt, when ground layers are not sufficiently thawed to allow infiltration of nutrient rich water. This is especially true if soil was wet before freezing (Chanasyk and Woytowich,1986; Zuzel and Pikul, 1997). Dissolved nutrient uptake also relies on fairly shallow flow through the root zone. Jacobs and Gilliam (1985) report little effect of N leaving in sub-surface drainage waters, whether by uptake or denitrification. If slopes are higher than 4% or surface soils are heavy, run-off will either flow overland or percolate to depths unavailable to root systems (Hill, 1996).

BMPs focussing on the physical characteristics of riparian buffers are better suited to the Canadian Prairies. A managed buffer with established vegetation will be successful in slowing terrestrial run-off. This slowing enhances sediment trapping, although it is more effective with larger sized particles than clay types. Good near-stream vegetation is also valuable in flood control. Thick plant cover reduces the velocity and erosive capabilities of high flow waters, especially on outside bends. Undercutting may still occur on banks with exposed soil (Beeson and Doyle, 1995).

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6.3 The Beaver: A Case for Biodiversity within Riparian areas and Riparian Buffers

Scientific literature suggests the presence of beavers on the landscape can significantly increase habitat heterogeneity and alter riparian structure, leading to increased abundance, richness, and diversity of numerous communities and taxa. Balance between engineered areas, non engineered and habitat created by old dams on the landscape would maximize heterogeneity and biodiversity while supporting species tied to specific habitats.

Conserving and managing riparian areas and wetlands with such practices as riparian buffers appears to play a key role in enhancing and ensuring biodiversity in the agricultural landscape. Providing not only habitat and habitat connectivity for species, these areas support the general notion that structural diversity on the landscape hosts more abundant and diverse biological communities. The beaver (*Castor canadensis*), being an obligate resident of riparian areas in nearly all ecoregions of the country, clearly benefits from the availability and conservation of riparian habitats. Yet, like humans, this unique mammalian species has the rare ability to drastically alter the structural, functional, and biotic make-up of its homerange and surrounding landscape. Though it has been, and currently is, viewed as a pest species in agricultural systems, it may be that the beaver should beheld as our friend, not foe, and could be employed as an instrument for creating natural habitat and a significant source of biodiversity within the landscape.

The North American beaver population has rebounded well since the 19th century and early 1900s when it was driven to near extinction by the ravenous fur trade. However, it again faces some peril from not only habitat loss, but due to the popular conception amongst farmers and landowners that the large rodent is a major pest species because it can cause flooding of uplands and creation of wetlands over production areas. Yet the beaver is a native species, with it's habitat engineering a common occurrence across the continent for millennia. Thus, because of its widespread removal prior to 1900, the literature strongly suggests that induced alterations to the structure and function of streams and riparian areas from the removal of beaver has substantial effects on the dynamics of lotic ecosystems and the surrounding biodiversity. The majority of the scientific literature, which examines the beaver's role and impacts in riparian systems, suggests that in fact beavers should be recognized as a keystone species under the current concepts of the organization and diversity of unaltered stream and wetland ecosystems in North America {Naiman R J, Melillo J M, et al. 1986 #1000530, Lamsodis & Vaikasas 2005 #1000420, Harthun 1999 #1000470, Rosell, Bozser, et al. 2005 #1000510}.

As an "ecosystem engineer", beavers are among the few species besides humans that can significantly alter the geomorphology, and consequently the hydrological characteristics and biotic properties of the landscape. Beavers are classified as ecosystem engineers because their building activities can change, maintain, or create habitats by modulating the availability of both biotic and abiotic materials for themselves and for other species (Jones, Lawton & Shachak, 1994; Gurney & Lawton, 1996 *in* {Rosell, Bozser, et al. 2005 #1000510}). Similarly, because tree felling by beavers rarely entails the consumption of the whole plant material, their foraging activity also alters organic material availability, thus creating habitat for other species. Nevertheless, the strength of beavers' impact varies from site to site, depending on the geographical location, relief, and the impounded habitat type {Rosell, Bozser, et al. 2005 #1000510}.

6.3.1 Nutrients, Sediments, Erosion, and Effects on Agricultural Practices

For the purposes of this report, discussion will be focused on the implications of beaver habitat alteration on the level of, and potential for, biodiversity within agricultural landscapes. However, from the literature available there is abundant discussion on the effects of beaver dams and beaver activity on stream flow and discharge, flooding, water quality, erosion, sediment carrying and deposition, nutrient cycling and storage, channel morphology, as well as management and land use implications. If this topic is to be assessed fully in terms of integrating biodiversity conservation into functional land use practices and management, these topics should be examined and the resources fully exploited.

6.3.2 Succession and Trophic Levels

Beaver dams and impoundments have been shown to exert considerable influence on the productivity of fresh waters by altering nutrient levels. For example, in the riffle areas of streams most of the nitrogen inputs are typically from allochthonous (terrestrial) sources, mainly deciduous leaves, while in beaver ponds most of the annual nitrogen input is accounted for by N fixation associated with sediment microbes {Lamsodis & Vaikasas 2005 #1000420}. Songster-Alpin & Klotz (1995) demonstrated that beaver ponds greatly increase microbial activity along streams. Further, beaver ponds retain a large proportion of nitrate, silicate, and phosphate by trapping sediments and organic matter. The enhanced nutrient levels can facilitate the growth of aquatic vegetation (Correll *et al*., 2000).

The beaver is a generalist herbivore, feeding on bark, shoots and leaves of woody plants, terrestrial herbs and forbs, ferns, and aquatic vegetation. Beavers can cut a significant amount of the mature trees in riparian areas, but unless collecting building material for dams and lodges, they tend to remove (ingest) only a proportion of the total biomass harvested. This behaviour alters above ground biomass and can influence the successional stage of wooded riparian areas along the waterbody, which may result in increased heterogeneity in the vegetation composition and structure. As discussed in the Woodlot chapter, felled trees and decomposing woody material can host an unique and diverse biological community of its own.

North American studies demonstrate that the continuous harvesting of early and mid-successional species by beavers can reverse the progress of succession. Moreover, by increasing light penetration and decreasing competition for soil and nutrients, beaver foraging could increase net primary productivity of existing non-preferred woody species (Barnes & Dibble, 1988; Johnston & Naiman, 1990). Yet while selective harvesting suggests that preferred deciduous stands may become replaced by shrub zones of unpalatable non-preferred species, light gaps created by beavers would also facilitate the regeneration of both their preferred and avoided food plants. Beavers generally prefer species belonging to the genera alder (*Alnus)*, ash (*Fraxinus)*, birch (*Betula*), cherry (*Prunus)*, hazel (*Corylus)*, maple (*Acer)*, mountain ash (*Sorbus)*, oak (*Quercus)*, poplar (*Populus)*, and willow (*Salix).*

These observations suggest that beaver browsing considerably shifts the species composition of the plant community towards non-preferred species. In the Biesbosch Nature Reserve of the Netherlands, Nolet *et al*. (1994) studied the impact of beaver foraging on the species composition of a riparian willow forest. By selectively harvesting the non-willow species, the beavers eventually decreased the diversity of woody species. However, it is not noted how the diversity of all other plant species was effected, though it may be presumed that, like productivity of non-preferred species, diversity would increase. These studies were not aimed at describing how beaver activity effects the ecosystem biodiversity of the impacted areas, nor whether plant species diversity is enhanced overall. What can be inferred from the scientific literature is that the harvesting of plant material by beavers alters the progression and/or state of succession in the riparian area and may create habitat heterogeneity. Furthermore, it is commonly understood that ecosystem biodiversity is highest at mid-successional states (i.e. very early and late succession communities have relatively low levels of biodiversity), to which beaver activity may maintain.

At a pond in Minnesota, Johnston & Naiman (1990) found that each of the six beavers in an individual colony felled nearly 1.300 kg/ha/year of woody plants. This decreased the above ground biomass by over 40% at the pond after 6 years of foraging. Less than one-third of this biomass was consumed, a small part was used for dam and lodge construction, and the rest was left unused. However, biomass reduction is probably less pronounced in ecosystems where the majority of felled trees are immature or where dam construction is unnecessary. Beaver's foraging impact is limited to about 60 m from the water and is concentrated along narrow shorelines {Rosell, Bozser, et al. 2005 #1000510}.

Although beaver dams and subsequent flooding may kill a portion of the woody vegetation, the increased water levels and surface area of unshaded water creates favourable conditions for other vegetation. The unshaded shallow waters, which retain nutrients and sediments, facilitate the growth of aquatic vegetation, while pond edges create favourable habitat for moisture demanding plants such as willow and alder (Correll *et al*., 2000; Nummi, 1989).

Ray, Rebertus & Ray (2001) studied the successional sequence of aquatic vegetation in beaver ponds in peatland areas. They concluded that the high internal heterogeneity found within beaver ponds facilitates the long coexistence of numerous species of aquatic vegetation. In the first 40–50 period, the species richness increased linearly, and up to 75% of the total richness found in surrounding lakes appeared in the ponds. After this

~50 year period, diversity and species richness of aquatic vegetation often levels off or even declines.

Though beaver ponds can last centuries and may be used by several generations, beavers often leave their ponds due to a reduction in food supply. In the absence of regular maintenance, the dams will ultimately collapse (Pollock *et al*., 1995). However, if dams resist structural failures during floods for long time periods, the gradual sedimentation in these ponds eventually results in the development of gently sloping, organically rich alluvial plains, so-called beaver meadows (Gurnell, 1998; Meentemeyer & Butler, 1999). Upon abandonment, ponds drain gradually and zones of open water, mud flats, wet meadows and dry meadows coexist soon after abandonment (McMaster & McMaster, 2000); once again creating landscape and habitat heterogeneity. For example, in the Adirondacks and Massachusetts abandoned ponds, which are not recolonized, develop into either open meadows dominated by grasses and sedges, or shrubby swamps dominated by alder, spirea (*Spirea* spp.), holly (*Ilex* spp.) and Viburnum (*Viburnum* spp.) (McMaster & McMaster, 2001; Wright, Jones & Flecker, 2002 *in* {Rosell, Bozser, et al. 2005 #1000510}). Specific studies on the species composition and levels of diversity within these created meadows is scant, however the research does imply that plant species numbers increase markedly and new species colonize these areas due to the habitat heterogeneity and soil fertility.

6.3.3 Arthropods

In streams, beaver activity and dams generally produce pond and standing water sectors in replacement of flowing water and riffle. A beaver impacted landscape therefore is characterized by an alternation of flowing and standing sectors. The recent reintroductions of the beaver in many European nations after long periods of extirpation has given way to several studies on the impacts of beaver induced stream and riparium alterations. Harthun {1999 #1000470}compared the composition of invertebrates in beaver homeranges and in non-influenced areas of the Spessart mountains (Germany). The new habitat and conditions resulted in the disappearance of a few *species (Drusus anulatus*, Trich., *Sericostoma personatum*, Trich., *Radix peregra*, Gastr.), however the beaver homeranges accommodated a significantly higher number of species of dragon flies and damsel flies, molluscs, and caddis flies than non-impacted waters upstream. Moreover, ephemeras had a significantly higher group dominance in the beaver ponds, while chironomids were more dominant in the lentic sectors not influenced by beavers. Even though some species which characterize lotic, flowing, and riffle habitats were absent from beaver ponds, beaver home ranges still included high current sections of water with their characteristic group of arthropods. The author also suggested that the higher number of insects would support greater numbers of predatory insects and fishes.

A similar study conducted in small streams in Pennsylvania and Maryland indicated that beaver activity effects both within-impoundment and downstream (up to 100m from impoundment) macroinvertebrate communities {Margolis, Raesly, et al. 2001 #1000460}. The taxonomic and functional changes in the macroinvertebrate assemblages were attributed to direct stream environment alterations (dams) and indirect alterations by beavers such as water temperature and chemistry and plant growth.

McDowell & Naiman (1986) found that the typical low-order stream invertebrate community of a small stream in Quebec was replaced by assemblages which were functionally more similar to large-order systems. Specifically, the running water communities of the non-impounded sites were dominated by blackflies (Simuliidae), chironomids Tanytarsini (Chironomidae), scraping mayflies (Ephemeroptera), and net-spinning caddis flies (Trichoptera). Following impoundment by beaver, these species were replaced by two different groups of chironomids, Tanypodinae and Chironomini, (Chironomidae), predatory dragonflies (Odonata), sludge worms (Tubificidae), and filtering mussels (Pelecypodae).

By contrast and depending on site characteristics, the situation on the dam structure itself can be different. In a low-gradient meandering stream in Alberta, Clifford, Wiley & Casey (1993) found that the invertebrate community of the dam was typical of a free-flowing environment, but other sections in the stream had a fauna more characteristic of slow-flowing or lentic environments. In slow-flowing streams, beaver dams can therefore have an important role in maintaining a lotic fauna. In addition to the heterogeneity of the invertebrate fauna, the lotic invertebrate community in a stream in Germany was found to be of the highest diversity in the dam structure compared with the free-flowing stream and the beaver pond (Rolauffs, Hering & Lohse, 2001). They also found that insect density may be higher in dam habitat, as the median emergence density of invertebrates in the dam was 3.2 times higher than the stream, and 5.5 times higher than the pond section.

These results demonstrate that, similar to the effects of beaver activity on riparian vegetation diversity, beavers increase the patchiness (or heterogeneity) of the stream not only in terms of habitat and taxa composition, but also in terms of productivity.

Adler & Mason (1997) also found that beaver dams were important sites for black fly production in Saskatchewan streams. Abandoned ponds may provide suitable habitat for a wide range of invertebrates. Crane flies (Tipulidae) were found to be an important component of the aquatic fauna of a series of beaver ponds in Alberta which had been abandoned for about 10 years (Pritchard & Hall, 1971; Hodkinson, 1975a *in* {Rosell, Bozser, et al. 2005 #1000510}). Other macro fauna commonly occurring in these ponds included sludge worms, midges, soldier flies (Stratiomyidae), caddis flies, alder flies (Sialidae), backswimmers (Notonectidae), water boatmen (Corixidae), predacious diving beetles (Dytiscidae), water scavenging beetles (Hydrophilidae), and water striders (Gerridae). Moreover, close relationships have developed between certain invertebrates and the activities of beavers. For example, most of the fruit fly species group *Drosophila virilis* are semiobligatory commensals of the beaver (Spieth, 1979). These flies require the rotting bark of a limited number of deciduous tree species as ovipositional substrates, and these substrates are typically abundant at beaver sites. An increase in beaver populations would, presumably, represent a proportional increase in any such commensal species.

Though it should be considered whether beaver activity will displace any species of concern, in some situations the activity of beavers may be of particular importance to the conservation of endangered species. The Hungerford crawling water beetle (*Brychius hungerfordi)*, a rare North American species, is often associated with the area downstream of beaver dams and removal of existing dams is considered to represent a significant threat to them {Rosell, Bozser, et al. 2005 #1000510}

6.3.4 Fish

In small streams that are easily dammed, beavers can alter many of the habitat features which are crucial to fish survival, growth, and reproduction. These beaver-created alterations can be either beneficial or detrimental, depending on the population density of the beavers and the prevailing constraints on local fish species composition and abundance (Collen & Gibson, 2001).

Beaver dams reduce flow rates, which in turn reduce the silt loads of water. This is of potential value to salmonids, which benefit from reduced sediment loads and require clean gravel for spawning. However long stretches of streambed can also be covered by silt and potentially important spawning areas may be damaged (Knudsen, 1962 *in* {Rosell, Bozser, et al. 2005 #1000510}). Silt deposition regularly occurred in beaver ponds in Utah, but Rasmussen (1941 *in* {Rosell, Bozser, et al. 2005 #1000510}) reported that, in areas where the average stream gradient was 2.2%, damage to spawning areas was minimal and extensive areas of spawning gravel remained.

Furthermore, the ability to migrate both upstream and downstream is essential to many salmonid species. Spring spawners (cutthroat trout-*Oncorhynchus clarki*- and rainbow trout -*O. mykiss*-) usually negotiate beaver dams (Rasmussen, 1941; Grasse, 1951 *in* {Rosell, Bozser, et al. 2005 #1000510}), whereas it has been suggested that autumn spawners (brook charr -*Salvelinus fontinalis*- and brown trout -*Salmo trutta*-) could be blocked during low-flow conditions when the dams are in a good state of repair (Cook, 1940; Rupp, 1955 *in* {Rosell, Bozser, et al. 2005 #1000510}).

As elluded to in the arthropod section, the beaver-induced changes to aquatic invertebrates, a vital food source for fish, and to riparian and stream habitats can have important consequences for fish populations. In small streams in Sweden, Hägglund & Sjöberg (1999) found that brown trout were larger in beaver ponds compared with those in riffle sections, and they also suggested that beaver ponds likely provide habitat for larger trout in small streams during periods of drought. Likewise, brook charr, coho and sockeye salmon were all significantly larger in beaver ponds than in unimpounded stream sections (Rutherford, 1955; Murphy *et al*., 1989 *in* {Rosell, Bozser, et al. 2005 #1000510}). Increases in abundance of lower trophic species (invertebrates and small fish) will have a bottom up effect and can significantly enhance the health and biodiversity of an ecosystem. In a Maine study, Rupp (1955 *in* {Rosell, Bozser, et al. 2005 #1000510}) reported that ninespine sticklebacks (*Pungitius pungitius)*, which featured prominently in the diet of brook char, were more abundant in beaver ponds than in the open stream.

Beaver ponds can benefit fish not only through trophic interactions but they can also by providing important winter habitat for many stream fishes, which is especially important in streams lacking deep pools (Cunjack, 1996). Nickelson *et al*. (1992) reported that beaver ponds in Oregon benefited coho salmon during the winter, and also during summer flow conditions (Leidholt-Bruner, Hibbs & McComb, 1992 *in* {Rosell, Bozser, et al. 2005 #1000510}). Also due to increased water volume, forage space, and warmer waters, Knudsen (1962) reported that mudminnows (*Umbra limi)* often increase in beaver ponds. Pike (*Esox lucius)* abundance was also found to increase within beaver ponds in Wisconsin, particularly in large ponds with abundant shallow grassy areas (Knudsen, 1962).

Hanson & Campbell (1963) suggested that beaver ponds could provide important refuges for fish in times of low flow, and consequently serve as reservoirs for recolonizing streams. With the strong possibility that climate-induced drought and low flow episodes will become more frequent across Canada in the near future, specifically in the prairies, beaver stream modification and pond creation may play an important role in preserving aquatic habitat and providing refuge for fish and other aquatic species. Beaver activity may also influence lake-dwelling fish. France (1997) found that in boreal headwater lakes in Ontario, the abundance of northern redbelly dace (*Phoxinus eos)*, finescale dace (*P. neogaeus)*, fathead minnows (*Pimephales promelas)*, white suckers (*Catostomus commersoni)*, brook sticklebacks (*Culaea inconstans)*, and slimy sculpins (*Cottus cognatus)* were significantly elevated near beaver lodges compared with the more typical sand-and-rock littoral zone habitats of these lakes.

6.3.5 Herpatofauna

Frogs and toads (Anura), and tailed amphibians (Caudata) propagate, often profusely, in the shallow parts of beaver ponds. In boreal headwater lakes, green frog (*Rana clamitans)* tadpoles and red-spotted newts (*Notophthalmus viridescens)* were found to be significantly more abundant near beaver lodges compared with other littoral zone areas of the lake (France, 1997). Likewise, Metts *et al.* (2001) showed that frog and toad abundance was significantly higher in beaver ponds than in un-impounded stream reaches of South Carolina. However, salamanders were less abundant in the beaver impoundments, likely due to their preference for small, free-flowing streams and also to the presence of predatory fish in the ponds.

Turtles (Chelonia) and water snakes (*Natrix* spp. and *Nerodia* spp.) may also utilize beaver ponds, as Metts *et al*. (2001) found that reptile richness and diversity were significantly higher in beaver ponds compared with un-impounded streams in South Carolina. Furthermore, habitat heterogeneity created by the presence beaver impoundments of varying ages appears to enhance species richness and abundance. In a study done by Rosell *et al.* (1999) of streams in South Carolina, the degree of amphibian community overlap across old beaver ponds (10 years old), new ponds (5 years old), and un-impounded stretches was low, indicating that the landscape species diversity increased by the presence of beaver ponds. What's more, the richness and abundance of reptiles were significantly higher at old beaver ponds compared with new beaver ponds and un-impounded streams.

6.3.6 Birds

Beaver ponds produce an abundance of invertebrates that provide protein and calcium rich foods for birds (Danell & Sjöberg, 1982; Nummi, 1984; Whitman, 1987; McKinstry *et al*., 2001 *all in* {Rosell, Bozser, et al. 2005 #1000510}). For example, the shallow water along beaver pond edges warms quickly and provides an excellent supply of plant particles, seeds and invertebrates for foraging ducks (Brown *et al.* 1996). Nummi (1984 *in* {Rosell, Bozser, et al. 2005 #1000510}) found that benthic invertebrates played an important role in the increase in duck brood numbers in beaver impacted systems. Moreover, the removal of woody vegetation from the riparian zone by beaver harvesting can increase the density and height of the grass–forb–shrub layer, which enhances waterfowl nesting cover adjacent to ponds. The habitat heterogeneity and interspersion of cover and open water of beaver-impounded wetlands may offer isolation for territorial pairs (Ringelman & Longcore, 1982 *in* {Rosell, Bozser, et al. 2005 #1000510}), as well as brood-rearing habitat (Carr, 1940; Beard, 1953; Brenner, 1960; Ringelman & Longcore, 1982 *all in* {Rosell, Bozser, et al. 2005 #1000510}), and roosting habitat for migratory and wintering waterfowl during autumn and winter (Arner & Hepp, 1989; Dieter & McCabe, 1989 *in* {Rosell, Bozser, et al. 2005 #1000510}).

Grover & Baldassarre (1995) surveyed 70 wetlands in New York State during winter and spring 1992, and found that those occupied by beaver contained significantly more species of waterfowl and a greater average number of species than inactive or potential sites of the same size. Swans and Canada geese (*Branta canadensis)* often build nests on the tops of lodges and McKelvey *et al.* (1983) concluded that beaver activity has an important influence on the development of ponds used by trumpeter swans (*Cygnus* spp).

Dead, decaying trees in beaver impoundments may provide nesting and feeding sites for woodpeckers. Lochmiller (1979 *in* {Rosell, Bozser, et al. 2005 #1000510}) found that woodpeckers used beaver ponds more frequently than a control area without beaver ponds. Moreover, abandoned woodpecker nests provide valuable nesting cavities for many other birds, including flycatchers (*Ficedula* spp., *Empidonax* spp.), tree swallows *Tachycineta bicolor*, tits *Parus* spp., wood ducks *Aix sponsa*, goldeneyes, mergansers *Mergus* spp., owls (Titonidae, Strigidae) and kestrels *Falco tinnunculus*. Much the same, these trees may provide important perching sites for raptors (Grover & Baldassarre, 1995) and raptors such as hawks (*Buteo* spp. and *Accipiter* spp.) and owls may hunt on beaver kits or may increase their hunting success for birds and mice.

Piscivores, such as herons (*Ardea* spp.), grebes (Podicipedidae), cormorant (*Phalacrocorax carbo)*, shag (*Phalacrocorax aristotelis)*, bitterns (*Botaurus* spp.), egrets

(*Egretta* spp.), mergansers and kingfishers (*Alcedo atthys),* and ospreys *(Pandion haliaetus)*, would also clearly benefit from the increased fish abundance which may be found in beaver ponds and beaver influenced streams. Grover & Baldassarre (1995) found that hooded mergansers *Lophodytes cucullatus*, green-backed heron *Butorides striatus*, great blue heron *Ardea herodias* and belted kingfisher *Ceryle alcyon* occurred more frequently in wetlands where beaver were active than at sites with no beaver activity.

Marsh songbirds may also benefit from nesting and foraging opportunities offered by beaver impacted wetlands. Carr (1940 *in* {Rosell, Bozser, et al. 2005 #1000510}) noted large numbers of song sparrows (*Melospiza melodia)* and marsh birds along with other non-game birds utilizing beaver ponds. The northern yellow-throat (*Geothlypis trichas brachydactyla)* and the yellow warbler (*Dendroica petechia)* were typical summer residents, especially of deserted beaver sites. Reese & Hair (1976) showed that the structural complexity and of beaver ponds was highly attractive, and offered an abundant source of invertebrate prey, to a large number of birds year-round, and concluded that the ponds value to waterfowl was minor when compared with their value to other species of birds. In total, 92 bird species (31 families and 2346 individuals) were identified at four beaver ponds. Open areas in woodlands created by beaver provide nesting, loafing, feeding and dusting places for wild turkeys (*Meleagris gallopavo)* and grouse (Tetraonidae) (Carr, 1940).

6.3.7 Mammals

Beaver ponds provide prey, stable water levels, unfrozen aquatic winter habitat and breathing holes, and den sites for semi-aquatic mammals. Muskrat (*Ondatra zibethicus)*, water voles (*Arvicola terrestris)*, North American mink (*Mustela vison)* and otter (*Lutra* spp. and *Lontra canadensis*) may all benefit from beaver created habitat and lodges.

Knudsen (1962 *in* {Rosell, Bozser, et al. 2005 #1000510}) and Rutherford (1955 *in* {Rosell, Bozser, et al. 2005 #1000510}) recorded that muskrats used beaver ponds more frequently than wetlands above or below the ponds. A positive correlation between numbers of beaver sites and densities of mink has commonly been observed in Belarus, likely because mink profit from ice-free access to water in winter around beaver lodges and burrows, and they use lodges as marking places (Sidorovich, 1992). Beaver and otter territories frequently overlap (Tyurnin, 1984 *in* {Rosell, Bozser, et al. 2005 #1000510}), and the presence of beavers is thought to be beneficial to otters. It has been suggested that the recent increase in the otter population in parts of the USA is due to the re-establishment of beaver populations (Tumlison *et al*., 1982; see also Vogt, 1981 *in* {Rosell, Bozser, et al. 2005 #1000510}).

The bark and branches of felled trees within beaver homeranges can produce an easily accessible food source for deer, elk, and moose. In addition, in forested areas, beaver meadows provide succulent vegetation for many species, including white-tailed deer (*Odocoileus virginianus)*, moose (*Alces alces)* and bears (*Ursus* spp). (Bailey &

Stephens, 1951; Müller-Schwarze, 1992 *all in* {Rosell, Bozser, et al. 2005 #1000510}). Also, the regrowth of aspen and birch are highly preferred food for these species {Rosell, Bozser, et al. 2005 #1000510}.

Bats also find good hunting for insects around beaver ponds (Solheim, 1987 *in* {Rosell, Bozser, et al. 2005 #1000510}). Furthermore, it has been suggested by Bailey & Stephens (1951 *in* {Rosell, Bozser, et al. 2005 #1000510}) that the increase of the beaver may be partly responsible for the parallel increase in raccoons. Andersone (1999) reported that beaver appeared to be the most important food item for wolves in Latvia during summer, and that beaver became an important alternative prey when ungulate populations were low.

Small mammal populations would presumably also be influenced by the successional and vegetation composition changes that beavers induce within riparian areas. Suzuki & Mccomb (2004 #1000440) examined the association between stream reach and riparian conditions influenced by beavers with capture rates of small mammals in Oregon. Capture rates of species typically found in either early successional stages or ponds were higher in beaver-occupied areas. For example, capture rates for 3 species of microtine voles were consistently higher at occupied than at unoccupied reaches. Variability in capture rates of all species was also highest in beaver occupied areas. The researchers here hypothesized that the high variability in capture rates was associated with more diverse vegetative and physical characteristics at beaver-occupied reaches and that, if conducted at larger spatial scales, further research would reveal contributions of beaver to riparian area heterogeneity and vertebrate diversity.

6.3.8 Conclusion

Wohl (2005 #1000410) examined how historical land uses near rivers of the Front Range of the Colorado Rocky Mountains in the United States continue to affect contemporary river characteristics. Wohl concluded that the net effect of beaver removal along rivers in the Front Range was probably a reduction in diversity and stability as channels locally incised, snowmelt flood peaks increased, flood-related sediment transport increased, and riparian and slow-velocity habitats were lost. Based on the estimates of Wright *et al.* (2002), wetlands created or modified by beavers may contribute to as much as 25% of the total vascular plant species richness in the riparian zone, and create favourable conditions for many species which otherwise would be excluded. They also predicted that the total species richness would decrease if beaver-modified wetlands dominated the riparian ecosystem, as the number of unengineered patches may not be sufficient to support their entire complement of species.

Although the beavers' keystone status has been challenged (Nolet *et al*., 1994; Donkor & Fryxell, 1999 *in* {Rosell, Bozser, et al. 2005 #1000510}), beavers obviously have a considerable impact on the course of succession, the species composition and structure of plant communities (Barnes & Dibble, 1988; Johnston & Naiman, 1990a; Pastor & Naiman, 1992; Nolet *et al*., 1994; Donkor & Fryxell, 1999; Barnes & Mallik, 2001 *in*

{Rosell, Bozser, et al. 2005 #1000510}) and the presence of animal species requiring substrates or food abundant at beaver sites for their survival and reproduction (Spieth, 1979; Martinsen *et al*., 1988; Hilfiker, 1991; Menzel *et al*., 2001 *in* {Rosell, Bozser, et al. 2005 #1000510}).

As ecosystem engineers, beavers are extremely unique in that they have a large impact on other species by altering the riparian area and landscape structure and geomorphology. Consequently, they may play a crucial role in the maintenance of other species and enhance diversity mainly through patch-creation in otherwise closed communities. The ultimate mode of biodiversity enhancement is increasing and protecting viable habitat through ecosystem management. Thus, management and protection of ecosystem engineers such as the beaver may simplify this challenge through not only single species management, but as an implement of ecosystem management. However, some species may be adversely affected by the activities of beavers, and this should be considered when assessing the specific landscape and their overall influence on ecosystems.

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Summary of Riparian Area and Water Management BMPs

BMP	Benefits to Biodiversity	Qantitative Effect	Descriptive Effect
Riparian Buffers/Riparian Habitat	• Retains ground-water, runoff, and soil nutrient and pollutant inputs produced from upland activities. • Prevents inputs into aquatic systems. • Creates valuable habitat, habitat connectivity and corridors. • Can act as source and/or pool of biota within landscape	See below	See below
Nutrient and Pollutant Loads	• Nutrient and pollutant inputs can be detrimental to ecosystem food webs and biodiversity (especially to aquatic systems). • Retention and removal enhances soil microbial, invertebrate, and native floral biodiversity.	• Buffers of various widths can remove 50-100% nitrogen and 25-90% phosphorus inputs. • Can be 100% effective in non-point source pollutant removal. • Native warm season grasses have high soil nitrogen uptake levels, often most effective buffers for nutrient removal. • Biodiversity is highest under low nitrogen and reduced disturbance regimes.	• Major functional differences by buffer vegetation composition and width. • Buffer width should be taken into great consideration, based site-specifically. • Grass buffers may not work well as a sole buffer against nitrogen and phosphorus runoff in temperate zones; often most effective are combined buffer systems such as forested buffers and 3 zone buffers.
Erosion	• Vegetation in a buffer strip reduces sediment-carrying capacity and sediment is trapped. • Mainly protect aquatic systems and riparian habitat itself. • Sedimentation in aquatic systems is detrimental to fish and reduces water quality and increases turbidity. • Biodiversity impacts	• 3, 15.2, and 122 m. strips were needed to remove the largest proportions of sand, silt and clay, respectively; much wider buffers are needed to remove significant amounts of clay. 4.6m and 9.1m grassed strips could remove 81% and 91% of sediment	• Experiments with grassed buffers suggested height and vegetation density is more important than the width of a buffer for sediment retention.

	related to stream degradation are minimized by erosion control through buffers.	respectively from feedlot runoff and 63% and 78% respectively from cropland runoff.	
Biota	• Riparian areas and buffers do not provide habitat for all biota that would be found in natural settings within these regions. • Should be used synergistically with other practices and habitat conservation such as grazing management to increase viable habitat area and decrease fragmentation. • Should be analyzed and implemented using site specific criteria. • Most studies indicate significant increases in many bird, small mammal, amphibian, and notably invertebrate numbers and species richness compared to surrounding uplands. Thus they may act as source for biodiversity on landscape	• Several studies show significantly higher abundance of insects in riparian areas compared with surrounding landscape. • Consequently, higher numbers of insectivorous birds and mammals are expected and have been documented in several studies. • Shrubby riparian strips have a higher diversity of herpetofauna, whereas a small mammal diversity is highest in herbaceous and wooded riparian strips.	• Most species assemblages studied have shown increased numbers and diversity within riparian areas and buffers than in surrounding agricultural settings. • However, specific communities and species use of riparian habitat can be dependant and linked to vegetation type within the riparian area; a structurally diverse buffer therefore may often be optimal for biodiversity enhancement. • Furthermore, some assemblages (e.g. grassland birds) may not use or benefit from riparian buffers.
Beavers in Riparian Areas	• Scientific literature suggests the presence of beavers on the landscape can significantly increase habitat heterogeneity and alter riparian structure, leading to increased abundance, richness, and diversity of numerous communities and taxa. • Habitat and geomorphological alteration of streams and riparian areas by beavers has a bottom up effect on the	• One study showed that in the first 40–50 yrs after daming, aquatic vegetation species richness increases linearly. • A German study found that insect density may be higher in dam habitat, as the median emergence density of invertebrates in the dam was 3.2 times higher than stream sites. • Studies have shown that brown trout, brook charr, coho and	• Balance between engineered areas, non engineered, and habitat created by old dams on the landscape would maximize heterogeneity and biodiversity while supporting species tied to specific habitats. • Beaver pond's value to waterfowl may be minor when compared to their value to other species of birds.

	systems trophic levels. • This can lead to increased diversity and abundance of invertebrates, fish, birds, and mammals and may also lead to a shift in community types.	sockeye salmon are all significantly larger in beaver ponds than in unimpounded stream sections. • Studied wetlands have found beaver occupied sites contain more species of waterfowl and a greater average number of species than inactive sites. • In four beaver ponds/sites, a total of 92 bird species (31 families and 2346 individuals) were identified.	

7.0 Nutrient Management

7.1 Pollutants

7.1.1 Terrestrial nitrogen pollution

The increasing contamination of ground and surface waters with nutrients and pollutants from agro-ecosystems is now considered a major global environmental problem (Foundation for Water Research 1998); with the majority of agricultural pollution originating from the production and application of commercial fertilizers and livestock manure to arable land (Hey et al. 2005). Intensified farming with its high requirements for inorganic fertilizers, pesticides and fossil fuels has also led to contamination of soils with nitrogen and pesticides and the air with greenhouse gases such as N_2O and CO_2, while also reducing the soils capacity for carbon sequestration (Stoate et al. 2001). This has become a particular problem in eastern Canada where high inorganic nitrogen application levels are coupled with high precipitation levels.

Nitrogen is found in different forms in all aquatic ecosystems across the globe. Nitrogen that occurs in water can be classified into four forms: ammonium ion, ammonia, nitrite, and nitrate (Rouse et al. 1999). The most toxic to biodiversity is the ammonia form, then nitrite and nitrate. However, bacteria and algae quickly convert the ammonia and nitrite to nitrates, making it a less toxic form. Problems have occurred with large concentrations such as feedlots and slaughterhouses (Rouse et al. 1999). Although nitrate is the least toxic of the forms, it tends to occur in the highest concentrations and is the most stable of the three in water (Rouse et al. 1999).

Nitrate that has been found in concentration in aquatic environments has been known to cause both acute and chronic effects on amphibians at various stages of development. In a laboratory experiment, the researchers subjected a number of frog species to different concentrations of nitrate (Rouse et al. 1999). The western chorus frog (*Pseudacris triseriata*), northern leopard frog (*Rana pipiens*), and green frog (*Rana clamitans*) were used for the experiment. The tadpoles from the western chorus frog were the most susceptible to toxic effects, followed by the northern leopard frog and lastly the green frog (Rouse et al. 1999). Hecnar (1995) found that physical and behaivioral effects occurred at concentrations as low as 3mg/L. Effects included reduced swimming and feeding, bent tails, body swelling and bulging, and other deformities (Rouse et al. 1999).

Frog tadpoles are consumed by a number of predators including mammals, birds, snakes, turtles, salamanders, other frogs, insects, and spiders (Rouse et al. 1999). Although nitrate is known to bioaccumulate in higher food webs, there is little scientific research conducted on the matter. Nitrate has been found to affect salmon eggs and fry. In an experiment where the eggs and fry were subjected to 2.3mg/L, a large percentage (31%) of rainbow trout (*Salmo gairderi*) eggs and 15% of the fry died (Rouse et al. 1999).

Elevated concentrations of nitrate have been found in a large number of watersheds across North America. Concentrations ranged from <1 to > 100mg/L. A large number of samples (n= 8,545) were collected around the Great Lakes, and 19.8% of them contained concentrations of nitrate exceeding those that cause sublethal effects in amphibians and aquatic organisms (Rouse et al. 1999).

Nitrogen in inorganic fertilizers is usually applied in the form of ammonia. Atmospheric nitrogen can also be fixed from the atmosphere by plants, where it then converts to ammonia in the soil, before being changed into proteins (Larson et al. 2002). Ammonia applied to soil is quickly converted by microorganisms to nitrate, or to nitrite or N2 gas under anoxic conditions. As nitrate is highly soluble, it readily travels in runoff and leachate from the point of fertilizer application in fields to contaminate ground and surface waters. Denitrification of fertilizer in the soil can also lead to the production of N_2O and NO, powerful greenhouse gases.

In grassland and arable systems, soil water nitrate levels are subject to root-microbial interactions and generally peak in spring when runoff is high and vegetation growth is insufficient to take up nitrogen, and low in summer when plant-microbial associations are actively taking up nitrogen (Ramundo et al. 1990). To emphasize the importance of this relationship, when grassland roots are deactivated with herbicides, nitrate levels of soil water beneath fertilizer-treated vegetation can be seen to double. However, because nitrogen inputs to soil through conventional farming practices have increased to such staggering levels, often most available nitrogen can not be completely taken up by vegetation, resulting in ammonia accumulation in the soil, soil acidification and the stimulation of populations of nitrifying bacteria which further nitrogen pollution (Bakker and Berendse 1999).

Nitrogen losses can be reduced by minimizing nitrogen application to agricultural lands and soil management for nutrients including improved cropping systems, cover cropping, soil and water conservation measures and irrigation management. Other effective means for managing nutrient losses include ecological or organic farming practices, the establishment of buffer strips and altering livestock and manure management. Directives towards establishing permanent vegetation should be undertaken as undisturbed grasslands lose only a fraction of the nitrogen entering the soil to groundwater and streams (Ramundo et al. 1990).

In a study conducted in England, a 24 meter buffer zone reduced nitrate concentrations in a water body from 12mg/L to less than 1mg/L. In a similar study, a 19 meter woodland buffer strip reduced nitrate contamination in a river from 7mg/L to less than 0.5mg/L (Rouse et al. 1999).

7.1.2 Atmospheric Nitrogen Deposition

Atmospheric deposition is also an increasingly important form of nitrogen pollution. Atmospheric NOx emissions originate from industry and agriculture (Foundation for Water Research 1998), and are deposited back on to the land, which results in eutrophication and soil acidification, impacting soil buffering capacity and nitrogen-immobilization (Bobbink et al. 1998). Agricultural sources of nitrous oxides are primarily from denitrification and ammonia volatilization from applied fertilizers (Bakker and Berendse. 1999), animal feedlot operations, biomass burning and fossil fuel combustion (Krupa 2003), along with the manufacture of nitrogen fertilizers (Stoate et al. 2001). Atmospheric nitrogen deposition rates have increased more than tenfold over the last 40 years (Wedin and Tilman 1996), and show no signs of decreasing.

Direct effects of nitrogen gases have not been studied in-depth, however ambient ammonia has been found to affect plant growth, productivity, tissue content, drought and frost tolerance, response to pests and disease, development of beneficial root symbiotic or mycorrhizal associations and competition within or between species (Krupa 2003). Eventually, nitrogen gases are also deposited onto soil and plants and contribute to overall nutrient pollution (Bobbink et al. 1998). This can result in increased availability of nitrates and ammonium in the soil, soil acidification and decreased viability of plants when placed under stressful environmental conditions or exposed to pests and diseases. Increased deposition of atmospheric nitrogen can also change fundamental soil processes (Stoate et al. 2001) and affect large-scale biodiversity and the composition of natural plant and microbial communities (Pitcairn et al. 2003) as increased levels of nitrogen and soil acidity can favor nitrophilic and acid-tolerant species (Bobbink et al. 1998).

7.1.3 Phosphorus pollution

Phosphorus is a necessary component to all forms of life. However in concentrated amounts it can be devastating to aquatic environments. Phosphorus is considered a major pollutant originating from agricultural use, primarily sourced from livestock manure and slurry and inorganic fertilizers (Foundation for Water Research 1998). Although it is not as soluble as nitrogen, phosphorus can also be affected through dissolution into surface and subsurface water, and biochemical uptake processes in the soil (Heathwaite and Dils 2000). Soil microbes play an important role, functioning as a transient nutrient sink releasing nutrients from organic matter for use by plants (Tu et al. 2006).

Earthworms can increase bioavailability of phosphorous from litter in soil, positively affecting phosphorus-limited soil micro flora (Le Bayon and Binet 2006). On grasslands and arable soils, the amount of phosphorus dissolved in surface and sub-surface water is often associated with high intensity rainfall events (Heathwaite and Dils 2000) and is also subject to the past and current use of fertilizers or manure in relation to potential crop uptake (Ekholm et al. 2005). As with nitrogen, soil water phosphorus levels peak in spring when vegetation has not yet started to grow and is low in summer when plants are active in phosphorus uptake (Uusi-Kamppa 2005).

Phosphorus in its environmental state is very toxic to life, and is subject to bioaccumulation. However, phosphates PO_4^{3-} are converted from this element and are found to be non-toxic to humans or animals, unless they occur in high concentrations where they can cause digestive problems (Heathwaite and Dils 2000). Phosphates exist in three forms: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Ortho forms are produced by natural processes and are found in sewage. Poly forms are used for treating boiler waters and in detergents. In water, they change into the ortho form. Organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides which contain phosphates. They may exist in solution, as particles, loose fragments, or in the bodies of aquatic organisms (Heatwaite and Dils 2000).

Runoff of surface water is a highly important vehicle for phosphorus contamination from agriculture because the levels required for eutrophication are lower than the soil phosphorus concentrations required for crop production (Heathwaite and Dils 2000). This can have detrimental impacts as the acceleration of eutrophication can reduce aquatic and terrestrial species richness, promote the proliferation of toxic algal blooms, devastate aquatic life including invertebrates and fish due to decreased dissolved oxygen levels, and lead to a long-term loss of ecosystem biodiversity.

The production of toxic algae blooms can be hazardous for humans as well as animals. Humans have been known to be poisoned when eating the flesh of shellfish that have fed on the toxic blooms (Uusi-Kamppa 2005). Rapid growth of algae blooms can lower the CO_2 levels in a waterbody, leading to increased pH. Normal pH levels for most organisms range from 6.5 to 8.2, however; when pH reaches 9.0 it becomes harmful to salmonids (trout) and perch (Heatwaite and Dils 2000). Eutrophication also depletes oxygen levels present in the water. Fish and other organisms will die if levels are too low, or will be replaced by species that are more tolerant of low oxygen. Pike, perch and bass are representative of eutrophic lakes, wheras trout, salmon and cisco are considered deep-dwelling, coldwater fish.

Ecological consequences that result from eutrophication include hypolimnetic anoxia due to algal decomposition and fish kills and a rapid shift in species composition of the biological community. In tropical areas, diseases such as malaria may be enhanced by eutrophication because the insect vector, mosquitoes in the case of malaria, breed in these waters (Knutson et al. 2002).

In a study conducted to research the reproductive success of amphibians, it was found that ponds used for watering livestock had elevated concentrations of phosphorus, higher turbidity, and a trend toward reduced amphibian reproductive success. Species richness was highest in small ponds, ponds with lower total nitrogen concentrations, tiger salamanders (*Ambystoma tigrinum*) present, and lacking fish. They concluded that small, constructed farm ponds, properly managed, may help sustain amphibian populations in landscapes where natural wetland habitat is rare. They recommend management actions such as limiting livestock access to the pond to improve water quality, reducing nitrogen input, and avoiding the introduction of fish to amphibian sensitive waters (Knutson et al. 2002)

As with nitrogen, phosphorus losses can be reduced by minimizing fertilizer application to agricultural lands, improved cropping systems, soil and water conservation measures, irrigation management, alternative farming systems, buffer strips and livestock and manure management (Uusi-Kamppa 2005). More scientific information is needed to study the effect of eutrophication on all organisms, residing in the waterbody as well as riparian areas. Agricultural inputs make up a huge proportion of phosphorus pollution, and should be managed to contain them and prevent them from entering water bodies.

7.2 Manure Management and Improved Manure Storage and Handling

Balance manure application with soil and plant needs, (avoid over- applying manure that can cause build up of phosphorus and other salts and combined with crop nitrogen from leguminous plants or by side dressings of nitrogen. Apply high nitrogen manures when the crops are growing rapidly and utilizing large amounts of nitrogen).

Excessive nutrient loading in terrestrial ecosystems leads to loss of diversity and toxicity to numerous species as has been amply demonstrated in previous sections. The most important aspect of nutrient management is to control, plan and optimize nutrient application whether it is through mineral fertilizers, manures or a combination of the two. With respect to manure, this can be accomplished by examining all aspects of the farm nutrient cycle, starting with livestock feeding practices, grazing, manure storage and handling, timing the application of manure, and optimizing crop cycles and sequences. For more information see Manure and Nutrient Land Application under the Non-Perennial Agro-Cropping Systems section.

High concentrations of nitrate are found in manure and can have a negative impact on the biodiversity of a system if left unchecked. Nitrates are naturally present in soil, water and food; however, in intensely managed livestock confinements huge concentrations are produced annually. Concentrated livestock confinements and poultry operations produce millions of tons of nitrate each year (Marco et al. 1999).

In an experiment conducted by Marco et al. (1999), they studied the effects of nitrate and nitrite solutions on newly hatched larvae of five species of amphibians: (*Rana pretiosa, Rana aurora, Bufo boreas, Hyla regilla,* and *Ambystoma gracile*). When the researchers applied nitrate or nitrite ions to the water, they noted that some larvae experienced reduced feeding activity, swam less vigorously, showed disequilibrium and paralysis, suffered abnormalities and edemas, and eventually died. The observed effects increased with both concentration and time, and there were significant differences in sensitivity among species. *Ambrystoma gracile* displayed the highest acute effect in water with nitrate and nitrite. The three ranid species had acute effects in water with nitrite. In chronic exposures, *R. pretiosa* was the most sensitive species to nitrates and nitrites. All species showed 15-d LC50s lower than 2 mg N-NO2-/L. For both N ions, *B. boreas* was the least sensitive amphibian. All species showed a high mortality at the U.S. Environmental Protection Agency-recommended limits of nitrite for warm-water fishes (5 mg N-NO2-/L) and a significant larval mortality at the recommended limits of nitrite concentration for drinking water (1 mg N-NO2-/L). The recommended levels of nitrate for warm-water fishes (90 mg N-NO3-/L) were highly toxic for *R. pretiosa* and *A. gracile* larvae (Marco et al. 1999).

7.2.1 Proper treatment of manure

Solid manure should be composted following a planned approach to reduce ammonia, nitrites and pathogenic organisms that negatively impact both biodiversity and soil fertility while benefiting beneficial microbial and invertebrate organisms.

Composting animal manures provides a technique for fixing ammonia in the form of nitrate and thereby potentially reducing overall manure atmospheric emissions of NH_3. N_2O emissions from manure are also a concern that can be mitigated by composting. Liquid pig manure releases 35 times more N_2O than composted amended manure (Yang et al. 2004). Composting provides the additional benefit of killing pathogenic bacteria and weed seeds while producing a well-textured soil amendment with high ease of manipulation.

A study conducted over 11 years in Ohio used ground beetles (Coleoptera: Caribidae) as their test subjects to look at the difference in applying liquid manure and waste (sludge) as opposed to uncontaminated urea-phosphate fertilizer. The control fields were left without any application. Larsen et al. (1996) found that ground beetle abundance was significantly higher on the sludge applied field compared to the control fields. The fertilizer treated field had similar numbers to that of the sludge field. From the sludge field 18 beetles were collected, 17 from the fertilizer field, and only 11 from the control field, thus showing that even when the soil is treated with sludge (known to contain heavy metal contaminants) there can still be an abundance of ground beetles (Larsen et al. 1996).

Several studies have reported increased efficiency of nutrient use by plants treated with compost compared to raw manure or mineral fertilizer. In silage corn plots the use of composted dairy manure allowed the slowest release of mineralized nitrogen compared to raw dairy waste. This allowed the nutrient availability to be synchronized with plant nutritional needs. Yields were increased relative to plants treated with unprocessed manure (Shi et al. 2004). In studies with wheat it has also been demonstrated that plant phosphorus and potassium uptake is enhanced by compost treatments compared to mineral fertilizer treatments (Chaoui et al. 2003).

A key consideration for environmentally beneficial composting is the need to limit ammonia emissions during the composting process itself. If this factor is not properly controlled the benefits of composting may be negated by atmospheric pollution and the low N concentration of the final composted product (Zvomuya et al. 2005). The quantity of ammonia emitted during the composting of manure is exponentially proportional to the temperature of the process during the initial (thermophilic) stage and linearly proportional to the temperature during the final (mesophilic) stage. In order to reduce NH_3 emissions the temperature of the pile should be monitored during the initial stage and through increased aeration or turning frequency, as required. The sanitation component of composting (allowing the compost to reach a high temperature to kill pathogens) should occur during the final stage, when NH_3 emissions no longer increase exponentially with temperature. High pH also increases ammonia volatilization by converting non-volatile ammonium ions to ammonia (Pagans et al. 2006). A possible solution is the addition of acidic amendments to the compost, such as phosphogypsum, an acidic by-product of phosphorous manufacture which reduces total nitrogen loss from beef cattle manure during composting (Zvomuya et al. 2005).

Other potential treatments of animal manure include the fermentation and acidification of slurry by endogenous microbes in the presence of sugars and organic residues to form organic acids and reduce NH3 emissions. In such treatment the pH first decreases and then increases to a value of 6. NH4+N- emissions were reduced from 54% to 32% in treated slurry (Angelidaki and Ellegaard 2003). The use of the alga Chlorella, naturally occurring bacteria (IMO) and nutrients has been demonstrated as an efficient procedure for fixing nutrients in swine waste as biomass (Baumgarten et al. 1999). These microbial technologies need to be further explored to develop efficient and optimized solutions for treating manure for reduced environmental impacts.

Benefits of compost application to nutrient management include a measured reduction of sediment and runoff loss of P more than 3 years after application (Wortmann and Walters 2006). Brown and Tworkoski (2004) conducted a study to document the effects of compost application on weed, fungal, and insect pest management in apple orchards. The use of compost in apple orchards was found to increase predator insect abundance and decrease pest insect abundance (Brown and Tworkoski 2004). The compost provided weed control for 1 year after application. There was no apparent effect on controlling apple scab (*Venturia inaequalis*) infection, however, in a laboratory experiment; growth of the brown rot fungus (*Monilinia fructicola*) was significantly slower on a compost substrate than a sterilized compost substrate (Brown and Tworkoski 2004). Populations of spotted tentiform leafminer (*Phyllonorycter blancardella*) and migrating woolly apple aphid (*Eriosoma lanigerum*) nymphs were reduced in the compost plots. This study showed that the use of compost in an orchard ecosystem is beneficial to management of weed, fungal, and insect pests. The use of compost as a mulch in orchard ecosystems should be encouraged as a sustainable management practice because of a potential to reduce pesticide use (Brown and Tworkoski 2004).

Compost並 manure is preferable to mineral fertilizers in terms of organic matter content and slow release of nutrients. Compared to raw manures and slurries, composted manure releases less ammonia and has sanitary advantages. However, it is still possible for ecological contamination to occur from compost if it is not well applied. Compost application should be managed in a similar manner to manure and fertilizer application because the most important determinants of nitrate leaching to surface water from compost are related to the site characteristics such as soil type and management practices rather than the type of compost added (Gerke et al. 1999). This reinforces the importance of the need for a good nutrient management plan and handling of agricultural inputs, regardless of their source.

7.2.2 Relocation of Livestock Facilities

Intensively managed livestock operations can potentially have a great impact on biodiversity in agricultural regions. Herd sizes are generally increasing over time to meet the demands of the beef and dairy industry. Livestock operations that harbour a large number of animals can produce an immense amount of manure annually. Livestock facilities are generally located nearby the farmstead, so the landowner does not have to travel far to check his herd. Unfortunately a large number of these facilities are located nearby a body of water as well.

Runoff originating from the facility can enter these water bodies and have catastrophic effects on the biodiversity of the system. Manure contains large amounts of nutrients (mainly nitrogen and phosphorous) and when it enters a body of water it encourages rapid growth of algae blooms. This is called eutrophication. Algae blooms use up all available oxygen and the die, leaving the system deprived of oxygen. Aquatic organisms will die soon thereafter as a result of depleted oxygen reserves. One toxic microorganism found in manure runoff, *Pfiesteria piscicida*, has been implicated in the death of more than one billion fish in coastal waters in North Carolina (Fonstad 1996).

Healthy water systems contain numerous species of insects and water organisms that provide food for many species in the food web. Livestock producers are encouraged to locate the holding facilities at least 150 meters from any water body (Davis et al. 1999). The facility should be south or west facing to encourage rapid evaporation of liquids in the manures. The slope of the facility should be angled away from and water body, as when it precipitates the runoff will follow the natural course into a water source or low area.

There is little quantifiable information on the benefits of relocating a livestock facility to biodiversity; however, the benefits gained are very similar to those that relate to water quality. Healthy water bodies support numerous organisms and in turn will support a more diverse chain of species inhabiting the area. Relocation of livestock facilities is not the only solution to improve water quality in agricultural regions of Canada. A number of other practices should be used around the farmyard to prevent manure from entering a water course. Buffer zones and vegetated filter strips should be planted or left unsprayed around any water body. For more information of these refer to the Riparian Area Management section.

7.3 Wintering Site Management

Livestock wintering sites should be kept away from any source of water body. Livestock kept at wintering sites are normally fed some type of forage throughout the winter. This leads to an increase in manure production in the area, and in turn can cause serious problems if the manure enters a water body. As mentioned before nutrient overloading in a water body can cause eutrophication, whereby algae blooms are massed produced then die-off, starving the system of oxygen. In Saskatchewan it is estimated that there are 10,000 cattle wintering sites that are located near a riparian area (SAFRD Unknown Date).

In cattle wintering sites proper manure management should be practiced to ensure safe disposal of livestock wastes. Manure should be stored away from any body of water that could lead to the manure polluting the water.

7.4 Product and Waste Management

7.4.1 Pesticide and Herbicide Storage and Handling

The use of chemical pesticides has a considerable effect on biodiversity in both agricultural and non-agricultural landscapes, with substantial impacts on populations and species richness and abundance of all major soil taxa including bacteria, nematodes, mycorrhizal fungi and earthworms, and insect and arthropod species including butterflies, spiders and beetles (Hole et al. 2005). Improper storage of these products can have the same adverse effects and can also be detrimental to water quality.

Pesticides and herbicides should be handled with the utmost care and attention. They should be stored in a well sealed building and in their original containers. The storage facility should be located at least 150 meters from a water well, and at least 200 meters from an open body of water. Containers should be rinsed a minimum of three times for 30 seconds per rinse to prevent any chemical from leaking out. These chemicals can have major ecological impacts if they come into contact with any source of water.

Reduced seed food resources and invertebrate abundance in conventional systems can also indirectly affect bird populations. Impacts on arable land in Quebec reveal that herbicide and tillage use in cultivated fields results in a higher proportion of annual and introduced plant species (Jobin et al. 1997). Direct impacts of herbicide drift from adjacent fields on non-arable areas is also evident (Boutin and Jobin 1998) with findings in Quebec indicating that the diversity and vegetation cover of hedgerows, field margins and woodland edges was lower at sites at which herbicides had been sprayed in recent years (Jobin et al. 1997). Runoff from arable land containing agricultural pesticides is also a main contributor to pesticide pollution (Popov et al. 2006; Stoate et al. 2001).

Vegetated buffer strips can substantially reduce the surface runoff load of moderately soluble herbicides through adsorption/ sedimentation of these dissolved chemicals during infiltration into the soil column, binding to soil particles or organic matter and later degrading (Popov et al. 2006). Buffer strips may reduce weed interaction between arable and non-arable habitats and provide important habitat for biodiversity however, it was found in Quebec that many farmers often deliberately spray herbicides on the outside margin of their fields with the intent of reducing weed invasion into cropland (Boutin and Jobin 1998).

7.4.2 Management of Agricultural Waste

Management of agricultural waste, including fruit, vegetable, wood and straw residues, can be undertaken by mulching and composting. Composting will stabilize nutrients, neutralized pesticide residues and kill weed seeds and pathogens in farm waste (Guthman 2000). Mulching wastes and adding them as a soil amendment can reduce soil erosion, suppress weed growth and increase soil water holding capacity. However, incorporating mulches and large amounts of residues in soil without composting them may actually lead to low yields (Blanco and Almendros 1997). This is because soil nitrogen may actually be immobilized as soil microbes first use available soil nitrogen to digest the high carbon content of the added organic material. This nitrogen is later made available through mineralization processes in the later stages of organic matter decomposition. Standard piling and composting of agricultural wastes before field incorporation will usually overcome these problems, over-composting is also not recommended however, due to severe losses of carbon and nitrogen during the process.

7.5 Nutrient Management Planning

On-farm nutrient management requires an assessment of the overall nutrient balance in an agricultural system and a subsequent detailed characterization of nutrient inputs and outputs. This should be followed by an assessment of any potential means to balance nutrient production and nutrient requirements. Farms can fit into three broad nutrient balance categories (nutrient-deficient, nutrient-balanced or nutrient-surplus) (Beegle et al. 2000). Therefore there should be a flexible approach to determining BMPs for nutrient management planning on each farm.

There are a number of areas which nutrient budgets need to address in order to reduce nutrient loss from agroecosystems. Proper animal housing can reduce emissions of NH_3, NO and N_2O. There are 136 trace gases in animal housing emitted from fresh and stored faeces, animal feed, and animals. Total NH_3 from animal production in Germany is 300 000 to 600 000 t/year. Between 12 to 21 kg/ha of this N is deposited on the soil per year, exceeding critical loads. Canadian studies should examine the impact of this nutrient source on overall agricultural nutrient balances. More research on emissions from different types of animal housing is also needed.

Improved livestock nutrition to reduce the nutrient content and improve the N to P ratio of manure, as well as improved timing and application of manure to reduce runoff, leaching and volatilization are also key components of nutrient management (Kuipers et al. 1999). Cropping systems should be planned so as to allow optimal nutrient use and minimize the need for external inputs. Animal management to limit the number of livestock per unit area is another method to reduce phosphorous loading.

A factor that should potentially be considered in the future development of nutrient management planning is the role of earthworms and other decomposers. Earthworms are important to soil nutrient dynamics due to their role in the breakdown of organic matter. They also create macropores in the soil that enhance water penetration. Deep-burrowing anecic earthworms are important to macropore formation and enhance the decomposition of leaf litter (Bugg 1997). It has been found that the anecic earthworm *L. terrestris* increased the rate of release of N from rye grass leaf litter by a factor of 3 compared to non-earthworm containing microcosms (Binet and Trehen 1992).

Earthworms regulate nutrient cycling through 3 mechanisms including (1) metabolism of organic matter leads to high availability of N and C in metabolic wastes (urine, mucus and tissue), (2) the dispersal and stimulation of soil microorganism activity by passage through the intestinal tract, (3) the distribution and mixing of organic matter and soil mineral particles. The presence of earthworms increases bioavailability of phosphorous from rye-grass litter in soil. This positively affects the P-limited soil micro flora (Le Bayon and Binet 2006). A potential problem associated with high earthworm densities is that they can enhance nitrate leaching to groundwater. This problem is much bigger in plots treated with fertilizer compared to manure, probably due to the less soluble nature of nitrogen bound in organic substrates (Dominguez et al. 2004).

Earthworm and microbial populations play an important role in decomposing organic nitrogen to a bioavailable form and in biological nitrogen fixation. Organic nutrient applications such as farmyard manure and dairy manure stimulate earthworm populations whereas mineral nitrogen applications have been reported to have minimal positive effects on earthworm populations and some negative effects, particularly at high concentrations. Therefore, any excessive mineral nutrient application that harms the earthworm population reduces the bioavailability of organic nitrogen, thereby requiring even higher application rates of nutrients in compensation. The increased leaching of nitrate from inorganic fertilizers in the presence of large earthworm populations is also of concern. It may be preferable to favor organic fertilizer use under such circumstances.

Nutrient management planning is a flexible practice that should maintain a specific goal of achieving a balance between nutrient inputs and outputs. The means for achieving this can vary widely between different agricultural systems. Novel factors of interest for the circulation of nutrients on the farm are earthworm populations, which affect the cycling of nutrients within the soil ecosystem.

7.5.1 Minimizing Chemical Inputs to Soils

Minimizing nutrient inputs in agricultural systems has long been part of responsible farm planning strategies, and when used in conjunction with soil testing can be quite effective for farm nutrient regulation.

Improved cropping systems that involve crop rotations can be used to match crop requirements with the manure nutrients to be applied. Cultivars should be selected that have an affinity for biological nitrogen fixation (Fox et al. 2004). The use of legume cover crops and alfalfa rotations can also liberate organic nitrogen and minimize the need for fertilizer application. Agrochemicals (pesticides) that interfere with signaling between symbiotic nitrogen-fixing bacteria and legume root nodules should also be avoided. Recommended management practices for Ontario and eastern Canada have been well documented by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA 2002).

Split applications of nitrogen fertilizers can also be employed during the crop production cycle (SSCA 2005). This involves applying some nitrogen during planting and then side dressing the crop with nitrogen when the plants enter the vegetative phase of their life cycle and their nitrogen uptake increases rapidly, usually five weeks after planting. Band application of fertilizer has also been proven to be more effective than broadcast application and can reduce overall fertilizer use. This involves the application of a concentrated band or stream of liquid nitrogen on the soil surface and improves penetration of the crop canopy, decreases contact between fertilizers and plant surfaces, and decreases the risk of nitrogen loss through volatilization.

Some types of fertilizers contain large amounts of ammonium nitrate. This product can be devastating to biodiversity if it is found in high concentrations. Ortiz-Santaliestra et al. (2006) studied the effects of ammonium nitrate on different developmental stages of amphibians. The observed lethal effects caused by ammonium nitrate increased with both concentration and duration of exposure. Significant differences were observed in sensitivity to ammonium nitrate as a function of developmental stage in *Discoglossus galganoi, Pelobates cultripes,* and *Bufo calamita.* In *D. galganoi* and *P. cultripes*, younger individuals displayed greater acute effects from the chemical fertilizer compared with older individuals (Ortiz-Santaliestra et al. 2006).

The researchers found that 100 percent of the *P. cultripes* hatchlings died after 4 days of exposure to a nominal concentration of 225.8 mg N-NO3NH4/L, whereas less than 40% of individuals from older larval stages died when exposed to this concentration. A delay of 4 days in the beginning of the exposure to the chemical was enough to cause significant differences in sensitivity (Ortiz-Santaliestra et al. 2006). *Bufo calamita* showed a higher sensitivity in later larval stages after 12 days of exposure. *Hyla meridionalis* and *B. calamita* were less sensitive than the other two species. Peak ammonium nitrate concentrations usually occur when amphibians are breeding and, thus, when the most sensitive aquatic stage is in the water (Ortiz-Santaliestra et al. 2006; Rouse et al. 1999).

The use of Integrated Pest Management can be a safe alternative to the use of pesticides and herbicides. Pesticide applications have been known to greatly affect certain species of birds. Pesticides have a tendency to bioaccumulate throughout the food web; originating from the insect and ending up in larger prey species (e.g. Raptors and owls). The chemicals also have a direct effect on insectivorous grassland birds that utilize insects as a large part of their diet. For example grasshoppers are a very important, nutritious insect for over 120 species of birds (McEwen et al. 1972). A number of chemicals that are used to kill grasshoppers are fatal a large number of grassland birds. Birds can be very beneficial for controlling insect outbreaks. Observations of large flocks of hawks (from 2000-8000 individuals) were seen in the 1930s cleaning up grasshopper infestations over their egg beds. Yet these bird populations are continuing to decline as a result of DDT and other insecticides cycling through the biosphere (McEwen et al. 1972).

The goal for landowners should be to reduce the input of chemicals into their land by implementing environmentally safe alternatives to pest management. Proper crop rotations and other methods can all be combined to create a sound management plan. More information on Integrated Pest Management can be seen under the Species Management section.

7.5.2 Optimized Nutrients in Animal Feed

The nutrient content of manure is of particular concern in managing the contamination of neighboring ecosystems. This applies particularly to the balance between phosphorous and nitrogen concentrations. There is a demonstrated link between animal numbers, manure application to a limited land area and P contamination of surface water(Boggess et al. 1997; Negahban et al. 1993). Phosphorous runoff to surface waters occurs independently of erosion when P is present in excess. Furthermore, 7-48% of P loading in aquatic ecosystems originates from animal agriculture (Smith and Alexander 2000). The deficiency of nitrogen relative to phosphorous in manure presents a major obstacle to the use of manure to provide nutrition to crops without exceeding acceptable phosphorous application rates.

Improving and optimizing animal nutrition and digestibility of feeds is a crucial strategy for controlling the nutrient content of manure. In modeling studies, nutritional approaches have had the most efficient and cost-effective impacts on reducing P and N excreted by farm animals (Adeola 1999). Livestock excrete 60-80% of consumed P (Knowlton et al. 2004), indicating that there is a large margin for optimizing the dosing and bioavailability of this nutrient in animal diets (Knowlton et al. 2004). Dietary inputs are of particular concern because excess nutrients imported to the farm via the diet remain on the farm as manure rather than being exported as meat or milk. Other problems to be addressed are the trace elements such as Co, Cu, Fe, Se and Zn which are added in excess to poultry feed to increase animal production and disease resistance (Williams et al. 1999). These elements are immobile in most soil types and may accumulate, leading to eventual toxicity problems, especially in the case of Copper and Zinc (Williams et al. 1999).

A number of strategies exist to reduce the nutrient content of animal manure. For the most part, these focus on reducing phosphorous quantities. There is a linear relationship between the P content of livestock diet and the quantity of excreted P. However, animals receiving diets with an excess of P excrete a higher proportion of water soluble P, leading to increased runoff potential (Ebeling et al. 2002). The runoff associated with high P diets is 10-fold greater than with an optimized P diet. The primary strategy is to determine the minimum requirement of P for optimal livestock productivity and health and to increase the efficiency of feed conversion. No benefits from P overfeeding of livestock have been identified.

The main reason for overfeeding is conflicting information from different sources (veterinarians, nutritionists, government extension workers) (Knowlton et al. 2004). Furthermore, the changing genetics of farm animals requires a constant re-evaluation of animal nutrient requirements. The P content of existing poultry, dairy, beef and swine feeds could be reduced with no negative impacts (Knowlton et al. 2004). An additional factor to consider is the growing use of residues from corn ethanol production for livestock feeding. These products have a high P content and as such lead to greater N and P imbalances in manures (Koelsch and Lesoing 1999). No supplemental inorganic P should be added to these feed sources and their economic viability should be re-evaluated in light of their potential negative environmental impacts.

Strategies for improving the efficiency of conversion of P in feed involve the use of microbial enzymes such as phytase. Phytase decomposes phytate, the primary storage form of phosphate in plants (30-80%). Phytase can be incorporated in non-ruminant feeds to improve P utilization efficiency. This allows a reduction of the inorganic phosphate in the diet and can reduce phosphorus excretion by as much as 50%. Phytase may also improve P availability in ruminant diets (Haefner et al. 2005).

Excess dietary Ca may negatively impact phytase activity by binding phytate, leading to competitive inhibition. Other strategies for increasing P bioavailability include the use of corn varieties with low phytate content and higher levels of available P, although total P remains unchanged. Organic acids such as sodium citrate and citric acid increase phytate P utilization in poultry diets based on soy and corn. Vitamin D has also been reported to increase phytate utilization as a source of phosphorous by livestock.

Optimized animal nutrition through phase feeding, increased bioavailability and avoiding the use of excess concentrations of inorganic mineral supplements in the diet is a crucial BMP for managing nutrient contamination of the terrestrial and aquatic environment. Currently, not all Canadian provinces regulate nutrient application using phosphorous limits; most provinces still regulate using nitrogen. If other provinces were to implement this practice the practical incentive to improve animal nutrition will become stronger due to the need for increased land area to spread manure. Consistent standards for animal nutrition need to be determined to avoid the distribution of conflicting information to farmers.

7.5.3 Organic Farming

Organic farming has been associated with a variety of potential benefits when compared with conventional agriculture including: improved soil structure, soil biodiversity, reduced environmental stress and food quality and safety (Tu et al. 2006), and improved landscape structure and soil, water and air quality (Stoate et al. 2001). Microbial biomass and activity have generally been found to be higher in organically managed soils (Tu et al. 2006), with higher numbers of bacteria of different trophic groups as well as larger species richness in both bacteria and nematode communities and higher numbers of arbuscular mycorrhizal fungi, nematodes, earthworms, insects and arthropods found (Hole et al. 2005; van Diepeningen et al. 2006). Species richness and abundance of birds were also significantly higher at organically managed sites (Freemark and Kirk 2001).

Organic sites have significantly lower levels of nitrate and total soluble nitrogen in the soil and leachate (van Diepeningen et al. 2006). Organic farming practices that limit nutrient pollution include lower stocking densities, reduced fertilizer inputs and the use of catch crops in the fall and winter (Hansen et al. 2001). However, some management practices such as fall tillage of grass or legumes in regions that have open winters with no subsequent crops to capture mineralized nitrogen and grazing livestock may destroy root systems could increase nutrient leaching and nitrous oxide production if used in organic systems.

7.6 Summary

These BMPs will help maintain and even create biodiversity on the farmland. Canadian agriculture comprises a large amount of the habitat that is available for wildlife. By implementing these practices it will help ensure that biodiversity remains strong in agricultural regions of Canada.

The BMPs outlined in this section should be combined with many others to create an environmental farm plan that meets the needs of the producer as well as the environment. A move toward organic farming can be the greatest management plan there is with respects to protecting this Nations farmland biodiversity. Organic agricultural has proven to benefit wildlife all over the world. Extensive studies have proven that biodiversity is greater on organic farms. Many of these BMPs can be considered organic practices, and if they are implemented and combined to form a large management plan biodiversity will be sure to benefit from it.

7.7 Gaps in Literature and Further Research Needs

Most of these BMPs have been studied with respect to protecting the livelihood of the producer and maintaining productive lands. There is little scientific documentation relating to the actual biodiversity benefits of implementing some of these practices. More research is needed in these areas to be able to accurately monitor the benefits derived from incorporating these strategies. There has been little research conducted on removing nutrients from wastewater. Landowners usually set up lagoons for this purpose that act as filters to remove nutrients; however there is little documentation relating to this topic.

More extensive research is needed to monitor the overall effects of a sound nutrient management plan, and determine the areas that need specific attention.

Summary of Nutrient Management BMPs

BMP	Benefits to Biodiversity	Qantitative Effect	Descriptive Effect
Manure Management and Improved Storage and Handling	• Reduces the risk of excess nutrients and contaminants entering a water source	None Available	• Amphibians are affected by nitrate contamination, and have been observed to have reduced feeding rate, irregular swimming, and eventually death
Proper Treatment of Manure	• Composted manure reduces the levels of harmful nitrates and ammonia that can kill organisms	• Carabid beetles were found significantly higher on fields treated with sludge (N=18) compared to untreated fields (N=11)	• Composting reduces levels of ammonia, nitrates, and pathogenic organisms that can have a great affect on biodiversity
Relocation of Livestock Facilities	• Increases both ground water quality as well surface water quality	• There are greater abundances of species in fresh water than polluted water	• Excess nutrients from manure can cause eutrophication of a waterbody, leading to depleted oxygen and death of aquatic organisms.
Wintering Site Management	• Decreases the risk of riparian degradation, and water contamination	• In Saskatchewan there are an estimated 10,000 cattle wintering sites located along riparian areas	• Riparian areas may be heavily graved and trampled from grazing cattle, as well large amounts of manure may be deposited into the water source
Pesticide and Herbicide Storage and Handling	• Reduced risk of pollution to water sources and accidental poisoning of organisms exposed to chemical.	None Available	• Chemicals should be safely stored in sealed containers, empty containers should be cleaned thouroughly
Management of Agricultural Wastes	• Composting will stabilize nutrients, neutralized pesticide residues and kill weed seeds and pathogens in farm waste	None Available	• Mulching wastes and adding them as a soil amendment can reduce soil erosion, suppress weed growth and increase soil water holding capacity
Nutrient Management Planning	• Reduces emmissions of NH_3, NO, and N_2O	• 136 trace gases in animal housing emitted from fresh and stored faeces, animal feed, and animals	• Animal management to limit the number of livestock per unit area is another method to reduce phosphorous loading.

Minimizing Chemical Inputs to Soils	• Some chemicals are detrimental to biodiversity if found in concentration, even nominal amounts	• Researchers found that 100 percent of *P. cultripes* hatchlings died after 4 days of exposure to a nominal concentration of 225.8 mg N-NO3NH4/L	• The use of legumes and other plants to reduce the input of chemicals can lead to a better abundance of species.
Optimized nutrients in animal feed	• Decreased levels of nutrients entering into ground and water bodies	• 7-48% of P loading in aquatic ecosystems originates from animal agriculture	• Optimized animal nutrition through phase feeding, increased bioavailability and avoiding the use of excess concentrations of inorganic mineral supplements in the diet is a crucial BMP for managing nutrient contamination of the terrestrial and aquatic environment.

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8.0 Species Management

8.1 Introduction

There are hundreds of animal species that live within a farm setting in the Canadian agricultural landscape. Bacteria, viruses, fungi, lichens, insects, birds, mammals, plants, amphibians and reptiles all live within their required habitat located on farms to feed and breed. Farming practices and available habitat limit their survival and contribution to biodiversity integrity. The presence of viable populations of all species within a farm provides valuable ecological services to the agro-ecosystem. Unfortunately habitat loss and species population losses due to agriculture demands and practices have eroded the biodiversity of most farms throughout Canada causing an imbalance of the natural processes that are necessary for the survival of the farming industry and the ecological landscape. The following farm practice categories deal with species specific issues and the beneficial farm practices that may preserve biodiversity integrity in the Canadian agriculture landscape.

8.2 Implementation of Integrated and Improved Pest Management

8.2.1 Improve Integrated Pest Management

Utilize and implement an ecologically based approach to pest (insect, plant or specific animal species) control (cultural, biological and chemical) that utilizes a multidisciplinary knowledge of crop/pest or livestock/pest relationships. establishment of acceptable economic thresholds for pest populations and constant field monitoring for potential problems/assessment

Pest Management affects all levels of biodiversity within the Canadian agricultural landscape. Dependency on specific pest management practices used to control insects and weeds have severely impacted the ecological processes, biodiversity landscape, species genetic integrity and specific species survival (Controlling a specific pest species disrupt the biological importance that species may have within the landscape.
Examples widespread use of chemicals
Ecolocial processes
Genetic
Species diversity/broad spectrum

Although pest management is a necessary activity to ensure the economic viability of the Canadian agriculture sector a true management approach to abating pest species is required. The utilization of an integrated pest management approach can reduce and reverse the negative ecological impact that occurs from the dependency of using specific pest management practices. The chart below identifies the numerous farm practices that make up an integrated pest management plan for insect and weed pests.

Integrated Pest Management Practices

Crop & Livestock Insect Pests	***Weed Pests***
Cultural Prevention	Cultural Prevention
Monitoring (pest types & numbers)	Monitoring (weed types & numbers)
Food Sources for Predators & Parasites	Use perennial crops (grasses & legumes)
Good Soil Fertility	Good Soil Fertility
Crop Rotation	Crop Rotation (competition)
Higher Seeding Rates	Higher Seeding Rates
Tillage Practices	Tillage Practices
Crop Residue Management	Burning Stubble
Crop Resistant Species	Use Mowing
Intercropping	Sow weed free seed
Early Maturity of Crop Species	Cut grain/silage prior to weed seed development
Trap crops/Buffer Crops	Use Clean feed (grains or fodder)
Spraying Techniques	Use row crops
Livestock Shelter (Design)	Compost/contain manure to kill weed seeds
Adequate Moisture Availability	Control fence lines/uncultivated area weeds
Traps	Clean machinery
	Proper disposal of screenings (grind/contain)
	Use a chaff catcher on the combine
Biological	Biological
Natural Insecticides	Grazing
Predators & Pests (mass released)	Predators & Pests (mass released)
Pheromones	
Microbial Diseases	
Chemical	Chemical
Insecticides	Herbicides
Fungicides	
Rodenticides	
Repellents	
Aversion Chemicals	

(Hanley 1980, Canada Agronomy and Research Information 2006, Bugg et al 1993, Alberta Agriculture Food and Rural Development 2004, Hilliard et al 2002, Mason 2003,

Saskatchewan Agriculture and Food 1996, Thomas 1996, Atkins et al 2003, Lomer et al 2001).
Economic thershold

An integrated ecological based pest management plan is the best way to ensure that ecological components are considered and assessed to address the need to control specific pest species.

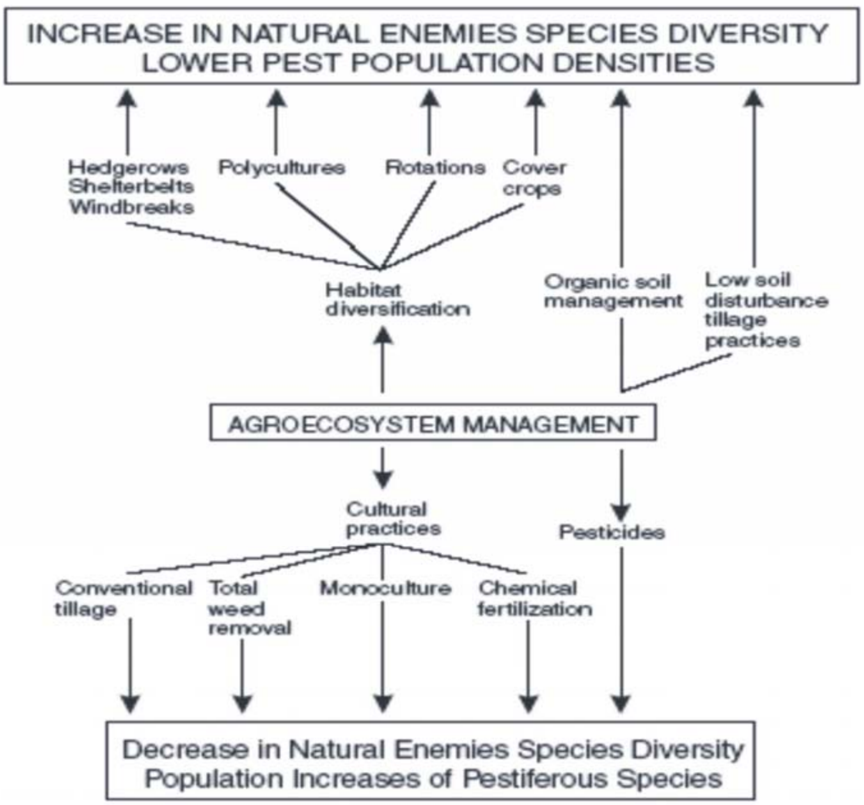

Figure 4: The effects of agroecosystem management and associated cultural practices on the biodiversity of natural enemies and the abundance of insect pests

(Altieri & Nicholls, 2000)

8.2.1.1 Chemical Use Reduction

The dependency of using chemicals in pest management is the primary reason that the biodiversity integrity of Canada's agricultural landscape has been so negatively impacted. The need to properly use and incorporate chemical use into ecological approach

Chemical use greatly affects the species richness of terrestrial and aquatic habitat. Reducing the use and dependency of chemical can increase species richness from 15 to 30 %

California reduction concept

Broadbase/selective

8.2.1.2 Tillage Timing and Frequency
The proper timing, type of tillage and intensity can prove very effective in abating crop pest populations Blackshaw 2001, Saskatchewan Agriculture and Food 1996

8.2.1.3 Crop Rotation
Crop rotations prove very effective in controlling large population growth of many of the noxious weeds Canada Agronomy and research Information 2006, Saskatchewan Agriculture and Food 1996, Thomas 1996

8.2.1.4 Cover Crops
Cover crops should be grown to manage insect pests population, provide habitat for specific species and nutrient replacement Bugg et al 1993, Hilliard et al 2002, Saskatchewan Agriculture and Food 1996

8.2.2 Biological and Cultural Control Methods

Biological and Cultural farm practices need to be considered on the farm to adequately develop an Integrated Pest Management plan.

Ecological Integrated Pest Management involves combining cultural, biological and chemical control practices to suppress or possibly eliminate an invasive crop and livestock pest populations and proliferation. Mason 2003, Hilliard et al 2002, Thomas 1996

Crop and livestock pests are major barriers to maximizing farm return. Prevention and control through careful planning is the most effective way to prevent losses from pests (AAFRD 2004; Axtell et al. 1990, BC Ministry of Agriculture and Food unknown date; DeVault et al. 1996; Dufour 2001; Gianessi et al 2002; Holelscher 2006; Thomas 1996).

Integrated Pest Management (IPM) is an ecologically based approach to pest (insect, plant or specific animal species) control (cultural, biological and chemical) that utilizes a multidisciplinary knowledge of crop/pest or livestock/pest relationships, establishment of acceptable economic thresholds for pest populations and constant field monitoring for potential problems/assessment (Atkins 1978; per conservation of Zitta and Saul 2005).

This definition does not exclude the use of chemicals, but it is implicit that the control methods used must be reasonably compatible if a harmonized system is to be the result. The value of chemicals in pest control is established and recognized, but it is also clear that the use of chemicals must be substantially reduced Nararko et al unknown date, George et al 1995, Carlsen et al 2005, McEwen et al 1972, Palmer et al 1998. Reduced risk integrated pest management has been utilized to reduce the dependency on chemical control and therefore reduces biodiversity degradation, Department of Pesticide Regulation 2006.

Ecologically sound IPM must utilize a combination of farming practices, of the three types of control approaches, to be effective in reducing the particular economic threshold of the pest and minimizing the biodiversity impact of the IPM (Mason 2004). The three control methods are categorized into cultural, biological and chemical control. There are numerous documented cultural and biological beneficial control practices or methods that can be incorporated into an integrated pest management plan.

For the most part these control methods have been tested and researched. However they have been used in an ad hoc manner, frequently with great success. However, sometimes less than desirable results are achieved, and far too often new pest problems have arisen out of the empirical approach to eliminating old pests. Chemical control stands out as the method that has produced enormous benefits on one hand, and catastrophes on the other. The catastrophes, in the form of ecological disruptions, pest resurgence, secondary pest problems and pesticide resistance, must bring on a re-examination of pest control methodology.

The lack of integrated pest management implementation and the use of chemicals as the only source of pest control have greatly impacted biodiversity throughout Canada. The extensive use of chemical and ad hoc IPM's have extreme affect on the biodiversity of the Canadian landscape. Numerous reports reveal that chemical use greatly affects the ecosystems and agrosystems by damaging the food chain and water resources.

Broad spectrum insecticides negatively impact the food chain and the beneficial insects that serve as ecological services such as pollinators, predators and parasites. These organisms are negatively impacted by the extensive use of chemical control. Improper IPM implementation and extensive use of chemicals have negatively affected endemic and non-endemic wildlife species. An example is that of the Swift Fox that was expirated from the Saskatchewan grasslands due to excessive use of poison to control Richardson Ground Squirrel and Coyotes. Excessive chemical use has also affected the genetic make-up of some pest species by developing resistance to the specific chemical used to control them. Controversy over the development and use of genetically modified organisms (GMO's) has created concern over genetic diversity and species preservation.

Weeds are usually defined as unwanted plants, such as wild oats or lambs quarter. Weeds are also usually plants that can survive well under disturbed conditions. Weeds flourish and evolve under the disturbed conditions of cultivated land. Most of Canada's weeds have come from Europe or Asia. Only five of the forty common weeds of western

Canadian crop fields are native plants. When any of these predominant weeds are removed (e.g. through the use of chemicals) there is a tendency for the ecological niche to be soon filled by another weed (e.g.control of wild mustard permits cow cockle to become more prominent) (Hanley 1980).

To maximize the efficiency of an integrated pest management program, it is necessary to understand the whole crop or livestock ecosystem of which the complex of pests is a part of. Certainly the successful application of integrated pest management is dependent upon understanding of the agroecosystem and the biological relationships of the pests within it. Two of the important considerations concern the size and delimitation of the ecosystem to be treated. Large monocultures form large targets for dispersing pests and natural enemies. However, large areas devoted to a single crop are less affected by the composition of adjacent ecosystems or the natural occupants of field margins.

The majority of Canada's agricultural pests, their biological life cycle, agricultural relationship and recommended control have been researched and available for public use. Unfortunately the extension of the pest information to the farmer is usually on a single species basis. Ideally, when an integrated pest management program is formulated, the entire pest complex should be considered at once.

The proper timing, type of tillage and intensity can prove very effective in abating crop pest populations Blackshaw 2001, Saskatchewan Agriculture and Food 1996

Crop rotations prove very effective in controlling large populations many of the noxious weeds Canada Agronomy and research Information 2006, Saskatchewan Agriculture and Food 1996, Thomas 1996

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8.2.3 Gaps in Literature and Further Research Needs

- Little research has been found pertaining to crop resistance to insect pests, predator and parasite habitat requirements, comparative studies of farm practices (non-chemical) impact on crop and livestock pests has been done to research and develop resistance to other insect pests.

- Items that require more research and detail, that were cited in the literature was the timing of farm practices, economic thresholds and on farm monitoring programs.

- Biological control of weeds research needs to be pursued further (Lomer 2001).

8.3 Invasive Alien Plant Species Control

An Invasive Alien Plant is any non-endemic plant species that is introduced, by natural or unnatural processes, and becomes established and aggressively reproduces to displace some of the original components within the plant community and eco-region.

Invasive Alien Plants have become introduced in Canada through a number of means: many, such as purple loosestrife, have arrived as contaminants with seed crops, livestock feed, or ballast dumped by ships from Eurasia; others, such as yellow flag (*Iris pseudacorus*), have spread from introductions of horticultural material; and some, such as smooth brome grass (*Bromus inermis*), have been intentionally introduced for use as forage crops or for revegetating roadsides, etc.

There are many alien plants in Canada. Kaiser 1983 reported that approximately 700 species (27% of the total flora) growing in Ontario are alien. Alien plants may not always be invasive—the vast majority of alien species consist of ephemeral garden escapes, dooryard weeds, and scarcely persisting seed mixture contaminants that do not pose a problem in natural areas because they are restricted to urban areas, agricultural fields, and other highly disturbed sites. Other alien species, such as dandelion (*Taraxacum officinale*) or the helleborine orchid (*Epipactis helleborine*), do grow in natural areas but they occur in small numbers and do not appear to displace or significantly compete with the native flora. Finally, there is a small group of primarily alien species that has the ability not only to grow in natural areas but to thrive in them and to do so at the expense of the original native flora. It is these species that are a cause for concern and the subject of the present report White et al 1993, Douce 2006.

Invasive alien plants may have a negative impacts upon a natural area. For example purple loosestrife, becomes established in a natural area, it displaces some of the existing native plants Balogh 1986, Keddy 1992, Maleki 1985, Comas 1992, Thompson 1987, Scheiman et al 2003. Reed canary grass (*Phalaris arundinacea*) which is a native of Canada could genetically alter native plant populations Paveglio 2000.

Controlling invasive alien plant species is difficult and pointless because they maybe well established. Therefore chemical control or removal of the invasive plants would have negative impacts on the natural habitat.

Natural areas that are most affected by invasive species are often under stress from disturbances such as air and water pollution, and habitat fragmentation White et al 1993. One of the possible control measures would be to return the disturbed areas to a natural state.

There are five principal control methods: the use of chemical herbicide, physical removal, the use of biological agents, prescribed burning, and ecological or integrated pest management. White et al 1993.

8.3.1 Ecological Integrated Pest Management

Ecological Integrated Pest Management involves combining cultural, biological and chemical control practices to suppress or possibly eliminate an invasive alien plant population and proliferation. Hanley 1980, Hilliard et al 2002, White et al 1993.

8.3.1.1 Physical Control

Physical control methods involves a range of devices from harvesters, tillers, dredges, flooding and clippings White et al 1993. Flooding has proved effective in control some aquatic invasive plants Haworth-Brockman 1993. Clipping of purple loosestrife was effective in deterring the spread of the plant through seed dispersal Gabor et al 1990.

8.3.1.2 Biological Control

Biological control methods involve introducing living organisms, such as insect herbivores or disease organisms, into populations of an invasive species in order to reduce the invasive species' vigour, reproductive capacity, or density White et al 1993. Biological control of loosestrife and leafy spurge has provided promising results Blossey et al 1991, USDA 1989

8.3.1.3Burning

Prescribed burning involves the use of fire to kill unwanted species. Timing of the fire is very critical in order to control the unwanted alien and at the same time leave the desired native species unharmed White et al 1993

8.3.1.4 Herbicide Control

Herbicide control involving the application of toxic chemicals to invasive plants. Herbicide has been used extensively with mixed results Cows and Fish 2002. For example herbicide was tested on purple loosestrife resulting in the killing of non target plant species Gabor et al 1995. Selective /not broad spectrum

8.3.2 Gap issues

There is little research literature found pertaining to invasive alien plant species prevention on the farm, transportation tarping of feeds and grains and manure management (composting to biodegrade invasive plant seeds).

In light of the concerns over the effects of using herbicides, biological control research requires more emphasis.

An evaluation and risk assessment of nurseries and seed distributors is required to determine the extent that they have in the spread and proliferation of invasive alien plant species.

8.4 Preventing Wildlife Damage

Wildlife damage is any wildlife species through their natural and inherent activities causes economic loss and damage to any agricultural activity or structure.

Wildlife damage is increasing due to expanding human population and intensified agricultural practices. Concurrent with this growing need to reduce wildlife-agricultural conflicts, public attitudes and environmental regulations are restricting use of some of the traditional tools of control such as toxicants and traps Dolbeer 1994.

The annual cost to farmers for reported wildlife damage to crops and livestock is estimated at $ 22.6 million nationally, CFA and WHC 1998.

Wildlife damage control activities must be based on sound economic, ecological, and sociological principles and carried out in a positive manner with the necessary components of wildlife management programs.

Management practices to prevent losses have been designed to deal with wildlife through lethal and non-lethal methods. Farm management practices can also be altered to reduce risk of damage including timing of harvest, barriers to access, hay storage techniques, and lure crops. Barriers to access and guard animals can also be used to reduce habitat use by wildlife species. Trapping, hunting and chemical toxicants and repellants are also control options. The cost of prevention is high and must be weighted against losses. Fencing and netting costs are not economically viable.

Prevention programs have been shown to be cost effective in conjunction with compensation. The need for prevention programs will increase due to the decline in hunters and trappers and a increase in many of game species population. Lure crops and dispersal mechanisms will minimize heavy losses.

Wildlife damage will continue in Canada. Losses to individual farmers can be very high. An appropriate mix of best management practices, and incentives for prevention needs to be balanced with compensation measures to reduce individual losses, Alberta Environment 2001, Bulte et al 2005, Wagner et al 1997. Most importantly, these programs help recognize the value of farm stewardship in providing wildlife and habitat on their farms.

To prevent or control damage from wildlife species a program must be developed consisting of four components:

1. problem definition
2. ecology of the problem species
3. control methods (recommended BMP listed below)
4. evaluation of control.

8.4.1 Encourage Hunting & Trapping

8.4.2 Habitat Modification and Management

Habitat that may be especially suited and attractive to wildlife can be modified or eliminated. Similarly access to food, water, and shelter wildlife requires can be reduced or eliminated. Cultural management techniques such as mowing, cutting down weeds and plant debris, remove breeding and hiding places are also effective, BC Ministry of Agriculture & Food 2003, Bomford et al 1995, Rodewald 2001, Newbill et al 2000, kuehl et al 2002

8.4.3 Fencing & Barriers

A fence is constructed barrier intended to prevent the intrusion or escape of undesirable species. Common fences designs to protect crops or feed sources from wildlife are woven wire fences or electric fences Clevenger et al 2001, McNamara et al 2002, new York

State Department of Environmental Conservation 2006, Knowlton et al 1999, Rosenberry et al 2001, Saskatchewan Agriculture date unknown

8.4.4 Netting

Netting is used to prevent birds and animals from entering valued areas. Overhead nets covering the entire area are normally used in small crops such as blueberries. Screens and netting should be incorporated in new buildings to keep birds out of farm structures that contain feed or feeding areas. BC Ministry of Agriculture & Food 2003, Dolbeer et al 1994

8.5 Repellents and Deterrents

Repellents that keep predators away or reduce their numbers include but are not limited to the following: Andelt et al 1992 & 1994, Avery 1995, Avery et al 1991 & 1992, Avery et al 1993, Brown et al 2000, Choquenot et al 1990, Crocker et al 1993, Cummings et al 2002, Wagner et al 2000

- natural repellents including plants, animals and natural products that are unpleasant to unwanted species of wildlife,
- chemical repellents that repel unwanted species of wildlife

8.6 Scare Tactics

Various devices are used to scare wildlife away from crop land, livestock and farm animals. The most common methods are:

Audible devices including, but not limited to: Bishop et al 2003, Cleary unknown date, Dolbeer et al 1994

- propane cannons or exploders
- broadcasting general sounds
- broadcasting bird calls such as distress, alarm and predator calls
- shell launcher with various shells (screecher and banger)

Visual devices including, but not limited to: Andelt 1999, Castelli et al 2000, Ujvari et al 1998, Dolbeer et al 1994

- inflated owls and other fake predators
- scarecrows
- strips or flash tape
- scare-eye ballons
- people
- dogs

Wildlife damage control activities must be based on sound economic, ecological, and sociological principles and carried out in a positive manner with the necessary components of wildlife management programs.

Management practices to prevent losses have been designed to deal with wildlife through lethal and non-lethal methods. Farm management practices can also be altered to reduce risk of damage including timing of harvest, barriers to access, hay storage techniques, and lure crops. Barriers to access and guard animals can also be used to reduce habitat use by wildlife species. Trapping, hunting and chemical toxicants and repellants are also control options. The cost of prevention is high and must be weighted against losses. Fencing and netting costs are not economically viable.

Prevention programs have been shown to be cost effective in conjunction with compensation. The need for prevention programs will increase due to the decline in hunters and trappers and a increase in many of game species population. Lure crops and dispersal mechanisms will minimize heavy losses.

Wildlife damage will continue in Canada. Losses to individual farmers can be very high. An appropriate mix of best management practices, and incentives for prevention needs to be balanced with compensation measures to reduce individual losses, Alberta Environment 2001, Bulte et al 2005, Wagner et al 1997. Most importantly, these programs help recognize the value of farm stewardship in providing wildlife and habitat on their farms.

To prevent or control damage from wildlife species a program must be developed consisting of four components:

5. problem definition
6. ecology of the problem species
7. control methods (recommended BMP listed below)
8. evaluation of control.

8.7 Species at Risk

Species at Risk are the approximately 213 Canadian plant, insect and animal species that are placed on the COSEWIC (Committee on the Status of Endangered Wildlife in Canada) list.

National recovery teams have been formed to develop recovery programs for the majority of Canadian species at risk. Each plan focuses on the actions needed to recover populations of the species. Unfortunately the approval and implementation of the recovery programs has been slow and cumbersome.

Single species recovery plan approaches requires an increase in the knowledge of the status of species through inventories, determine the life history of the species, its interactions with other species, how and why the populations change over time and the species habitat needs. Effects of Beneficial Management Practices are very species specific.

The main reasons for so many species at risk are as follows. Overhunting in the last century caused low populations for several species such as the trumpeter swan (*Cygnus buccinator*), whooping crane (*Grus Americana*) and the Eskimo curlew (*Numenius borealis*) Holroyd 1993. Toxic chemicals caused the decline and continue to depress population of numerous species at risk such as the peregrine falcon (*Falco peregrinus*) Fyfe 1987. Habitat loss or alteration is the primary cause of the declines for the majority of the species at risk throughout Canada. Habitat loss may not have been the primary cause for a specific species at risk population to decline. However habitat loss is the main obstacle preventing recovery of many species at risk to sustain viable population levels.

8.7.1 Promote Species at Risk Conservation and Stewardship Programs

Species at Risk Incentive and Stewardship programs should be promoted and adopted by farmers to encourage species at risk conservation. The recovery of the swift fox is an example of cooperation among numerous groups and the application of knowledge base management Carbyn et al 1993. Operation Burrowing Owl is an excellent stewardship program for the habitat retention and public awareness of the burrowing owl Scobie 1992. It illustrates that the integration of species at risk needs and agricultural activities can be achieved.

8.7.2 Preserve and Maintain Specific Species at Risk Habitat

Over 75 % of the prairies have been ploughed or paved WWF 1988. About 75% of the mixed grass and parkland eco-regions, 90% of fescue grasslands and 99 % of the tall grass prairie are gone in Canada. The conversion of native grasslands to cultivation is still encouraged by agricultural subsidies and programs and by continued expansion of irrigation Holroyd 1995. Numerous farming practices are detrimental to the recovery or survival of species at risk. Many Canadian farmers are unaware that their farming practices are deterring the recovery of species at risk.

Excessive use of chemicals to control insect pests poisoned endangered species such as the Burrowing Owl Poulin 2003. Documentation and research has shown that numerous grassland birds and passerines have perished due to eating insects killed by insecticides Johnson 2004, Brennan etal 2005 and Smet 1993. Rare amphibian and reptiles have also been poisoned by insecticides by ingestion or absorption Mitchell 2003, Romanchuk 2006.

Habitat loss for the propose of cultivation is a major contributing factor to the demise of numerous species at risk Breininger et al 1999, Cassidy et al 2000, De Smet 1992, davis etal 1999, The plowing and over grazing of native prairie has dramatically decline prairie plant species at risk Harms et al 1993. Also loss of riparian habitat negatively affect specific species at risk Holweger 2004. nest predation by predatrs increase with the loss of habitat Thompson et al 2003

Habitat fragmentation also attributes to the species at risk being unable to establish a territory for breeding and nesting. Fragmentation may also impend the species at risk, such as the Swift Fox, to survive due to exposure to predators and lack of food availability Davis 2005, Brinkman et al 2004, Foster-Willfong 2003, Kamler 2002. If habitat becomes to fragmented the species at risk lives within a biological sink where it's offspring are unable to establish a territory or require food requirements.

Habitat quality is the specific habitat elements that a species at risk requires to live. For example Sage Grouse and Loggerhead Shrike need specific vegetation and space to successful bred and feed. Smet 1993, Davis et al 1999, Prescott et al 1993. The Le Conte's Sparrow requires tall grass prairie habitat to inhabit Winter et al 2005.

Despite the importance of habitat as a common thread in recovery plans, recovery teams have been unable to tackle many habitat problems because of size and complexity of the topic.

Habitat retention will enable numerous species at risk to maintain their populations. Research on the Conservation Reserve Program lands in the USA has show that numerous insect and bird species benefit by the retained habitat McIntyre et al 2003

Shelterbelt establishment will benefit specific species at risk by providing the necessary nesting or feeding habitat that they require. The establishment of buffalo berry and hawthorn hedgerows encourages Loggerhead Shrike to nest and breed Prescott et al 1993.

8.7.3 Grassland Management

Over or under grazing negatively impact several species at risk. Sage grouse require specific density and quality of sagebrush/grassland mixture therefore over grazing a rangeland has detrimental affects on the survival of that species Aldridge 2002 & 2005. Baird's Sparrow requires specific grass height to breed and nest Davis 1998, Johnson et al 2004. Numerous Manitoba's grassland birds that are at risk are negatively impacted by overgrazing. Native

Lower carrying capacities for rangeland and pastures will deter over grazing thus provide viable feeding, breeding and nesting habitat for several bird species at risk Aldridge 2002 & 2005, Davis 1998, Johnson et al 2004

8.7.4 Gap Issues

There little scientific research pertaining to farming practices that benefit species at risk. Apart from the Stewardship programs and shelterbelt establishment mentioned little literature refers to positive impacts of farm practices upon species at risk.

The majority of Canadian farmers value the presence of wildlife and habitat on their farming operations. They have been recognized for their stewardship actions through conservation award programs. For landowners to take action, they need to be informed about the needs of species at risk, and motivated to act accordingly. Excellent literature is available pertaining to species at risk and their recovery. Farmers need to be informed of the specific species at risk within their agro-ecosystem.

Many of the Canadian eco-zones are heavily affected by agriculture. An ecosystem approach to species at risk recovery should be studied to complement the individual species recovery programs. The ecosystem approach would include natural interactions of the full range of physical and biological components as well as the broad issues that affect land use activities. Habitat conservation, protection and restoration would be a major focus of this approach. Topics such as agricultural policy, land use practices, taxation systems and subsidies could be dealt with such an approach.

Summary of Species Management BMPs

BMP	Benefits to Biodiversity	Qantitative Effect	Descriptive Effect
Integrated Pest Management Improved Pest Management	• Minimizes biodiversity impacts by incorporating ecological parameters into a multi-practice pest management approach	None Available	•
Chemical Use Reduction	• Reduces the impact of chemical use on species diversity and ecological processes	• 15-30% reduction in species loss	•
Tillage Timing & Frequency	• Reduces tillage and proper timing will crop residues, moisture	•	•
Crop Rotation	• Prevents insect and weed population eruptions thus maintaining species diversity	•	•
Cover Crops	• Increases species diversity and richness • Increases predators and parasites		•
Biological & Cultural Control Methods	• increase habitat for beneficial species & targets specific species for control		•
Invasive Alien Plant Species Control Ecological Integrated Pest Management	• Incorporating ecological components into management approach to control		•
Physical Control	• Prevents any losses to the species compostion of the local area		•
Biological Control	• Species specific control measure		•
Burning	• Prevents the spread of invasive plants and impacts small area of habitat		•
Herbicide Control	• Minimizes species richness by using selected species specific chemicals		•

Preventing Wildlife Damage Hunting and Trapping	• Lethal manner to reduce and deter specific problem wildlife species		•
Habitat Modification and Management	• Preserve and enhance habitat for local wildlife species		•
Fencing/Barriers	• Non-lethal		•
Netting	• No-lethal		•
Repellants and Deterrents	•		•
Scare Tactics	• No-lethal method to deter problem wildlife allowing them to cohabitate		•
Species at Risk Promote Conservation and Stewardship	• Encourages landowners to be aware of species at risk and to preserve their habitat		•
Preserve and Maintain SAR Habitat	• Provides species at risk habitat and reduces habitat loss		•
Grassland Management	• Increase the species at risk habitat/food/breeding needs by reducing grazing pressures and preserving native grassland		•

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9.0 Summary

Extensive review of literature has revealed that biodiversity benefits from farm BMP's are as variable as farming practices themselves. Most papers and scientific experts indicate that specific practices designed to benefit biodiversity must be tailored to local conditions to be effective. For example, the practices suggested for prairie grain farmers to implement extensive management of permanent cover and to reduce summerfallow will have little application for apple farmers in the Annapolis Valley. Further, BMP's that are beneficial to biodiversity in one region or local area of the country may be detrimental to certain elements of biodiverity elsewhere. Practices that benefit native wildlife in districts where the natural vegetation was forest may be unsuited to districts that originally supported grassland.

On the other hand, nutrient management and various kinds of waste management appear to be well accepted by agricultural producers across the nation. Unfortunately, we found few documents and test cases that related directly to or were designed to study benefits to biodiversity of nutrient management. There were numerous passing references or inferences to biodiversity benefits, at the basic ecological health level. These benefits (almost always unquantified) included water quality improvement related to aquatic organisms, enhanced population of invertebrates in soils where good nutrient management was applied and improved biomass production (i.e. increased food and cover production) all of which can be assumed to be beneficial to biodiversity in the largest sense.

The analysis of scientific documents and experts opinion has resulted in some common features that could be developed into principles for measuring impacts of BMP's on biodiversity.

1. **Bigger is Better**
   An overwhelming revelation throughout the review was the need to preserve what natural habitat remains and when restoring natural habitat, to create a block of habitat of sufficient size and structural complexity. When preservation of habitat blocks are part of agricultural BMP's, the need to ensure that the critical ecological functions for the indigenous wildlife are retained is all important. When habitat blocks are not of sufficient size, are fragmented or have little habitat complexity, the efforts to promote biodiversity are far less successful. This concept prevails for grasslands where many species use areas many hectares in size as their home range. It relates to wooded habitats where absolute size requirements for interior species may exceed 100 hectares. Size is also important for conservation of riparian areas. Riparian areas provide edge between the aquatic and terrestrial habitats and may be confined by the water and land components. But, unless the full extent of this riparian area between the water eco-community and the terrestrial eco-community is preserved, the biodiversity values are compromised.

2. Native Species of Vegetation Are Most Useful

Habitat restoration has been extensively practiced on the prairies of the USA and Canada. Use of exotic species for these restoration efforts has benefited some species of opportunistic animals but may have excluded other obligate species to native grassland habitats. In many cases populations of these obligate species are in serious decline.

Reforestation efforts in Eastern Canada which create ecologically sterile plantations of coniferous trees have done little to conserve endangered elements of biodiversity in habitats that were originally forested by deciduous trees and shrubs. Although some common species seem to benefit from tree plantation, the species that are declining or are most jeopardized by forest clearing in the first place are benefited little. The need to use native species and to plant in formations that mimic natural ecosystems dictates that localized restoration strategies and plans are needed to optimize biodiversity benefits

3. Avoid Creation of Ecological Sinks

The literature revealed that there is a significant danger of creating population sinks for taxa that are attracted to habitat created through BMP's but which suffer overwhelming mortality as a result of overall habitat deficiencies . In these situations, the BMP offers attractive ecological benefits such as abundant food, or initial suitable habitat for reproduction but fail to supply other ecological requirements such as water or isolation from predators, parasites and poisonous substances. An ecological trap or sink develops and the taxa involved suffer catastrophic loss. The BMP's with the potential to create ecological sinks should to be used very carefully especially if there are implications to taxa or functions of ecological concern such as species at risk.

4. Protect Hotspots of Biodiversity

Certain parts of the landscape have an inherently superior capability to supply the ecological requirements of a great diversity of taxa. Many wetlands fall into this category as well as areas of old forest that support endemic or obligate species. In each ecological region and as part of each environmental farm plan, it would be useful to identify these biodiversity hotspots that require special protection. BMP's that are implemented should recognize the unique localized ecological character and requirements of these hotspots and ensure that implementation of these BMP's are complementary to the hotspot's continued existence and function.

5. Recognize and Enhance Synergistic Effects

This study determined that in isolation, individual BMP's operating at the local level would have relatively small benefits to protecting regional biodiversity by themselves. In many cases however, there was obvious benefits of combining a number of BMP's and coordinating their action to complement each other. In other cases there may be situations where implementation of a BMP in association with other initiatives, may actually negate the benefits to biodiversity. Thus it is important to understand the mode of action on biodiversity of each BMP under consideration at the individual farm level and to understand the ecological implications of integrated farm management. The concept of integrated pest management is really a combination of many BMP's, some of which have no direct relation to specific pest control. Instead these BMP's working synergistically, reduce the suitability of environmental conditions for pests rendering them less of a problem.

Actions of government policy or cooperative efforts by producers themselves that can pool the activities of a community of producers to provide critical mass of beneficial farming practices will be useful. For example, if one farmer sets aside a small parcel of wildlife habitat in isolation, it may have negligible effects on preservation of biodiversity, If a second then a third agricultural producer do the same and they can be located in one block, the benefits will multiply for biodiversity. This concept has particular relevance when trying to implement BMP's that address the need to reduce edge effect and create large enough blocks of habitat to support species and ecosystems in decline.

In conclusion, the effort to develop BMP standards that will maximize biodiversity benefits have to relate to regional farming practices and agricultural producer values that will enable the practices to have a sufficiently large land base to facilitate effective action. An initiative to identify where BMP's that benefit biodiversity can be accepted by producers will be needed. These areas are likely to be located in more marginal for intensive and extensive agricultural production as opposed to intensively farmed areas such as the Regina Plains or the Fraser River Delta. Within these areas of more marginal agricultural capability, the focus needs to be on ways of grouping beneficial practices to ensure a critical mass of habitat. If this can be combined with existing or future conservation land set asides in parks or other protected areas, the biodiversity benefits will be further enhanced.

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Appendix A: Recognizing Regional and Environmental Differences within Riparian Areas

Examples taken from (Bellows 2003)

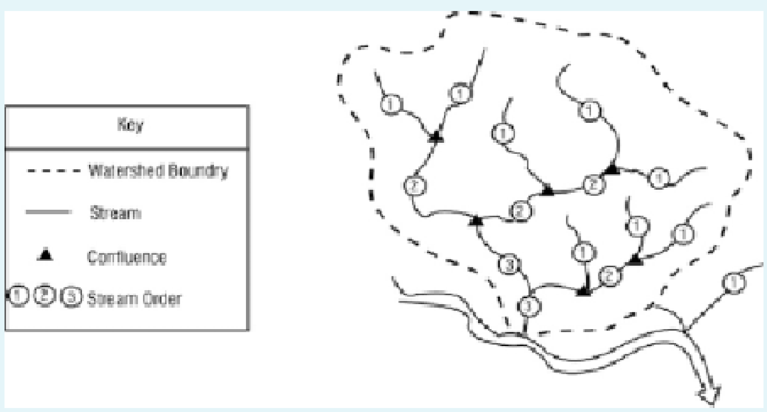
Appendix 1: Impacts of Local Ecology on Riparian Characteristics

Differences in Local Ecology

…different riparian areas have their own unique attributes and can and do function quite differently. As a result, most areas need to be evaluated against their own capability and potential. Even for similar areas, human influence may have introduced components that have changed the area's capability and potential. Assessments, to be correct, must consider these factors and the uniqueness of each area. (*Prichard, 1998*)

Streams and their adjacent riparian areas exhibit differences in their hydrology, geology, and biology, not only on a regional basis but also as a stream moves from its headwaters to its outlet (Renwick and Eden, 1999). These differences are important to understand when choosing appropriate vegetation and land management practices for riparian restoration or when monitoring the conditions of streambanks and their surrounding riparian areas.

Stream order refers to changes in stream shape and flow from its origin as a headwater, or first order stream, to where it flows into a lake or ocean as a higher order stream.



Stream order designations. Lower numbers refer to headwaters and tributaries while higher numbers refer to larger downstream rivers.

Schueler, T. - No additional reference, as used on the web page of the Chester County Water Resource Authority, West Chester, PA. <http://www.chesco.org/water/Resource_Library/1st_order.html>.

The effects of stream order on riparian geology and vegetation are examined in Table A.1.

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Table A.1. Effect of Stream Order on Natural Riparian Characteristics

	Stream Order		
	Headwater or low order streams	Transition or mid-order streams	Outlet or high-order streams
Stream Characteristics			
Stream slope	• steep slopes	• moderate to steep gradient (between 1 to 6 degrees)	• shallow bank slopes
Riparian terrain	• hilly to mountainous terrain	• hilly	• rolling
Streambanks	• impermeable gravelly or rocky soils	• sandy or silty soils on banks • boulders and gravel on stream bottom	• deep soils with fine sediments
Stream shape and flow	• relatively narrow • rapidly flowing • cool water	• some meanders present	• slow moving • uniform width and depth • continuously changing meanders • wide basins
Hydrology	• predominantly runoff flows • flooding common	• combination of runoff and groundwater flows	• predominantly groundwater flows • stream flow levels are moderated
Streambank erosion	• occurs as infrequent, mass wasting processes		• occurs more frequently, but each incident tends to cause incremental changes • wider streams are better able to contain floodwaters
Stream structure debris	• boulders and large woody debris	• large amounts of woody debris	• sand bars, pools and riffles
Vegetation	• moisture-loving woody species	• combination of trees and grasses	• sedges, rushes, and grasses

Sources: Naiman et al., 1992; Undersander and Pillsbury, 1999; Federal Interagency Stream Restoration Working Group, 2001; Sovell et al, 2000; Gebhardt et al., 1989; Moseley et al., 1998

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Regional differences in climate have a large impact both on riparian characteristics and how wildlife and grazing animals use these areas. The Table A.2 examines how regional differences in rainfall and temperature affect the structure and function of riparian areas.

Table A.2. Effect of Rainfall and Temperature on Riparian Characteristics

Rainfall		
	Arid	**Moist**
Vegetation	• riparian vegetation is much more diverse than upland vegetation • woody vegetation is shrubby and relatively sparse • microbial soil crusts are an important component of soil vegetation cover	• riparian vegetation is relatively similar to upland vegetation • combination of trees, shrubs, grasses, and herbaceous plants
Soil characteristics	• alkaline	• neutral to acid pH
Seasonality	• short, distinct wet or monsoon season and long dry season	• relatively moist throughout the year
Streamflow	• distinct changes in stream height based on rainfall	• stream levels relatively stable throughout the year
Animal use	• animals dependent on lush vegetation except during the short, wet period	• animals feed more evenly between riparian and upland areas
Temperature		
	Mild Winter	**Cold Winter**
Seasonality	• ground does not freeze completely or throughout the winter • water infiltration can occur throughout the year	• ground freezes throughout the winter • distinct snow melt period common with accompanying ground saturation and runoff
Streamflow	• streamflow moderated by on-going water infiltration	• flooding common following snowmelt
Animal use	• animals less dependent on riparian vegetation during winter • animal trampling can compact moist, unfrozen soil	• animals more dependent on riparian vegetation during winter • frozen soil can withstand impact of animal trampling

Sources: Naiman et al., 1992; Huel, 1998; Prichard, 1998; Winward, 2000.

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Riparian Management in the Context of Local Conditions

Understanding how characteristics of riparian areas differ depending on local or regional conditions is important in the management, monitoring, and regeneration of riparian areas. Unfortunately, several examples exist of agencies or landowners who inadvertently harmed riparian conditions by using practices that were not appropriate for their locations.

Case 1. Soil conservation practices implemented in the 1930s did not take into account the ecological role of native vegetation and sought to protect streams by planting fast-growing trees, such as box elder, along streambanks. Unfortunately, the dense, woody vegetation did not permit the growth of understory vegetation. Without a deep-rooted grass cover, the streambanks in these riparian areas were severely undercut. In the absence of grasses and forbs covering the riparian soil surface, runoff water did not infiltrate into the soil where soil chemicals and organisms could filter out or transform contaminants. Instead, water running off the surrounding watersheds flowed directly into streams, forming rills and gullies and picking up additional sediments as it moved between trees planted in the riparian zones (Sovell et al., 2000).

This situation may have provided the context for results obtained from a Sustainable Agriculture Research and Education (SARE) funded project in Minnesota (Lentz, 1998) that monitored three areas along a stream.

> *This area was entirely fenced free of livestock in 1967. In 1988 the area was divided into three sections: the upper section was grazed three days per month, the middle section was grazed heavily once a year in early summer, and the lower section was never grazed.*
>
> *Ten years later, both the upper and middle sections, where grazing was allowed, have developed into prime trout habitat with the return of many native grasses and forbs, while the ungrazed lower section is heavily wooded and grass free, with broad shallow water and extreme bank erosion.*

These results appear to portray riparian grazing as better for the environment than natural wooded systems. However, other riparian grazing research, conducted in similar ecosystems, reported a high species richness in woody buffer strips (Paine and Ribic, 2001). Thus, non-native, fast-growing tree species that restricted understory growth probably dominated the lower section of the streambank in the Minnesota research.

Case 2. Streambanks in the Pacific Northwest were originally dominated by willows and other shrubs (Elmore, 1992). To restore these areas, a three-paddock rotation system was implemented. Each paddock in this system was subject to spring grazing one year, fall grazing the next year, and total rest the following year. This system of livestock grazing favored the growth of forage grasses but did not provide sufficient rest for woody plants to become established. Livestock access to mature trees during times when they were setting shoots and budding hindered the ability of the trees to grow and reproduce. Livestock ate or trampled the shoots of young trees. The lack of native woody species caused streamflows to become erratic, decreased water infiltration and water filtering, and increased streambank erosion.

Case 3. In other areas of the Pacific Northwest, some restoration projects recommended adding pieces of wood to streams to provide fish and wildlife habitat. Unfortunately, this "restoration" activity was used in some streams that historically flowed through meadows

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and did not previously contain much wood debris. In previously forested areas, where trees have been removed, these restoration projects added wood debris without considering restoring the riparian forest (NRC, 2002). This practice provides aquatic habitat on a short-term basis, but it does not address more fundamental riparian concerns, such as streambank erosion, stream shading, habitat for terrestrial species, and food for aquatic species.

These examples raise questions that you may want to ask when choosing or evaluating a riparian management practice:

- Does the practice favor the growth of either native vegetation or vegetation that grows under similar conditions and serves similar roles to native vegetation? For example, are you using practices that favor the growth of grasses and other herbaceous plants on meadowland, or are you planting riparian forests on land that under natural conditions did not support trees?
- Does the riparian management practice provide long-term solutions to environmental concerns, or is it just designed to provide short-term relief?
- If a new practice protects riparian areas better than an existing practice, do you know whether the existing practice is natural or introduced? Also, do you know whether the new practice is appropriate for the local conditions? For example, the intensive rotational grazing practices described by the SARE-funded project in Minnesota may provide significant watershed protection benefits. But the woody treatment was probably the remnant of an inappropriately designed "restoration" project rather than a natural "control."